Racing thoughts: psychopathological and cognitive mechanisms

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Les mécanismes psychopathologiques et cognitifs de la tachypsychie

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Les mécanismes psychopathologiques et cognitifs de la tachypsychie

Résumé

Habituellement décrite dans les états maniaques chez des patients présentant un trouble bipolaire, la tachypsychie est définie comme une accélération de la pensée qui peut également être observée dans les états dépressifs mixtes. Pour évaluer les mécanismes psychopathologiques impliqués dans ce phénomène peu étudié, nous avons élaboré un auto-questionnaire, le *Racing and Crowded Thoughts Questionnaire* (RCTQ), et nous avons évalué ses propriétés psychométriques chez les sujets sains et chez les patients avec trouble bipolaire. Les mécanismes cognitifs ont été investigués par le biais d'approches temporelles et langagières. Nos résultats suggèrent que la tachypsychie est un phénomène composite présent même chez les sujets sains en cas d'instabilité mineure de l'humeur. Sur le plan cognitif, la tachypsychie a été associée à la présence d'anomalies lexico-sémantiques et exécutives relevées à des tâches de fluence verbale ainsi qu'à une accélération du passage du temps.

Mots-clés : tachypsychie ; trouble bipolaire ; psychopathologie cognitive ; fluence verbale ; passage du temps

Résumé en anglais

Racing thoughts have been traditionally described in manic states in patients with bipolar disorder. Recently, attention has been raised to this symptom in depressive episodes. In this thesis, we aimed at investigating the phenomenology of racing thoughts, a phenomenon that has been understudied so far, via a self-report questionnaire that we have developed – the Racing and Crowded Thoughts Questionnaire (RCTQ) -, in patients with bipolar disorder and in healthy individuals. From a cognitive standpoint, we assessed the cognitive underpinnings of racing thoughts via temporal and verbal fluency tasks. Our results suggest that racing thoughts are a multi-faceted phenomenon, that can be observed even in healthy individuals with mild affective instability. Importantly, our results show that racing thoughts are associated with lexico-semantic and executive abnormalities as well as with a feeling of faster than usual passage of time.

Keywords: racing thoughts; crowded thoughts; bipolar disorder; verbal fluency; passage of time.

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1 – Introduction

"Once the mind gets hot it can't stop."

Virginia Woolf[1] (2003, p. 161)

"Get this: I coulda been happy in hell. The soothers tell me that most manic-depressives *enjoy* their time in Up land. *My god*. The fact that I had a problem with it indicates to them that I may have been both manic and depressed at the same time. Something that really shoulda worked itself out, if you ask me. Either that or I was just so sped up that I spiraled into oblivion.

I thought manic-depression was a mood disorder – people who get real happy, and real sad. Turns out you get real *fast* and real *slow*, and how that manifests is determined by your frame of mind. A fast brain fills in blanks in your visual field, makes stuff up at you. A slow one can't even cope with what's already here.

But they can both make you want to die."

Kristin Hersh[2] (2008, p. 148).

[1] English writer, 1882 - 1941. Excerpt from her diaries.
[2] American musician and writer, 1966 -. Excerpt from her memoir 'Paradoxical Undressing'.

1.1 Racing thoughts: an overview

Racing thoughts refer to a subjective acceleration and overproduction of thoughts, which have been essentially associated with manic episodes in bipolar disorder (Piguet et al., 2010). Indeed, racing thoughts, and their verbal equivalent, flight of ideas, are extremely characteristic, if not pathognomic, of manic thinking (Goodwin & Jamison, 2007). As Jamison (2017) so vividly described it, manic thought is characterized by "... a torrent of near-unstoppable speech; thoughts bracchiate from topic to topic, held only by a thin thread of discernible association. Ideas fly out, and as they do, they rhyme, pun, and assemble in unexampled ways. The mind is alive, electric." (Jamison, 2017, Setting the River on Fire, p. 278).

In his groundwork textbook on bipolar disorder, Kraepelin (1899/2008) was the first to use the term 'flight of ideas', to refer interchangeably to both the experience of speeded thought pressure, and its expression in the patient's speech. These terms were later to become dissociated in modern psychiatric jargon, but remain part of an unitary diagnostic criterion of manic/hypomanic episodes in the Diagnostic and Statistical Manual for Mental Disorders-fifth edition (DSM-5; APA, 2013; the exact wording is "Flight of ideas or subjective experience that thoughts are racing."). This has been the case since the third edition of the DSM (Braden & Ho, 1981).

Although the wording of the diagnostic criterion has not changed considerably over the last decades, whether or not racing thoughts are specific to manic episodes has been a matter of debate (Piguet et al., 2010). This debate stems from a larger controversy involving, on the one hand, the classification of mixed states in bipolar disorder (Shim, Woo, & Bahk, 2015), and, on the other hand, the conceptualization of bipolar disorder as either a discrete category, qualitatively different from healthy functioning, or a spectrum spanning from full-blown mood disorders to affective temperaments found in healthy individuals (Akiskal & Akiskal, 2005; Goodwin & Jamison, 2007).

In the first section of this thesis (cf. 1.2), the evolution of the clinical concepts related to what is called nowadays 'bipolar spectrum disorders' will be presented. Then, in the second section (cf. 1.3), the phenomenological literature on racing thoughts will be reviewed. Indeed, although racing thoughts have been abundantly described by psychiatrists, it is still unkwown whether they belong to a single entity, or are rather a multi-faceted phenomenon. Since questionnaires able to reliably assess racing thoughts are lacking, the clinical boundaries and characteristics of racing thoughts have not been thoroughly evaluated in patients with mood disorders, nor in healthy individuals with sub-affective temperamental traits. As will be outlined in the first two sections of this thesis, there are reasons to believe that racing thoughts might be associated not only with full-blown manic, but also with depressive episodes in bipolar disorder. Kraepelin (1899/2008) had already suggested that depression "with flight of ideas" and other mixed typologies of depression were common occurrences of mood episodes in manic-depressive illness. However, only in its most recent version did the DSM fully acknowledge that this might be the case, coining the term "depression with mixed features" to refer to the co-occurrence of subsyndromal manic symptoms in depressive episodes (APA, 2013). However, when racing thoughts co-occur with depressive mood, instead of conveying a sense of speed and flow, associated with pleasant emotions, thoughts are described as numerous and "overcrowded" in the patient's head, and are associated with unpleasant emotions (Braden & Ho, 1981; Piguet et al., 2010; Keizer et al., 2014). Thus, phenomenologically speaking, although the term "racing thoughts" reflect an unitary concept, racing thoughts might consist of at least two kinds of thought activity – 'racing' and 'crowded', associated with manic and depressed mood, respectively (Piguet et al., 2010). This distinction has not been empirically assessed and remains hypothetical to date. In fact, when reporting of this specific symptom, most studies have thus far only used the term 'racing thoughts', and have not addressed its polymorphous phenomenology. In healthy individuals, recent longitudinal studies have reported racing thoughts in the unaffected offspring of patients with bipolar disorder, suggesting that, like mood, thought activity might be conceptualized as a continuum (Correll et al., 2014). In addition, indirect evidence suggests that racing thoughts might be present in healthy undergraduate students (Dodd et al., 2010). Yet to date little is known regarding the relationship between sub-affective temperamental traits and racing thoughts. The first aim of this thesis was to quantitatively assess whether or not racing thoughts are multi-faceted relative to the predominant mood experienced by the subject, via a self-report questionnaire we have developed, the Racing and Crowded Thoughts Questionnaire (RCTQ; article 1: Weiner et al., submitted). Given that racing thoughts have been described in mania, but also in depression, we hypothesized that elevated rates of racing thoughts would be found in association with elated, and also low mood, and that this would be the case in individuals with bipolar disorder (cf. article 2), but also in healthy subjects with sub-affective temperamental traits. However, if racing thoughts are indeed multi-faceted, their characteristics should differ according to the predominant mood experienced by the subject at the time of the assessment (cf. article 1).

The second aim of this thesis was to investigate the cognitive underpinnings of racing thoughts. By the late nineteenth century, Kraepelin and his contemporaries (e.g., Aschaffenburg, Isserlin, and Killian & Gutmann) had already attempted to capture the racing thoughts phenomenon via psychological tasks (Kraepelin, 1899/2008). These tasks involved mainly verbal association paradigms, i.e., subjects were instructed to generate words during an alloted time following the presentation of a cue word (Kraepelin, 1899/2008). This task choice was due to the fact that the racing thoughts phenomenon is essentially manifest in the patient's speech. Early results from this kind of experiment, comparing manic and depressed patients, suggested that two kinds of cognitive mechanisms were involved in racing thoughts: one temporal, and the other linguistic. The specific methods employed in these studies were not specified by Kraepelin, but they give some indication of the kind of results we can expect in patients with bipolar disorder. For instance, Aschaffenburg (cited by Kraepelin, 1899/2008) showed, using verbal association tasks, that associative speed (inter-word latency) was slowed down in manic patients, contrary to initial predictions. Less paradoxical results were reported by Isserlin using the same task: he found that duration of ideas in manic patients was shorter than in healthy individuals – i.e., 1, and between 1.2 and 1.4 seconds, respectively (reported by Kraepelin, 1899/2008). These results are less paradoxical because they fit with the observation that manic patients switch frequently from one thought to the other. Kraepelin also found, among other linguistic results, that manic patients made more associations based on sound, rather than on the meaning of words. Verbal association tasks were later criticized, especially by Binswanger (1933/2000), for not being reliable estimates of speed of thought because of their explicit nature, i.e. patients were explicitly instructed to generate ideas following an initial word provided by the experimenter. Thus, although informative, these tasks had two problems: first, they did not necessarily reflect the spontaneous discourse of patients, which might partially explain some counterintuitive results, such as the relative slowing of speech rate in mania. Second, these associative tasks were not developed with a specific cognitive framework in mind, hence authors were not able to address their cognitive underpinnings, and many confounding aspects, such as vocabulary size, were not controlled for. Nevertheless, these results are extremely interesting, and consistent with the phenomenology of flight of ideas, e.g., the fleetingness of ideas, and increased associations based on sound. Since these early attempts, dating back from the nineteenth century, surprisingly few studies have investigated racing thoughts from a neuropsychological pespective. As mentioned above, this might be due to the fact that the phenomenon at stake has not been sufficiently delineated so far. In the third section of this thesis (cf. 1.4), we will review the cognitive models that have arisen from phenomenological descriptions of racing thoughts. These models suggest three ways of assessing racing thoughts, i.e., via temporal, verbal or executive paradigms. In our work, these three perspectives were investigated via verbal fluency and time perception tasks (cf. articles 3, 4 and 5).

1.2 From mania and melancholia to the bipolar disorder spectrum

The current definition of bipolar disorder, as outlined in the 5th edition of the DSM (APA, 2013), encompass mood disorders characterized by cyclicity as well as significant impairment imputable to mood disturbances. Manic/hypomanic symptoms lie central to the diagnosis: it is their severity, their duration, and their context of onset, that are determinants of the kind of bipolar disorder one suffers from. In contrast, depressive symptoms are an important part of the clinical expression of bipolar disorder, but are not specific. Figure 1, taken from Stahl et al. (2017), depicts manic symptoms as a continuum across mood disorders in the DSM-5.

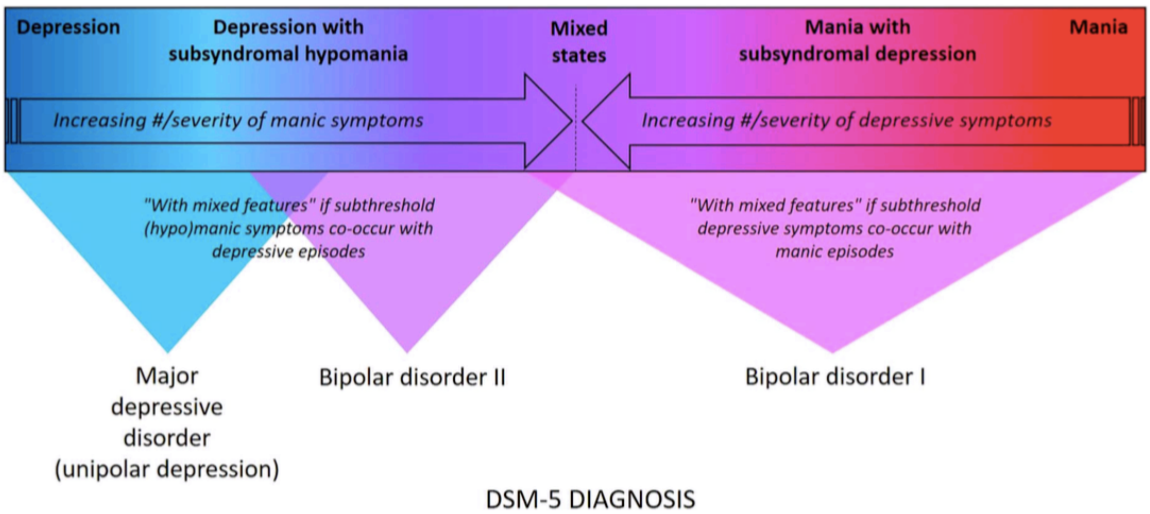

FIGURE 1. Mood disorders spectrum and DSM–5 diagnosis. Mood disorders can be conceptualized as existing along a spectrum that spans from pure unipolar depression with no intra- or inter-episode symptoms of (hypo)mania all the way to threshold level mania.

Among its most frequent and severe forms, bipolar type 1 disorder, is characterized by at least one full-blown severe manic episode during its course, whereas bipolar type 2 disorder is characterized by alternating milder manic episodes (hypomania) and major depressive episodes (APA, 2013). Other diagnostic categories delineated by the DSM-5 include: (i) cyclothymic disorder, which is characterized by alternating subthreshold manic and depressive episodes resulting in functional impairment; (ii) substance/medication-induced bipolar and related disorder; (iii) bipolar and related disorder due to another medical condition; (iv) other specified bipolar and related disorder; and (v) unspecified bipolar and related disorder (APA, 2013). Lifetime prevalence rates are high; using relatively narrow classifications, they have been estimated to be 1% for bipolar type 1 and 2 disorder, and 3.8% for subthreshold bipolar disorder conditions (Merikangas et al., 2011).

Reportedly common in mania (Cutting, 1997), flight of ideas or racing thoughts are not strictly necessary for the diagnosis of manic/hypomanic episodes. Indeed, according to the DSM-5 (APA, 2013), only elated or irritable mood accompanied by an abnormal increase in energy or activity levels are strictly required, while other cognitive and somatic disturbances frequently observed during manic episodes – e.g., decreased need for sleep, racing thoughts, distractibility, and grandiosity – might be selectively impaired (only three of the seven possibilities if the mood is predominantly elated, and four in the case of irritable mood).

As we will review below in more depth, although the DSM-5 acknowledges that depression might also be accompanied by racing thoughts -- as part of the diagnostic specifier 'with mixed features' of major depression (APA, 2013) --, this was not the case in the prior versions of the DSM. According to recent studies, the 'mixed features' specifier is present in up to 26% of individuals with major depression, and 31-34% of individuals bipolar type 1 and 2 disorders (McIntyre et al., 2015). These rates are even higher when broader definitions of mixed depression are applied (Perugi et al., 2015a). In order to clarify the clinical relevance of this symptom within the field of mood disorders, in the following sections (1.2.1, 1.2.2, and 1.2.3), the evolution of the clinical aspects related to bipolar disorder will be reviewed.

1.2.1 From Ancient Greece until the DSM

The origin of bipolar disorders has its roots in the work of the ancient Greek physicians, mostly the Hippocratic school, of the the fifth and the fourth centuries BC. Hence mania and melancholia are two of the earliest described human illnesses, although in a different or broader way than in the modern definitions (Angst and Marneros 2000; Goodwin & Jamison, 2007). Based on their understanding of health as an equilibrium of the four humors – blood, yellow bile, black bile, and phlegm --, Hippocrates and his school considered that melancholia and mania had a biological basis, which was the result of an excess of black, and yellow bile, respectively (Goodwin & Jamison, 2007). Although the etymology of the word melancholia is clear -- "melancholia" means literally "black bile" in Greek ("melas" = black, and "cholé" = bile) --, the origin of the word "mania" is unknown, because of its numerous usages in ancient Greek – i.e., a state of anger and rage in Homeric verse, and a divine or erotic state in Plato's Phaedrus (Marneros & Angst, 2005). In addition to the severe pathological forms of melancholia and mania, Hippocrates, as well as Aristotle, described corresponding melancholic and hypomanic 'personality types', being thus the forerunners of the later concept of bipolar disorder as a continuum spanning from subsyndromal affective temperaments until mood disorders (Marneros & Angst, 2005).

In the second century AD, Arateus of Cappadocia was the first to provide a unified view of melancholia and mania, noting that depression and mania were alternating phases of the same illness ("*Some patients after being melancholic have fits of mania… so that mania is like a variety of being melancholy*", Arateus of Cappadocia, cited by Goodwin & Jamison, 2007). This view was extremely influential, and prevailed in the centuries that followed. However, it was only in the nineteenth century that manic-depressive illness was explicitly acknowledged as a single disease entity. Anticipating ideas that Kraepelin would later synthesize and develop in his work, in 1854, French psychiatrists Jules Baillager and Jean-Pierre Falret reported almost simultaneously that depression and mania were part of a single circular disease, which they described under the term '*folie circulaire*' (Falret, 1854 in Goodwin & Jamison, 2007) and '*la folie à double forme*' (Baillager, 1854 in Goodwin & Jamison, 2007). Henceforth, cyclicity, and not only mood disturbance, became an integral part of conceptualizations of bipolar disorder. In addition, by the end of the nineteenth century, German psychiatrists provided descriptions of milder manic states, which were defined by the term 'hypomania' (Mendel, 1881 in Marneros & Angst, 2005), mixed states of weakness and exaltation, then called 'hypo-asthenia' (Heinroth, 1818, in Swann et al., 2013), as well as milder cases of mania and melancholia, which seem to correspond to modern day cyclothymia (Kahlbaum, 1882 in Goodwin & Jamison, 2007), and bipolar-II disorder (Hecker in Koukopoulos & Koukopoulos, 1999).

It is Kraepelin, however, with his 1899 and 1921 works "Manic-Depressive Insanity" and "Manic-Depressive Insanity and Paranoia", who provided a definitive contribution for the clinical understanding of bipolar disorder, which remains extremely influential until this day. One of his main contributions is related to the distinction between dementia praecox (now known as schizophrenia) and manic-depressive insanity. In contrast to schizophrenia, Kraepelin (1921, 2017) emphasized the periodic course, the stronger genetic component, and more benign outcome of mood disorders. Moreover, he provided an extremely detailed and broad description of mood disturbances in manic-depressive illness, which included, according to his view, recurrent depression and subsyndromal affective temperaments[3]. Thus, the concept of a spectrum of mood disorders was clearly delineated by Kraepelin (1899/2008): he suggested that there was a continuum between unipolar depression and bipolar disorder, on the one hand, but also between full-blown mood disorders and milder

[3] Kraepelin (1899/2008) considered that bipolar disorder stood on a continuum that merged imperceptibly with healthy functioning via the notion of "temperament".

states or traits, i.e., temperaments (Goodwin & Jamison, 2007). This latter continuum was further studied and conceptualized by Hagop Akiskal in many of his works, as described below. Importantly, Kreapelin clearly distinguished schizophrenia and bipolar disorders as two categories, but proposed that there was some kind of continuum with regards to mood symptoms and their combinations in full-blown but also subsyndromal bipolar disorder. This means that mood symptoms are continuous, and it is their combination and severity that constitute discrete categories (cf. table 1). However, over this mixed dimensional/categorical view of mood disorders, future nosology up until the DSM-5 favored narrower category-based classifications, which left out many of the nuances outlined by Kraepelin. Among them, one of the most important is linked to the concept of mixed states.

Indeed, according to Kraepelin (1899, 1921), mood disturbances in manic-depressive illness involved three key psychopathological domains – i.e., mood, thought, and volition/activity. Based on this tripartite model, he proposed numerous categories which reflected the combinatory nature of mood states in manic-depressive illness. Mania was thus defined as elevated mood, with flight of ideas, and elevated energy/activity. In contrast, depression was characterized by low mood, inhibition of thought, and decreased energy/activity (Piguet et al., 2010; cf. table 1). More importantly, Kraepelin (1899, 1921) acknowledged that, among the clinical presentations of bipolar disorder, mixed states, combining co-occurring symptoms of depression and mania, were particularly frequent and polymorphous. Kraepelin identified a total of six different types of mixed states, depending on the combination of disturbances in the three domains mentioned above (i.e., mood, thought, volition/activity): (i) "manic depression or anxiety", with depressed mood, flight of ideas and hyperactivity, (ii) "excited depression", with depressed mood, inhibition of thought and hyperactivity, (iii) "unproductive mania", with elated mood, inhibition of thought and hyperactivity, (iv) "manic stupor", with elated mood, inhibition of thought and apathy, (v) "depression with flight of ideas", with depressed mood, flight of ideas and apathy, and (vi) "inhibited mania", with elated mood, flight of ideas and apathy (cf. table 1 taken from Piguet et al., 2010). Later, Kraepelin and his pupil Weygandt broadened the concept of mixed states beyond the initial tripartite model, and included numerous other possibilities of concurrent depressive and manic symptoms in the same patient (Maina et al., 2013). Thus, according to Kraepelin (1899, 1921), flight of ideas could be associated with depressed mood in at least one of the mixed depression typologies that he described, i.e., "depression with flight of ideas" (cf. table 1).

Table 1: Classification of mixed states based on Weygandt and Kraepelin, Manic Depressive Insanity, 1921 (Source: Piguet et al., 2010)

	Intellect (associative thinking)	Emotion (mood, affect)	Volition (psychomotor activity)
Mania	↑	↑	↑
Depressive or anxious mania/furious mania	↑	↓	↑
Mania with poverty of thoughts/unproductive mania	↓	↑	↑
Excited/agitated depression	↓	↓	↑
Inhibited mania/manic arrest	↑	↑	↓
Depression with flight of ideas	↑	↓	↓
Manic stupor	↓	↑	↓
Orthodox depression	↓	↓	↓

Furthermore, Kraepelin suggested that mixed states were driven by a mechanism resembling hyperarousal and represented a more severe form of bipolar disorder. He also classified mixed states according to their temporality as either 'transitional', occurring between depression and mania, or 'autonomic'. Autonomic forms were the most severe manifestations of manic-depressive illness, with longer course, more chronicity, and longer episodes (Swann et al., 2013). Studies since the 1970s have supported many of Kraepelin's observations. Specifically, consistent with the hyperarousal hypothesis of mixed states, Swann and his coworkers reported in a succession of studies that mixed mania and depression were characterized by increased anxiety, compared to their non-mixed counterparts (for reviews, Swann et al., 2013, 2017). In addition, mixed episodes have been associated with a more recurrent and unfavorable illness course (Benazzi and Akiskal, 2001; Akiskal and Benazzi, 2003; Zimmermann et al., 2017) with increased suicidality and impulsivity (Akiskal et al., 2006; Swann, 2009; Pachiarotti et al., 2013; Solé et al., 2017), more comorbidities (Agosti &

Stewart, 2008), and decreased quality of life (Lee et al., 2015). For instance, McElroy et al. (1992) and Dilsaver et al. (1993) reported that patients with mixed mania had a significantly poorer response to anti-manic agents, such as lithium, compared to patients with pure mania. Interestingly, using a modified version of the Sctructured Clinical Interview for Diagnosis (SCID; First et al., 1997), Benazzi (2007b) reported that racing thoughts, distractibility, and goal-directed activity were more frequent in patients with mixed mania, compared to those with pure mania. In contrast, functional impairment was severe in mixed mania, whereas functioning could be improved during manic episodes. Moreover, factor analysis showed that pure mania had three underlying symptom factors: (i) elevated mood, (ii) irritability and racing thoughts, and (iii) overactivity (goal-directed and risky); mixed mania, on the other hand, had five underlying factors: (i) depressive vegetative symptoms, (ii) low mood and psychomotor agitation, (iii) risky activities, (iv) loss of interests, and (v) racing thoughts, worthlessness and suicidality. Of particular interest to the subject matter of our work, according to these results, racing thoughts were not only observed in manic episodes, but also, and even more so, in mixed manic episodes.

Regarding mixed depression, McIntyre et al. (2017) found that, compared to the typical depression group, the mixed depression group had more suicidality (2.0% vs. 0.5%), anxiety disorders (46.8% vs. 34.0%), substance use disorders (15.5% vs. 6.1%), and hospitalizations rates (24.2% vs. 10.5%). In a prospective study over the course of seven years, Miller et al. (2016) reported that patients with at least one monthly mixed depression episode, compared to those with no mixed depression episodes, were less likely to experience euthymia. Thus, given that chronicity, suicidality and overall severity are particularly increased in mixed depression compared to pure depression (McIntyre et al., 2017), and that individuals with mixed depression are more likely to have a diagnosis of bipolar disorder over the course of their illness (Benazzi, 2003b), it is of the utmost importance to be able to identify subthreshold hypomanic symptoms in depression. This is all the more true since an increasingly high number of studies have shown that antidepressants are less effective for individuals with mixed depression (Stahl et al., 2017; Smith et al., 2009), and may increase the likelihood of a switch to mania (Baldessarini et al., 2013; Barbuti et al., 2017), and risk of suicide (Takeshima & Oka, 2013). Therefore, antidepressant prescriptions in individuals with mixed depression, as either part of bipolar or unipolar mood disorders, need to be handled with caution (Stahl et al., 2017); akin to recommandations regarding individuals with bipolar disorder (Pacchiarotti et al., 2013), some authors suggest that antidepressants should be avoided altogether, warranting the use of antipsychotics and mood-stabilizers instead (Ghaemi & Vohringer, 2017).

Because of these major clinical implications, the identification of reliable diagnostic thresholds of mixed features in depression has been a matter of debate over the last decades. Previous versions of the DSM, and the current version of the International Classification of Diseases (ICD-10; WHO, 1992), only acknowledged episodes fulfilling criteria for both depression and manic episodes simultaneously as “mixed”; hence excluding mixed states with subthreshold manic or depressive symptoms. Recently, the DSM-5 (APA, 2013) introduced a mixed features specifier, thus broadening the diagnostic categories within mixed states (cf. Figure 1). According to the current established criteria (APA, 2013), the mixed features specifier should be applied in the case of major depression or hypomania/mania concurrent with at least three symptoms of opposite polarity (for instance, in the case of depression, racing thoughts, talkativeness and grandiosity). Symptoms shared by mania and depression (i.e., distractibility, irritability, and psychomotor agitation, or DIP) were excluded from the specifier. The DSM-5 workgroup excluded DIP symptoms arguing that they overlap in depression and mania, hence lacking the ability to differentiate between the two states. However, many authors argue against the controversial decision to exclude the overlapping

DIP symptoms from the specifier (Weibel & Bertschy, 2016; Malhi et al., 2017), and accumulating evidence suggests that DIP symptoms may be in fact core features of mixed states (e.g., Perugi et al., 2015b).

Consistently, Miller et al. (2016) showed that the presence of few concurrent manic symptoms (overlapping or not) -- i.e., a score above 2 on the Young Mania Rating Scale (YMRS; Young, Biggs, Ziegler, & Meyer, 1978) -- had better sensitivity and specificity than the current DSM-5 diagnostic criteria for depression 'with mixed features' (APA, 2013). Irritability, increased psychomotor agitation, and racing thoughts were among the most prominent symptoms in patients with mixed depression in their prospective study (Miller et al., 2016). Similar results were reported in a study by Perugi et al. (2015b), which enrolled a large cohort of patients with mood disorders (n = 2811). In this study, using the 3-symptom threshold of detection of manic symptoms in major depression, the most frequent manic/hypomanic symptoms found in their sample were irritable mood (84.2%), emotional/mood lability (74.3%), distractibility (66%), and racing thoughts (62.3%). These features were present in around one-third of patients experiencing a depressive episode, regardless of the longitudinal diagnosis (bipolar disorder or major depression). Hence, some overlapping symptoms – i.e., distractibility, irritability -- seem to be particularly prominent in mixed depressive and manic states. Importantly, among non-overlapping (non DIP) symptoms, racing thoughts appear to be consistently linked to mixed symptoms in depression, with some studies suggesting that they might be a key symptom, present in 89% of these patients (Akiskal et al., 2006; Faedda et al., 2015).

In sum, racing thoughts have been described in relation to manic, depressed, and mixed manic and depressive episodes in bipolar disorder. However, to our knowledge, only two studies (i.e., Keizer et al., 2014; Ferrari et al., 2016) have investigated, using specifically-designed psychometric tools, racing thoughts across mood episodes in bipolar disorder. These studies had some limitations, such as sample size, and the choice of the tools administered. We will further develop these points in section 1.4.1. More importantly, these studies did not fully address two aspects that are central to improve our understanding of racing thoughts: (i) its phenomenology, and how it is different from other thought patterns such as rumination, (ii) and, from the point of view of a continuum, to what extent this phenomenon might also be observed in healthy individuals with sub-affective presentations. This latter aspect will be addressed in the next section of our work.

1.2.2 From the DSM, back to Kraepelin, via Akiskal: the bipolar spectrum

Although useful to diagnosis and treatment, the DSM category-based approach that underlies nosology has some limits compared to spectrum models (Goodwin & Jamison, 2007). This is particularly the case for research on genetic markers, which relies on the characterization and validation of endophenotypes, i.e., shared traits between affected individuals and those at-risk and/or with subsyndromal temperaments similar to bipolar disorder. Temperament is a heritable personality factor that establishes the baseline level of reactivity, mood, and energy of an individual (Greenwood et al., 2012). Bearing on the concept of a broad bipolar disorder spectrum with shared genetic vulnerabilities, several studies have indicated that healthy individuals who display temperamental traits of the disorder and unaffected family members of patients with bipolar disorder have an increased risk of developping the illness (Zeschell et al., 2015; Grierson et al., 2016). An elevated risk for familial bipolarity represents the main external validation of the bipolar nature of "soft" phenotypes of the disorder (Akiskal, 2001).

Although there is no consensus regarding its definition, the concept of bipolar spectrum is generally thought to include syndromes below the threshold of bipolar type-2 disorder, and cyclothymic disorder (Goodwin & Jamison, 2007). These conditions, characterized by subsyndromal manic symptoms and recurrent depression, were part of the vague "bipolar, not otherwise specified" category in the DSM-IV-TR (APA, 2000), and now fit in more clearly defined categories in the DSM-5 (APA, 2013). These new categories broadened the operationalization of bipolar disorder via the recognition of subsyndromal hypomanic symptoms in patients with recurrent depressive episodes (other specified bipolar and related disorder); dysthymic temperament concurrent with a hypomanic episode (other specified bipolar and related disorder); and substance or medication-induced hypomania, mainly related to atypical response to antidepressants (Angst, 2013). Hence, the continuum between recurrent unipolar depression and bipolar disorder, on the one hand, and, to a lesser extent, between healthy functioning and mood disorders, on the other hand, gained more recognition in the DSM-5.

Akiskal & Akiskal (2005) suggested that temperamental conditions, such as cyclothymia and hyperthymia (or hypomanic personality), should also be considered as part of the bipolar spectrum. This assumption was based on longitudinal data suggesting that cyclothymic temperament in particular, which is characterized by marked affective instability, was one of the main predictors of subsequent diagnosis of bipolar disorder (Correll et al., 2014; Zeschel et al., 2013). More specifically, during their own 2–4 years of follow-up of healthy adults with cyclothymic temperament, Akiskal et al. (1977) found that 35% of their sample switched to bipolar disorder diagnosis.

As mentioned in the previous section, although this diathesis model may seem new, it had already been explicitly outlined by Kraepelin by the end of the nineteenth century. Along with other ancient physicians before him, Kraepelin (1899/2008) posited that bipolar disorder stood on a continuum that merged imperceptibly with healthy functioning via the notion of "temperament". According to him, subsyndromal affective temperaments were a risk-factor for the development of manic-depressive illness: "…permanent and uniform mood colorations are usually the background upon which circomscribed, but fully-formed psychopathological states of manic-depressive illness evolve." (p. 6). More specifically, he acknowledged four predisposing affective temperament types relative to specific 'permanent mood colorations': (i) dysthymic, (ii) hypomanic, (iii) irritable, and (iv) cyclothymic. Only recently, however, the validity of this conceptualization was directly assessed, via the development of a self-rating questionnaire, the Temperament Scale of Memphis, Pisa, Paris and San Diago-Autoquestionnaire (TEMPS-A; H. S. Akiskal et al., 2005). Because of its ease of use, the TEMPS-A has been widely utilized in numerous contexts in the general population. For instance, in undergraduate students, Vellante et al. (2011) found that increased involvement in creative activities was associated with elevated cyclothymic traits, hence establishing a relationship between 'healthy' mood instability and a psychological feature usually observed in full-blown bipolar disorder (Jamison, 2017).

In recent years, biological studies in individuals with exacerbated temperament traits have provided further evidence consistent with this broad spectrum view. For instance, via a MRI cross-sectional study, Hatano et al. (2014) found that healthy subjects with high cyclothymic and high hyperthymic traits had significantly larger gray matter volume of the left medial frontal gyrus than their counterparts with low temperament traits. Morphological abnormalities in the medial prefrontal cortex have been widely described in bipolar disorder (for a review, Savitz, Price, & Drevets, 2014), and this region is viewed as a key system in the regulation of emotional, behavioral, endocrine, and innate immunological responses to stress, supposedly involved in the pathogenesis of bipolar illness (Savitz et al., 2014). In addition, in patient and healthy populations, underlying hyperthymic and cyclothymic temperament have been reported to be associated to lithium efficacy (Rybakowski et al., 2013). Recent genetic findings are also supportive of a continuum between exacerbated temperament traits in healthy individuals and full-blown bipolar disorder. For instance, Gonda et al. (2009) reported that increased cyclothymic traits found in healthy women were significantly associated with

5-HTTLPR polymorphism of the serotonin transporter gene, which had been previously linked to bipolar and unipolar mood disorders (Bellivier et al., 1998; Bellivier et al., 2002).

To sum up, racing thoughts have been reported in all phases of bipolar disorder, including euthymia (Ferrari et al., 2016). Recent studies suggest that they might also be observed in healthy individuals with marked affective temperament traits. However, as mentioned earlier, psychometrically sound and validated questionnaires able to assess racing thoughts in both patients and healthy subjects are still lacking. Hence, the validity of these observations, usually based on the reports of clinicians, have not been empirically assessed until now. As will be further developed in the next two sections, thought disturbances are common in psychiatric disorders: e.g., rumination is typically linked to depression and formal thought disorder to schizophrenia. Similar to the ongoing debate regarding diagnostic boundaries between bipolar disorder and schizophrenia (Bora & Özerdem, 2017) and bipolar disorder and unipolar depression (Benazzi, 2007d), the exact delineation of the racing thoughts phenomenon relative to rumination and formal thought disorder has raised some controversy since the beginning of the twentieth century. Thus, it is still not clear whether racing thoughts are a distinct phenomenon, qualitatively different from rumination and formal thought disorder, on the one hand, and whether they are pathognomonic of the bipolar disorder spectrum, on the other hand. We will be briefly review in the next two sections diagnostic aspects that are relevant for the delineation of racing and crowded thoughts relative to other thought disorders.

1.2.3 Bipolar disorder and schizophrenia: implications for the understanding and delineation of racing thoughts

According to Kraepelin (1899/2008), dementia praecox was characterized by a deteriorating course into chronic dementia, while manic-depressive illness followed an episodic course with intermittent recovery[4] (Goodwin & Jamison, 2007). Later, Bleuler (1911/1950) renamed dementia praecox as schizophrenia and identified symptoms supposedly specific and pathognomonic of the illness: i.e., splitting of thought from feeling and behavior, formal thought disorder, blunted affect, autism, and ambivalence. In line with the Kraepelinian dichotomy, Bleuler (1911/1950) conceptualized schizophrenia as mainly a thought disorder, whereas manic-depressive illness was viewed as a disturbance of the moods (Lake, 2008). More specifically, disordered thought in schizophrenia consisted of hallucinations, delusions, catatonia, formal thought disorder and/or disorganization, all of which were supposedly rare in bipolar disorder (Lake, 2008). In the last forty years, especially since the introduction of the borderline category 'schizoaffective disorder' in the DSM-III (APA, 1980), the dichotomy of bipolar illness and schizophrenia has been called into question. Given that psychotic symptoms are frequent during acute mood episodes (Goghari & Harrow, 2016), the current diagnostic criteria for schizoaffective disorder of the DSM-5 (APA, 2013) require the occurrence of at least two episodes of psychosis, lasting a minimum of two weeks, without mood disorder symptoms. The validity of the schizoaffective category has not reached a consensus up to this day, with some authors arguing that the concept lacks reliability and temporal stability (Pagel et al., 2013)[5].

Relevant to our work, one of the distinguishing features of schizophrenia, formal thought disorder, was poorly delineated by Bleuler (1911/1950), blurring the boundaries relative to thought disorders found in bipolar illness. According to Bleuler (1911/1950), formal thought disorder is characterized by 'associative loosening', but also 'pressure of thoughts' and

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[4] The distinction between schizophrenia and bipolar disorder posited by Kraepelin (1899/2008) is called 'the Kraepelinian dichotomy' in the psychiatric literature.

[5] It is beyond the scope of our work to discuss the diagnostic boundaries between schizophrenia and bipolar disorder, and whether there is a 'psychosis' continuum linking schizophrenia to bipolar disorder. Thus, we will not go into further detail regarding these points. In this section, our aim is to focus rather on the delineation of racing and crowded thoughts relative to formal thought disorder in schizophrenia. We will further discuss this point in 1.3.1.

‘blocking’ (i.e., stopping in the middle of a thought), which hold a striking resemblance to racing and crowded thoughts, respectively. Based on continuum models linking schizophrenia to bipolar disorder, and, more specifically, thought disorders in mania to those observed in schizophrenia, studies dating back from the 1970s (e.g., Andreasen, 1979; Andreasen, 1986) attempted to provide a more consistent delineation of formal thought disorder via the characterization of thought and language abnormalities found in the two groups of patients. These studies were thus based on the assumption that thought disorders in schizophrenia and mania were qualitatively similar; their severity only varied along a spectrum: schizophrenic and manic thought disorders being respectively the most severe and less severe forms (Andreasen, 1979; Lake, 2008; Yalincetin et al., 2017). This view remains influential, and most experimental investigations of racing thoughts and flight of ideas (for a review, Roche et al., 2015) have used scales that were developed on the basis of this unitary conceptualization of formal thought disorder that cuts across ‘psychotic’ diagnoses, e.g. the Scale for the assessment of thought, language and communication (TLC; Andreasen, 1979) Yet, phenomenological and linguistic accounts have outlined substantial differences between schizophrenic formal thought disorder, and racing thoughts found in bipolar disorder (Binswanger, 1933/2000; Braden & Ho, 1981; Piguet et al., 2010; Sass & Pienkos, 2015). Our work, and the development of the Racing and Crowded Thoughts Questionnaire (RCTQ), drew from this literature. The phenolomenological minutiae of racing thoughts and their relations to other thought disturbances will be further discussed in section 1.3.

1.2.4 Bipolar disorder and unipolar depression: implications for the understanding and delineation of racing thoughts

Although Krapelin’s initial description of manic-depressive illness (1899/2008) included recurrent depression among its clinical forms, the DSM-III up to the DSM-5 (APA, 1980, 2013) have instead conceptualized depression and bipolar disorder as distinct disorders. As mentioned in the previous sections, unlike the prior versions of the DSM, in the DSM-5 (APA, 2013), the mixed feature specifier contributed to bridge the gap between bipolar and unipolar affective illnesses, and moved towards the initial continuum conceptualization of manic-depressive illness as outlined by Kraepelin (1899/2008). These recent modifications are due to accumulating data suggesting that concurrent subthreshold hypomanic symtoms are common in unipolar depression, arguing against a hypomania/mania-depression splitting (Benazzi, 2007b), and the high rates of misdiagnosis of bipolar disorder as unipolar depression (Goodwin & Jamison, 2007; Swann, 2017).

Recently, Benazzi (2007b) reviewed 109 papers on unipolar depression and bipolar disorder, and investigated whether depression and bipolar disorder could be viewed as a continuum or not. Both the categorical distinction and the continuum approaches were supported by his findings, with bipolar type 1 disorder differing in a number of parameters from unipolar depression, whereas very few distinguishing features were observed between bipolar type 2 disorder and unipolar depression. According to Benazzi (2007b), bipolar type 2 disorder and unipolar depression stood on a continuum, a view that was later partially adopted by the DSM-5 (APA, 2013; cf. figure 1), but bipolar type 1 disorder and unipolar depression seem to represent two distinct categories.

Cross-sectionally, it can be difficult to distinguish bipolar from unipolar depressive episodes, and the relative risk of misdiagnosis of unipolar depression concern up to 40% of patients with bipolar disorder who seek treatment during a depressive episode (Smith & Ghaemi, 2010; Vöhringer & Perlis, 2016). This difficulty arises at least in part from the fact that nosology itself does not differentiate bipolar depression from unipolar depression – i.e., in the DSM-5 (APA, 2013), the same set of clinical symptoms is required for the diagnosis of both cases of depression. Thus, only the longitudinal course of the illness (i.e., past hypomanic episodes) and the presence of distinguishing symptoms can improve the detection of bipolar disorder in such cases (Vöhringer & Perlis, 2016).

Among the clinical characteristics which require increased surveillance, mixed symptoms (Takeshima & Oka, 2015), and racing thoughts in particular (Diler et al., 2017), have attracted attention as a bipolar-suggestive feature in unipolar depression (Takeshima & Oka, 2013), as well as a predictive risk factor of future progression from unipolar to bipolar affective illness (Fiedorowicz et al., 2011). For instance, Diler et al. (2017) reported an increased odds ratio for racing thoughts (7.6; 95% CI: 1.3-44), and, to a lesser extent, for mood lability (6.3; 95% CI: 1.2-33.4), in depressed youth with high familial risk for bipolar disorder compared to those with low familial risk. In another study, the same team found that subsyndromal hypomanic symptoms, particularly motor hyperactivity, distractibility, and flight of ideas/racing thoughts, were higher in bipolar depressed youth, and discriminated bipolar depressed from unipolar depressed youth (Diler et al., et al., 2017).

Because mixed features might be key in differentiating unipolar from bipolar affective illness, there has been some recent interest in how to quickly and reliably assess them in depression (Prieto et al., 2015). However, while questionnaires assessing depressive symptoms are routinely used in clinical practice, concurrent hypomanic symptoms are rarely screened during the follow-up of patients with depression (Zimmerman, 2017). Specifically, racing thoughts, which is one of the main non-overlapping (non-DIP) mixed feature found in association with depression (Perugi et al., 2015b), have been remarkably understudied. Thus, when racing thoughts occur during depressive episodes, its delineation relative to rumination is poorly understood.

Traditionally, rumination has been the most prominent thinking pattern associated with low mood, whether in major depression or in "healthy" mood fluctuations (Treynor et al., 2003).

Rumination has been defined as a repetitive, and analytical pattern of thinking found to be associated with the onset and the maintenance of major depression (Aldao et al., 2010). Like racing thoughts in depression, rumination is often accompanied by low mood, but unlike racing thoughts it is repetitive in nature, and is characterized by poverty of thought (Desseilles et al., 2012; Marchetti et al., 2014).

Compared to unipolar depression, few studies have investigated rumination in bipolar disorder (Kim et al., 2012). For example, Van der Gucht et al., (2009) found that the tendency to ruminate was highly correlated to depressive symptoms, but not manic symptoms, suggesting that it is selectively linked to depressive mood. In at-risk populations, Pavlickova et al. (2014) found increased levels of rumination in offspring of bipolar parents compared to unaffected offspring of healthy controls, but they did not control for the presence of racing and crowded thoughts. Thus, it still unknown whether rumination is observed in association with other mood states than depression – for example, in mixed depression.

In sum, the boundaries between unipolar depression and bipolar disorder (mainly bipolar type 2 disorder) seem porous, with mixed features, particularly racing and crowded thoughts, representing a potential discriminating feature between the two conditions (Diler et al., 2017). In the next section, we will review the existing phenomenological literature on racing thoughts, in order to clarify how, in our work, we addressed this phenomenon from a psychopathological and neuropsychological perspective.

1.3 The phenomenology of racing thoughts in bipolar disorder

In the preface of his groundwork, *Phénoménologie de la perception*, Merleau-Ponty (1945/ 1976) defined phenomenology as the study of 'essences' inasmuch as it aims at providing a direct description of experience as it is; hence, without taking account of its psychological origin and the causal explanations which the scientist may be able to formulate. Ultimately, it is “a matter of describing, not of explaining or analysing” (Merleau-Ponty, 1945, p. 9). By focusing on subjective experience, phenomenology evolved as a reaction to the overly naturalistic stance of early psychological science, which considered psychological phenomena (i.e., objects of consciousness) as physical phenomena liable of third-person empirical accounts (Giorgi et al., 2012). Husserl’s first directive to phenomenology, in its early stages, to be a ‘descriptive psychology’ or to return to the ‘things themselves’ (in Merleau-Ponty, 1945/1976), layed the ground to what would become, according to Heidegger (1988), the name for the *method of scientific philosophy in general*. Before we define the basic components of the phenomenological method, it is important to emphasize that phenomenology was founded upon the phenomenon of consciousness, i.e., how it presents itself and its various manifestations (Giorgi, 2012). According to Husserl (1913/ 2014), conciousness is both intentional and non-sensorial, meaning that consciousness is consciousness ‘of something’, and it is also the means by which one becomes aware ‘of something’. That is, we may become aware of physical, psychological or biological phenomena (perceptions), but consciousness is none of these things; as Giorgi (2012, p. 178) puts it: “it is the medium of access to anything whatsoever that can be experienced”. As such, phenomenology acknowledges that consciousness is both the ‘content’ and the ‘container’ (or structure) of experiences. Phenomenologists thus aim to define the structure of conscious experiences, and this is why Husserl focused on time, because the temporal structure of consciousness shapes our subjective experiences.

The phenomenological method is best illustrated by an example. When we see an apple, we take for granted the underlying knowledge of the apple being a type of fruit, due to the fact that we are immersed in a meaningful world. Thus, how we perceive the apple is both a series of ‘appearances’ (perceptions) of the apple, and an interpretation of what the apple is. An accurate and systematic study of world experience thus requires a radical method in order to move beyond the natural attitude. In phenomenology, such method is called ‘bracketing’ or *epoché*. Bracketing consists of setting aside our naïve (or taken for granted) attitute towards the world, in order to focus on the world as it is given to us – i.e., the phenomena --, including the conditions related to their appearances – dreams, perceptions, hallucinations, and so on. In his own words, Husserl (1913/2014) defined bracketing as “the complete exclusion of every assumption, stipulation and conviction…”. Through the bracketing of previous knowledge, phenomenologists are able to explore the contribution consciousness makes in constituting the objects of our experience – in allowing them to appear and giving them meaning. This approach differs from the empirical method which aims at exploring the objects as separate from how they are experienced. Because of this, first-person narrative accounts of experiences are the material of choice of phenomenological science.

As a scientific method, phenomenology was not only influential within the field of philosophy, but also in other scientific fields, and particularly in psychiatry. Swiss psychiatrists and philosophers, Karl Jaspers (1959) and Ludwig Binswanger (1933/2000) emphasized that phenomenology should precede diagnosis and treatment, entailing that accurate description and understanding of a patient's experience are one of the fundaments of clinical psychiatry (Ghaemi, 2007). Yet, according to Ghaemi (2007), in contemporary psychiatry, phenomenology is often skipped over, due to an overemphasis on the last steps of the process: diagnosis and treatment. That is, there is an over-reliance on third-person accounts (the clinician’s observations) and prior nosological knowledge. As a consequence, empirical research on relevant phenomena, which might ultimately aid diagnosis and treatment, may be impoverished.

While historically phenomenology evolved as a reaction against empirical psychology, considered then as overly naturalistic, ideally, the relationship between psychiatry (and neuroscience as a whole) and phenomenology should be a reciprocal one (Bowden, 2013).

Indeed, phenomenological science may help to improve our understanding of experiences of psychiatric disorders, in turn aiding classification, empirical research, and treatment, but used by itself it suffers from a number of problematic features. The main one is related to the use of first-person narrative accounts which may be influenced by a number of factors such as memory, culture, and motivation (Sass & Pienkos, 2015). Thus, if such factors are not carefully acknowledged, instead of refering to a shared 'essence', phenomenological analyses of first-person narrative accounts may convey the singular experience of a person embedded in a particular culture and context, including one's motivation and mood state. This is all the more true in the context of psychiatric disorders such as bipolar disorder, with its characteristic disturbances in motivation and memory processes (including mood-congruent recall biases;e.g., Gaddy & Ingram, 2014). Another potential problem of first-person narrative accounts refers to the fact that psychiatric disorders do not simply involve alterations in the content of experience – what the experience is about – they also frequently involve alterations in the structure of experience (Bowden, 2013). If such is the case in bipolar disorder, the reflective and narrative nature of the phenomenological method may prove insufficient to fully grasp, by itself, related anomalous subjective experiences, because structure of experience itself may be altered. Conversely, the experimental approach alone may prove insufficient to fulfill this goal. Biswanger (1933/2000) considered that the use of explicit paradigms (e.g., verbal association) by some of his contemporaries was unfit to reveal the complex nature of racing thoughts in bipolar disorder, because the structure of the experience itself (e.g., how words are connected to each other) may be altered. This argument was used to highlight the limits of the neuroscientific method and to advocate for the phenomenological approach. As a matter of fact, at least some of the arguments Binswanger (1933/2000) has put forward may be used to advocate for a combined phenomenological and neuroscientific approach. Indeed, flight of ideas is a complex phenomenon, which probably affects both the content and the structure of conscious experiences. Thus, first-person accounts might prove insufficient to address its complexity. In this sense, the neuroscientific method might inform phenomenologists by providing methods to disentangle impairments in the structure and contents of consciousness. As outlined by Bowden (2013), the aforementioned limits of first-person narrative accounts are the reasons why neuroscientific findings might inform and enhance phenomenological studies, and such has been the case since the beginning of phenomenology. For example, Merleau-Ponty (1945/1976) made use of cases of phantom limb syndrome to inform his investigation of bodily experience. Therefore, used judiciously and in conjunction with other resources, such as empirical findings, first-person narrative accounts can be particularly informative to clinicians and researchers, and, conversely, neuroscientific findings can help improving phenomonological studies (Bowden, 2013).

Consistent with this integrative and reciprocal view linking neuroscience and phenomenology, recently, Sass & Pienkos (2015) highlighted that phenomenology had an important role to play in neurobiological and neurocognitive accounts, given that subjective experiences are among the factors that contribute to the development of the theoretical ground this kind of research builds upon. This process whereby phenomenology contributes to and interacts with the neuroscientific understanding of disorders is called "front loaded phenomenology" (e.g., Gallagher, 2003). The idea is to gather insights developed in phenomenological analyses to inform the way experiments are set up (Bowden, 2013). In line with this train of thought, in our work, both the psychopathological and neuropsychological approaches of racing thoughts were built upon the phenomenological literature summarized below. It has to be emphasized, however, that we are aware of the pitfalls of this approach. The scientific method attempts at reducing the part of subjectivity, and considers only few variables while addressing its objects. The phenomenological method is based on first-person accounts and addresses phenomena as they are experienced. Given their differences, conceptual correspondence between the two fields is for the most part tentative.

In this section, we will provide a brief review of the phenomenological literature on racing thoughts and flight of ideas, starting with the major psychopathological contributions by Kraepelin (1899/2008) and Binswanger (1933/2000), then focusing on specific phenomenological frameworks, such as temporal (e.g., Minkowski, 1933/2013; Binswanger, 1933/2000), and linguistic accounts (e.g., Sass & Pienkos, 2015) of racing thoughts. Although Kraepelin was in no way a phenomenologist – the philosophical traditions underlying his ideas have been mostly attributed to naturalism and realism (Hoff, 2015) --, his emphasis on the descriptive approach in psychopathology in general and in psychiatric diagnosis in particular remains the cornerstone to later developments provided by phenomenologists such as Binswanger. Because of this, we have integrated his detailed descriptions of racing thoughts in this section of our work.

1.3.1 Psychopathological phenomenology

1.3.1.1 Early descriptions

« The thinking of the manic is flighty. He jumps by by-paths from one subject to another, and cannot adhere to anything. With this the ideas run along very easily and involuntarily, even so freely that it may be felt as unpleasant by the patient… »

Bleuler (1924, cited by Goodwin & Jamison, 2007, p. 33)

The early descriptions outlined by Kraepelin (1899/2008), but also by Bleuler (1924 in Goodwin & Jamison, 2007), suggested that, as an 'excitement' symptom, racing thoughts were first and foremost observed in mania, but were also frequent in depressive states. Regardless of the mood episode to which it was associated, Kraepelin (1899/2008) considered that distractibility was one of the core characteristics of flight of ideas and racing thoughts; racing thoughts were, according to him, a “partial manifestation of an increased distractibility” (Kraepelin, 1899, p. 17), which might result in the increase in discourse shifts observed in the patient’s speech. He added: “each object they come across, each inscription, each fortuitous noise, may trigger a series of similar representations, sometimes associated solely based on a linguistic routine, or by assonance… the perceptions are very fleeting, and the patient seems not to care about others… everything they perceive has an influence on their stream of thoughts, and generally, on their speech.” (Kraepelin, 1899, p. 17).

In addition to distractibility, Kraepelin’s (1899/2008) description of racing thoughts acknowledged three other features which are key to this phenomenon: (i) the lack of purpose, (ii) the acceleration or fleeting nature of representations, and, in terms of speech, (iii) the increased associations based on sound, rather than on the meaning of words. Of particular interest to our work, his broad descriptions of racing thoughts entailed more detailed accounts bearing from specific frameworks such as time and language. These frameworks will be further developed in the next specific sections.

Lack of purpose is manifest in the patients’ thinking through tangentiality; it is perceived by patients as uncontrollable, and might be related in some ways to ‘distractibility’ (Kraepelin, 1899). Reflecting on this krapelinian observation, Jamison (2017) suggested that, in healthy individuals, ideas move along in a reasonably straight line, following a main purpose, whereas manic flight of ideas move in all possible directions. Binswanger (1933/2000) argued however that lack of purpose was not uniformly observed in individuals with racing thoughts. Instead, he claimed that there were at least two kinds of racing thoughts, i.e., ‘organized’ and ‘disorganized’, differing with regards to their ability to pursue a given purpose. According to Binswanger (1933/2000), organized flight of ideas was in fact characterized by intact intentionality (or purpose), although purpose may seem more fleeting – hypomanic stream of thoughts may seem coherent to others, despite the numerous digressions. Thus, in 'organized flight of ideas', "the goal is reached, but the path is shortened" (p. 44). By contrast, in disorganized flight of ideas, the purpose is lacking, leading to sudden conceptual shifts. The subject reaches his or her mental goal through "an electric choc" or does not reach it at all (p. 44); this is often accompanied by irritability and aggressive behavior. According to Binswanger (1933/2000), the subject's world becomes "narrower, simpler, and flat, like a flight over a hillocky landscape" (p. 44). Hence, organized flight of ideas seems to correspond to the racing fluidity of thoughts associated with elated mood in hypomanic states, whereas his description of disorganized flight of ideas holds a striking resemblance to what was later termed as 'crowded thoughts' in mixed states. It is also worth noting that Bleuler (1924 in Goodwin & Jamison, 2007) suggested that fluidity, associated with increased productivity and creativity, was a feature of racing thoughts found in mild hypomanic states: "…because of the more rapid flow of ideas, and especially because of the falling off of inhibitions, artistic activities are facilitated even though something worth while is produced only in very mild cases…" (p. 33). Instead, in severe manic states, thinking is described as fragmented, at times incoherent, distractibility becomes all-pervasive, and rapid thinking proceeds to disjointed thinking, similar to what was later termed as 'crowded thoughts' (Goodwin & Jamison, 2007). Like mixed states, severe mania is often associated with irritability, and aggressive behavior (Goodwin & Jamison, 2007). Recent psychopathological accounts (e.g., Piguet et al., 2010), outlined in the next section, further developed this point (section 1.3.1.2).

The fleeting nature of thoughts is in turn more specifically related to the temporal characteristics of racing thoughts, i.e., "…they do not remain enough time in consciousness, they disappear very fast, and do not have the time to be developed" (Kraepelin, 1899, p. 17). Binswanger (1933/2000) also stressed the fleeting nature of racing thoughts: "the contour of thoughts becomes blurry. In this place where everything is always changing (volatility), the limits (of thoughts) are more fluid, and less well-defined, resulting in a thinking that may seem vague, whose object is difficult to seize." (p. 107). The subjective experience of time in individuals with racing thoughts is outlined in more detail in section 1.3.2.

Lastly, Kraepelin (1899/2008) emphasized the unique pattern of associations found in states of 'manic excitement', with its characteristic pacing and sounds, i.e., increased rhymes, alliterations, citations and free associative speech. Based on the observations of Bleuler (1924 in Goodwin & Jamison, 2007) and Falret (1854) among a number of clinicians, Goodwin & Jamison (2007) and Jamison (2017) pointed that, to a point, associational fluency was furthered by mild hypomania, and was involved in the increased creative achievements found in some individuals with bipolar disorder. Isserlin & Liepmann (cited by Binswanger, 1933/2000) claimed, based on their experimental findings via verbal association tasks, that associations based on sound (or clang associations) were still meaningful to the subject; thus, phonemically associated successive words were somewhat semantically coherent. Bearing on the works of Griesinger and Bumke, Binswanger (1933/2000) added that the idiosyncratic association pattern characteristic of racing thoughts was not necessarily verbalized – it could be manifest only in the subjective realm. According to him, this was likely to be due to an overly abundant supply of representations available over a given time unit, that could not be filtered by attention processes (Binswanger, 1933/2000). Because of this, he argued that verbal but also temporal paradigms were unlikely to capture the racing thoughts phenomenon (Binswanger, 1933). We will further discuss this point in section 1.4.3. Recent linguistic accounts of racing thoughts are presented in more detail in section 1.3.3.

Importantly, Kraepelin (1899/2008) also noted that patients were usually aware of, and able to report their racing thoughts. However, he did not specify the determinants of this ability, which, as noted later by Binswanger (1933/2000), might actually be diminished in some manic patients, due to a lack of insight. Most reports cited by Kraepelin (1899/2008) were characterized by the negative consequences of racing thoughts, which might be suggestive of the co-occurrence of manic and depressive symptoms found in mixed episodes. According to Kraepelin (1899/2008), patients with racing thoughts often reported difficulties in "organizing their thoughts" and "concentrating" because of their numerous rapid thoughts, which he examplified with the following reports: "there is a storm in my head", "one thought race after another, and they simply flow away", "I have too many thoughts in my head", "I cannot have a grasp on my thoughts, because they disappear too quickly".

More specifically, in depressive episodes, Kraepelin (1899/2008) noted that racing thoughts were frequent, but difficult to assess clinicallly: "it is often difficult to recognize (racing thoughts) in the concise speech of these laconic patients; they are rather more visible in their writings" (Kraepelin, 1899, p. 16). Binswanger (1933/2000) claimed that, instead of being over-talkative, during mixed episodes, some patients displayed "language compression" with a "telegraphic style" (p. 86). Patients with mixed depression complained overtly of the effects of their numerous thoughts on their functioning: "I cannot pray, work, because new thoughts arise all the time in my mind" (Kraepelin, 1899, p. 16). Of particular interest to the phenomenology of mixed depression, Kraepelin (1899/2008) also noted that racing thoughts in depression could alternate with periods of "inhibition of thought", i.e., rumination. To this matter, he quoted the following report of a depressed patient: "my thoughts are still, then all of a sudden they come back, by themselves, and they race all over the place. (p. 17)"

According to Kraepelin (1899/2008), inhibition of thought had the exact opposite characteristics of racing thoughts, with a slowing of thinking, association patterns based on the meaning of thoughts, rather than on sound or outside stimuli, and a decreased number of thoughts, whose content was limited to a few negative topics. These thoughts were usually described as uncontrollable: "I cannot stop ruminating for hours on end about self-judgmental things, and other trivial things" (p. 18). Recent phenomenological accounts proposed similar differences between racing thoughts and rumination in mood disorders (Piguet et al., 2010).

Interestingly, although not described in as such depth as in full-blown episodes, Kraepelin (1899/2008) also reported racing thoughts in healthy individuals with exacerbated hyperthymic (hypomanic) and cyclothymic temperament traits. These individuals were, according to his observations, particularly loquacious, prolific in their projects and ideas, and displayed unusual shifts in conversation topics. He thus identified, in milder forms of racing thoughts, the same characteristics of racing thoughts found in association with manic mood. Binswanger (1933/2000) was also supportive of this continuum view, arguing that, phenomenologically speaking, there was no clear split between 'normal' train of thought and racing thoughts in individuals with mood disorders. He argued, for instance, that the creative flow after a whole night of work, in a healthy individual, resembled the 'loosening of attention, and disturbed purpose' (p. 108) characteristic of racing thoughts in manic individuals.

1.3.2.2 Recent developments

While racing thoughts attracted a great deal of attention from psychiatrists in the beginning of twentieth century, this attention decreased substantially in the subsequent decades. This is partly due to the fact that, formal thought disorder, a major feature of schizophrenia outlined by Bleuler (1911/1950), became an overinclusive term refering to thought disorders in schizophrenia, but also in mania and, to a lesser extent, in depression (Andreasen, 1982). In a recent review, Lake (2012) acknowledged that this confusion took its roots in Bleuler's initial descriptions of patients with thought disorders in schizophrenia. Indeed, both 'pressure of thoughts' and 'blocking', supposedly characteristic of formal thought disorder, were described by Bleuler (1911/1950) as an 'increased flow of ideas'; they were later reattributed to manic racing thoughts by more recent authors (e.g., Braden & Ho, 1981; Lake, 2012), claiming that the reports given by Bleuler (1911/1950) were instead reflective of a manic state in a patient that was initially diagnosed with manic-depressive illness. Pressure of thoughts was described by Bleuler (1911/1950, cited by Lake, 2012) in the following way: "many (schizophrenic) patients complain that they must think too much, that their ideas chase each other in their heads… thoughts overflow (because they cannot hold anything in their minds)… too much seems to come to mind at once…" (p. 32); hence, in a very similar way to his own description of racing thoughts in mania. Blocking, instead, was illustrated by an example of sudden conceptual shift, which Lake (2012) attributed to an overproduction of thoughts which the patient could not filter and put into words. Similarly, loosening of associations, another main feature of formal thought disorder according to Bleuler (1911/1950), was conceptually very close to the associational patterns found in manic episodes. It was examplified as follows by Bleuler (1911/1950): "the (schizophrenic) patient may lose himself in the most irrelevant side-associations, and a uniform chain of thought does not come about." (p. 18).

It was only in the 1970s and 1980s that authors attempted at clarifying the speficities of thought disorders in schizophrenia, and across mood episodes in bipolar disorder. However, whereas some authors (e.g., Andreasen, 1986) compared linguistic and thought abnormalities between schizophrenia and mania based on the premise that both belonged to a psychosis spectrum, others (e.g., Braden & Ho, 1981) investigated whether racing thoughts in particular were observed across different diagnostic groups, i.e., depressed, manic and schizophrenic inpatients. Using the Scale for the Assessment of Thought Language and Communication, Andreasen (1986) found that schizophrenic and manic patients had similar levels of thought disorder, which differed however on a number of qualitative domains: manic patients displayed more pressure of speech, derailment and tangentiality, whereas schizophrenic patients' thinking was characterized by poverty of speech and content. Emphasizing the speed of associations between the two disorders, Andreasen (1979) stressed that derailment in schizophrenia was a "slow, steady slippage", whereas in mania "flight of ideas was a derailment that occurs rapidly in the context of pressured speech". Thus, the acceleration and overproduction of thoughts, i.e., racing thoughts, were a distinctive feature of the manic group. In another study, using a definition of formal thought disorder which included tangentiality, neologisms, drivelling, private use of words, and paraphasia, Jampala et al. (1989) found that narrowly defined formal thought disorder was rare in manic patients, whereas racing thoughts and flight of ideas were very prevalent. In addition, following treatment, thought disorder improved significantly in manic patients, but not in schizophrenic patients, suggesting that formal thought disorder and racing thoughts were actually distinct phenomena specifically linked to schizophrenia and bipolar disorder, respectively.

Focusing specifically on racing thoughts, Braden & Ho (1981) reported via a semi-structured interview that racing thoughts were rare in patients with schizophrenia. However, they were very prevalent in manic, but also in unipolar and bipolar depressed inpatients. Their study was particularly important in describing the specific characteristics of racing thoughts in depressed and manic patients. For instance, the results suggested that 'disturbed concentration' and 'ideomotor pressure' were equally found in racing thoughts in depression and mania, whereas 'exciting ideas' were a defining feature of racing thoughts in mania (present in 100% manic patients, and only in 14% of depressed patients). In addition, racing thoughts were experienced as pleasant in 50% of manic patients, and only in 6% of depressed patients. Conversely, they were experienced as unpleasant in 78% of depressed patients, and only in 25% of manic patients. Functional impairment (interference with work) was also more common in depression (83%) than in mania (50%). Consistent with the assumptions put forward by Kraepelin (1899/2008), these results indicated that racing thoughts were common in depression, and that, regardless of the mood episode, two of their main features consisted of distractibility (termed here as 'disturbed concentration'), and speeded thinking (termed here as 'ideomotor pressure'). Like racing thoughts in manic episodes, patients with depression had difficulties to describe the content of their thoughts "as if each thought was attended for only a brief time". Qualitatively, according to Braden & Qualls (1979), patients with depression described their racing thoughts with metaphors implying rotation and lack of control, both aspects probably contributing to the unpleasant feeling specific to depression: i.e., their thoughts were "like a whirlpool", "a hurricane", "a merry-go-round", "a paint-machine", "It was continuous like a TV screen… thoughts kept flashing on, and I couldn't stop it".

Only recently, however, Koukopoulos & Koukopoulos (1999), and Benazzi, (2003a; 2005; 2007), in a number of studies, explicitly acknowledged the possibility that racing thoughts might be a multi-faceted phenomenon, consisting of at least two types of racing thoughts – i.e., racing and crowded – associated with manic and depressive mood, respectively. According to Benazzi (2003a), "in racing thoughts the head is full of rapid thoughts that the patient cannot stop, while in crowded thoughts the head is full of non-rapid thoughts that the patient cannot stop". He further developed the idea, initially outlined by Koukopoulos & Koukopoulos (1999), that in mixed depression, thoughts of all kind accumulate in the patient's head, i.e., crowded thoughts. First-person accounts suggest that this accumulation of thoughts of all kind is experienced as dysphoric. Sarah Kane, the playwright who so vividly evoked her experience with depression (supposedly with mixed features) in her play *4.48 Psychosis*, described her thinking with the metaphor of 'ten thousand cockroaches' accumulating in one's mind: there was a "… darkening banqueting hall near the ceiling of a mind as ten thousand cockroaches…" (2008, p. 3).

In a later study, Benazzi (2007a) introduced a severity gradient in racing thoughts with, in that order, crowded thoughts (non-stop thinking), racing thoughts (speedy thinking), and flight of ideas (quick, disconnected thinking). Consistent with this severity gradient, in a review on the phenomenology of racing and crowded thoughts, Piguet et al. (2010) proposed a broader description of thought patterns in mania and depression, including a distinction between rumination and inhibition of thought. Five combinations of mood and thought disturbances were outlined by the authors: (i) racing thoughts with flight of ideas (the verbal equivalent of racing thoughts) were observed in manic states, (ii) linear racing thoughts with pressure of speech without flight of ideas were characteristic of hypomania, (iii) deficit of production of new thoughts (psychic retardation) was characteristic of inhibited depression without rumination, (iv) deficit of production of new thoughts with deficit of inhibition of previous thoughts was found in inhibited depression with rumination, and (v) acceleration of thinking concomitant with a deficit of inhibition of previous thoughts resulting in crowded thoughts was characteristic of mixed depression.

Interestingly, Piguet et al. (2010) proposed an integrative model that took account of phenomenological reports of racing thoughts, but also of current neuropsychological models of rumination suggesting that this clinical symptom was related to impaired inhibition of previous negative thoughts and switching (e.g., Whitmer & Gotlib, 2012). In this model, thought patterns in mood disorders were thus conceptualized as disturbances involving two cognitive processes: production of new thoughts and inhibition of previous thoughts. Figure 2 illustrates the integrative model proposed by Piguet et al. (2010).

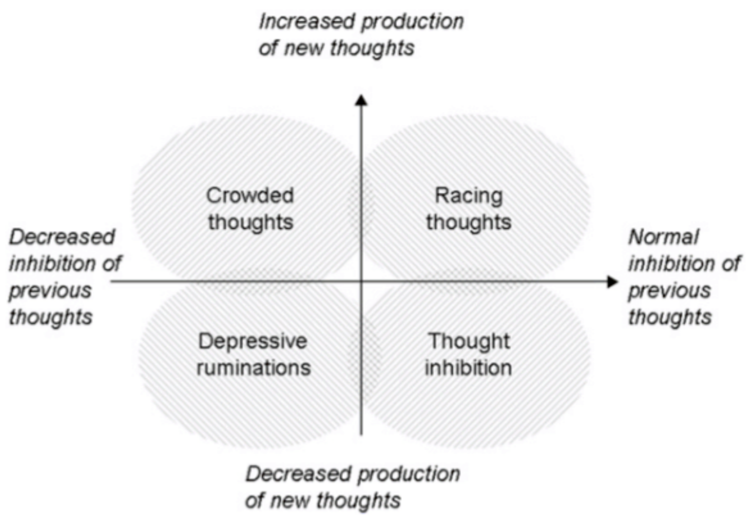

Figure 2: Piguet et al.'s (2010) model of thought disturbances in mood disorders

According to Piguet et al. (2010), racing and crowded thoughts were both characterized by an overproduction and acceleration of thoughts, but, unlike racing thoughts, in crowded thoughts, the authors speculated that impaired inhibition of previous thoughts explained the subjective complaints of thoughts accumulating and overcrowding in the patients' heads. Importantly, in this model, crowded thoughts differed from rumination, even though both thought patterns display impaired inhibition of previous thoughts. Crowded thoughts are indeed characterized by an overproduction of thoughts, whereas, in rumination, thinking is repetitive and circumscribed to few negative topics. From a clinical standpoint, whereas rumination has been the most prominent thinking pattern described in association with low mood (Treynor et al., 2003), it does not seem to be associated with elated mood nor manic symptoms (Van der Gucht et al., 2009); hence, it should not distinguish typical depression from mixed depression. Along with Piguet et al. (2010), we hypothesized that racing thoughts, and not rumination, might be one of the key manic symptoms allowing the distinction between unipolar depression and bipolar depression, on the one hand, and the early detection of subthreshold symptoms in at-risk individuals, on the other hand (Zeschel et al., 2013; Diler et al., 2017).

Taken together, phenomenological accounts of racing thoughts suggest that the phenomenon is multi-faceted, and specific to bipolar disorder. Whether or not the different facets of the racing thoughts phenomena are specific to different episodes of bipolar disorders is still unclear however, since the results of Braden & Qualls (1979) showed both similarities and differences between racing thoughts in mania and depression. Further, if racing thoughts represent a potential risk-factor for the development of bipolar disorder, they should be observed in subjects at-risk. However, little is known regarding the presence of racing thoughts in the general population, but anecdotal evidence (i.e., Dodd et al., 2010) is supportive of the hypothesis according to which racing thoughts can be observed in individuals with sub-affective bipolar temperament traits, as suggested by Kraepelin (1899/2008) himself. We investigated this assumption in article 1.

Although the recent synthesis proposed by Piguet et al. (2010) offered a solid psychopathological framework of racing and crowded thoughts, it also had three limitations: first, it did not consider racing and crowded thoughts in at-risk individuals, and particularly in those with exacerbated temperament traits, whereas such is usually the case in studies focusing on rumination; second, their severity gradient did not explicitly acknowledge the possibility of 'disorganized flight of ideas' (Binswanger, 1933/2000), or 'disjointed and fragmented thinking' (Goodwing & Jamison, 2007) in severe mania or in mixed mania which are phenomenologically similar to crowded thoughts; third, from a neuropsychological standpoint, their model relied on data from studies on rumination, hence acknowledging only the contribution of top-down executive processes, and neglecting the potential contributions from other cognitive domains like temporal and linguistic processes in the emergence of racing thoughts.

Bearing from the phenomenological accounts reviewed here, we propose an alternative to Piguet et al.'s (2010) model, which includes mild forms of racing and crowded thoughts in healthy individuals with subsyndromal symptoms, on the one hand, and explicitly acknowledges, on the other hand, that linear racing thoughts, usually associated with increased productivity and creativity, are found in hypomanic states, whereas in severe manic and in mixed manic states, rapid thinking proceeds to 'fragmented and disjointed' thinking (Goodwin & Jamison, 2007), and is associated with irritability and lack of control. Hence, we theorize the existence of two kinds of racing thoughts: the first is predominantly racing, and is associated with hypomania and subthreshold hypomanic symptoms, while the second is predominantly crowded, as is found in mixed, subthreshold mixed as well as severe manic episodes.

In line with the latter description, in her memoir, the musician Kristin Hersh (2008/2011) reported that during a severe manic episode she was "… just so sped up that I spiraled into oblivion."; "one minute it was beautiful: fast heaven. Then heaven took a dive and hell was waiting."; "I'm falling so fast. Falling *up*, on a high that's spun out of control. A wacky fucking tornado of heat, electricity and energy. Music follows me around, blasting my ears, its colors steaming my brain one after another, mixing and swirling in a war of churning rainbows… the noise is brutal: songs crashing into each other, soaked in static. Separating one from the other is impossible. Chords layered over more chords, congested melodies and lyrics that've become a jumble of confused syllables. *I can't think*." (p. 128). Hence instead of conveying a sense of fluidity, and increased productivity (the "fast heaven" of linear racing thoughts), while in a severe manic state, her thoughts became "brutal", "a tornado of heat, electricity and energy", "soaked in static", "congested", impossible to separate one from the other and "confused", leading to the inability to think altogether.

Similar to severe manic states, in a study focusing on mixed hypomanic states, Benazzi, (2007b) highlighted that self-reported racing thoughts were more severe in these states, and were accompanied by irritability, more impulsivity, and interference with daily life activities.

The phenomenology of racing thoughts in severe manic and mixed manic states seems thus somewhat similar to crowded thoughts in mixed depression inasmuch as thoughts are not experienced as fluid and sequential, but instead their overproduction overcrowds the patient's head, and is experienced as overwhelming. Thus, in our model, we propose that fluid/ sequential racing thoughts are only found in association with mild to moderate hypomanic symptoms in healthy individuals and those with bipolar disorder. By contrast, thinking becomes "crowded" when manic symptoms are severe and/or when few subthreshold manic symptoms are mixed with depressive symptoms (Bertschy et al., 2008). Rumination and inhibition of thought are observed in depression without or with very few hypomanic symptoms. Since the cognitive processes involved in racing thoughts have not been elucidated thus far, they were not integrated in this model. After the inspection of our preliminary results on executive functions, we hypothesized that other frameworks were necessary in order to grasp the racing and crowded thoughts phenomenon. This observation, along with the aforementioned phenomenological descriptions, oriented our research toward two other domains, i.e. time and language. Temporal and linguistic phenomenological frameworks of racing thoughts will be reviewed in the next two sections. Figure 3 illustrates our model, which takes into account racing and crowded thoughts associated with subsyndromal mood symptoms in healthy individuals, and their phenomenology in severe manic and mixed manic episodes.

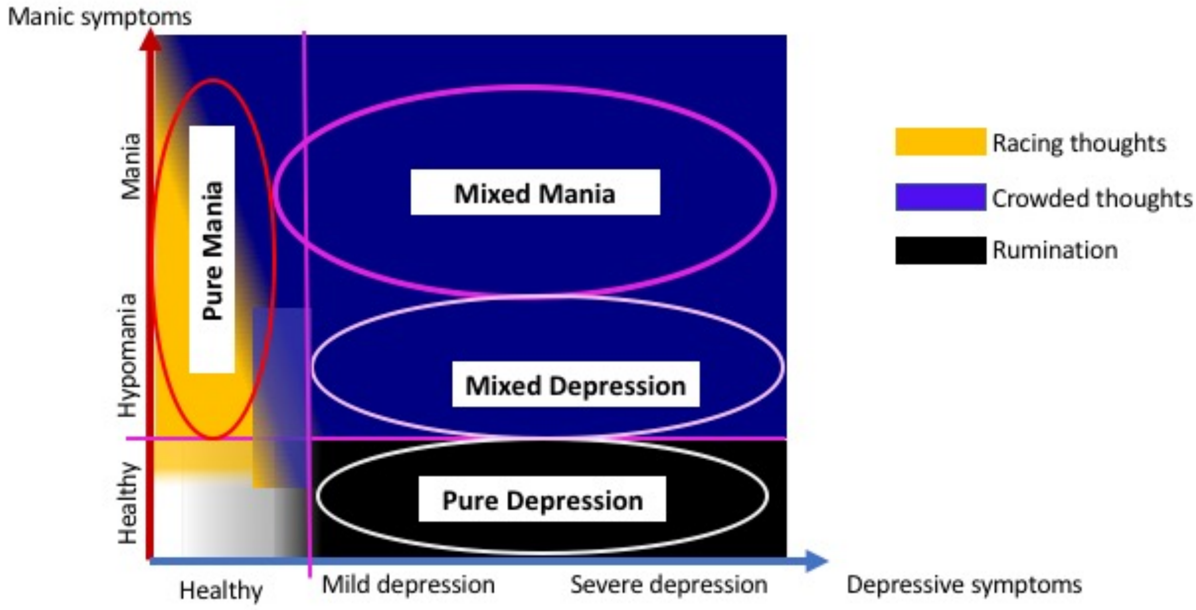

Figure 3: Our phenomenological model of racing and crowded thoughts in healthy functioning and mood disorders.

1.3.2 Time experience

Phenomenology has long recognized the inseparability of subjective experiences and the world. Husserl (1931, in Sass, 2013) noted that all consciousness is consciousness of *something*, emphasizing that cognition and subjectivity are intrinsically linked to one's experience in the world. This world-oriented experience concerns objects, space and, to some extent, time (Sass, 2013). Time can sometimes be the focus of experience, when time is attended to, e.g., when focusing on clock-time or the length of specific durations. However, the pervasive influence of time also concerns experiences in a more implicit way, i.e. independent of the task at hand and without requiring a conscious inspection. As a matter of fact, any cognitive activity occurs in time. Thus, time is not only a content, involved in one's sense of clock-measured time, but also a 'container', insofar as it shapes and structures consciousness. For example, the time taken to pronounce syllables and words, i.e., the rhythmicity of language, determines whether we are understandable and can understand others' speech. It can also convey emotional information. In such examples, time intervenes in an incidental way, without requiring a conscious self-reflective effort.

Phenomenology acknowledges inner-time consciousness as a stream or flow of experiential 'nows', and aims to reconcile the contradiction between our sense of 'flow of time' and experiential 'nows' or 'present moments'. To achieve this sense of continuity of events in time, Husserl (1913/2014) suggested that temporal consciousness is constituted of a tripartite structure, including the immediate past and future. According to Husserl (1913/2014), within this tripartite structure, the 'primal impression' is " the primary consciousness of time" (p. 64) inasmuch as it corresponds to the binding of perceptual contents and interpretative intentions, which gives way to present 'now' experiences (Mensch, 2014). As a matter of fact, if we were to experience a series of impressions, those would be perceived as discrete phenomena, rather than a spontaneous flow with a continuous "departure (of now) into the past" and its anticipation of the future (Mensch, 2014, p. 46, 48). To address this particular feature of temporal conciousness, Husserl (1913/2014) posited that 'nowness' refers to an automatic or 'passive' temporal synthesis (or 'intentional arc'), which includes the sense of the immediate past (retention), and the immediate future (protention). Husserl described this as "the living horizon of the now" (1991, p. 45; in Bowden, 2013). As such, moving through time we experience a degree of continuity, through retention and protention. A typical example, provided by Husserl (1913/2014) himself, is that of listening to a familiar melody. In this situation, as the new tones sound, the previous ones continue to be present (retention), and those to come are expected and fulfilled as the melody unfolds (protention). The same applies to language as well as any other cognitive activity: e.g., while uttering a sentence, one retains at the same time what was just said, and anticipates what is about to be said without having to reflect about oneself as a speaker nor on the order or the rhythm of words. Indeed, words are usually not understood or spoken discretely but as elements of a meaningful whole. This semantic combination is based on an implicit temporal process -- the protentional–retentional coherence of consciousness (Fuchs, 2013). If this passive temporal synthesis were disturbed, we would be no longer able to spontaneously listen or speak during a conversation; instead, we would be forced to put together the sentences actively from single words and constantly check whether the word just spoken was uttered by the self or not. A disruption of the passive temporal synthesis might thus create micro-gaps or a fragmentation of conscious experience, hence altering the implicit sense of temporal continuity of the self and the world. Importantly, the assumption of a passive temporal synthesis, consituted of the just-past and the about-to-come, has its equivalents at the neuropsychological level. As we will develop in section 1.4.2, empirical data suggests that perception, cognition and motor behavior occur in discrete temporal windows or epochs corresponding to processing levels at different time scales, from timing at short times level, including the extended feeling of now (tens of ms until 2-3 seconds on average), until the experience of durations in the multiple seconds and minutes range (Wittmann, 2011; van Wassenhove, 2009).

1.3.2.1 Time experience in bipolar disorder

Although anomalous temporal experiences have been frequently described in first-person narrative accounts of individuals with bipolar disorder (e.g., Hersh, 2008/2011; Jamison, 1997), suprisingly few phenomenological studies have focused on time experience in bipolar disorder. Typically, first-person accounts of temporal experience in mania are suggestive of an increase in subjective temporal velocity, whereas in depression, time is experienced as slowed down or even of stopping altogether (e.g. Minkowski, 1933/2013; Fuchs, 2013). Comparing manic and depressive states, the musician Kristin Hersh (2008, p. 148) claimed that "…a fast brain fills in blanks in your visual field, makes stuff up at you. A slow one can't even cope with what's already here…", hence suggesting that subjective temporal velocity, but also assimilation of events in world-time, might be altered in mania and in depression. Instead, in severe manic or mixed episodes, while not explicitly acknowledging the conscious experience of time – either as accelerated or slowed down -- , first-person accounts suggest that thinking itself becomes fragmented, confused and congested (Hersh, 2008; Goodwin & Jamison, 2007). For example, Kristin Hersh (2008, p. 128) described her experience while in a severe manic episode as follows: "chords layered over more chords, congested melodies and lyrics that've become a jumble of confused syllables". Kay Redfield Jamison[6] (1997, p. 82-83) also outlined how thinking might become fragmented and ultimately lose its coherence and meaning in severe mania: "My thoughts were so fast that I couldn't remember the beginning of a sentence halfway through. Fragments of ideas, images, sentences, raced around and around in my mind like the tigers in a children's story...a million other thoughts – magnificent and morbid, wove in and raced by". In a mixed state, Jamison (1997) also wrote that the chronological order of time itself lost its meaning: "I could not follow the path of my own thoughts. Sentences flew around in my head and fragmented first into phrases and then words; finally, only sounds remained. At one point I was determined that if my mind... did not stop racing and begin working normally again, I would kill myself by jumping from a nearby twelve-story building. I gave it twenty-four hours. But, of course, I had no notion of time, and a million other thoughts—magnificent and morbid—wove in and raced by...". Thus, first-person accounts suggest that the experience of time in bipolar disorder might be polymorphous and affect both time as a 'content' and as a 'container' of experiences; moreover, subjective time seems intrinsically related to the speed of thoughts in acute mood states.

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[6] Kay Redfield Jamison is a Professor of Psychiatry who has written extensively about her own personal experience with bipolar disorder. The excerpt is taken from her memoir, An Unquiet Mind (1997).

Phenomenological accounts have suggested yet another aspect of temporality, termed as 'conation' (e.g., Fuchs, 2013). Conation has been used in most phenomenological accounts of the psychopathology of bipolar disorder, hence we will further define it here (e.g., Sass, 2013; Bowden, 2013). According to Fuchs (2013), conation refers to the the energy, volitional and affective mechanisms that lends the "passive synthesis" the tension and energy it needs to constitute the speed or flow of time. Conceptually, the conative drive holds some resemblance to what Minkowski (1933/2013) termed as '*élan vital*' (Ratcliffe, 2012), inasmuch as it is a future-oriented drive towards perceptual or practical possibilities. Diminished conation may thus manifest itself in psychomotor retardation, thought inhibition, and in a slow-down or standstill of subjective time; enhanced conation, on the other hand, may manifest itself in increased energy and drive, racing thoughts, and an acceleration of subjective time (cf. figure 4 taken from Fuchs, 2013). Thus, disturbances in conative drive should be implicitly manifest in thinking and behavior, and explicitly manifest to the subject when time is the focus of attention[7].

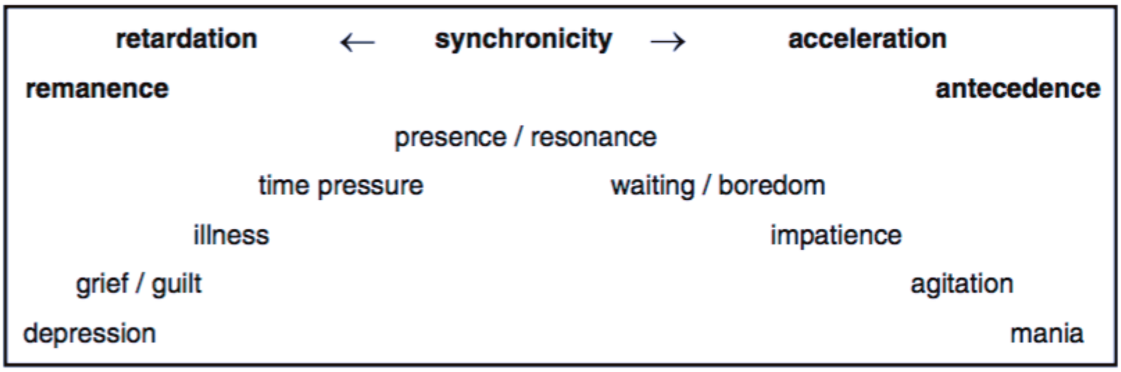

Figure 4: Synnchronization and desynchronization between subjective time (or inner time) and world time. Source: Fuchs (2013).

[7] Correspondingly, an analogy with the body is often made in phenomenological studies. Indeed, the lived body is the body that I am – the body taken-for-granted in everyday situations --, whereas the corporeal body is the body that I have (of which one is consciously aware) – for instance, in the case of an illness, we become consciously aware of our body (Fuchs, 2015).

Importantly, as outlined by Fuchs (2013), time here is not necessarily viewed as a metaphysical entity – such as in how one perceives it while quantifying durations --, but rather as the temporality of the being, which results from its relation to the social rhythms in which one's life is embedded. In this sense, temporality is experienced only in relationships (as our being-in-the-world), and primarily in relation to others, giving way either to the experience of synchronization or desynchronization (being 'out of sync'). Since it does not require attention processes in order to constitute the speed of the flow of time, Fuchs (2013) considered that conation was an integral part of implicit timing. It is only when subjective and world time are 'desynchronized' that attention is directed towards the flow of time, inasmuch as subjects detect a discrepancy. Such is the case, for instance, when one is bored or late for an appointment – subjective time might be relatively sped up, while the world and those around us do not go fast enough (Fuchs, 2013). Going back to the aforementioned example of uttering a sentence, in such cases where there is no discrepancy, the flow of time is not consciously acknowledged but it structures our experience in an incidental manner (the drive to talk and the speech rate during a conversation, for instance). If we are synchronized with those around us, the rhythmicity of back and forth conversational stances will not be consciously acknowledged. It is important to note that conation has played an important role in recent phenomenological conceptualizations of temporal disturbances in bipolar disorder (e.g., Fuchs, 2013; Bowden, 2013; Northoff et al., 2017). However, its conceptual affiliation to neuropsychological time has not been clearly alluded to.[8] We will further focus on psychological and neuroscientific frameworks relative to time in section 1.4.2.

[8] When it is not consciously acknowledged, hence implicit, we could argue that the speed of time corresponds to how fast a subjective 'now' occur and switches to a new 'now' (see section 1.4.2). By contrast, when subjects are asked to assess how fast time seems to pass, as in passage of time judgment paradigms, the speed of time is consciously attended to, and arguably corresponds to explicit time (Wearden, 2015). This attempt at translating 'conation' to psychological terms is however purely speculative.

In his comparative analysis of temporal experience across different disorders, Minkoswki (1933/2013) considered that, generally speaking, individuals with bipolar disorder were characterized by excessive vitality, and increased atunement with things in the world. Whereas excessive vitality could be attributed to an increase in the ‘conative drive’ as it was later termed by Fuchs (2013), atunement here is conceptualized as a form of intersubjective synchronicity, i.e., when inner-time and world-time, or the time of those around us, are synchronized (Fuchs, 2013). In other words, being “in tune” with others is experienced through our “simultaneous referral to the world” (Fuchs, 2013, p. 82) – through shared projects and actions. In this sense, being “out of tune” or “out of sync” means that subjective time might be either accelerated or slowed down, whereas others and the world are perceived as having an opposite speed. Conversely, ‘an increased atunement with things in the world’ might translate as both the increased emotional reactivity of patients with bipolar disorder compared to healthy individuals and their extreme sensitivity regarding circadian rhythm routine, i.e., sleep, interpersonal relationships, etc., in order to remain ‘in-tune’ with the world (Bowden, 2013).

Most authors considered the experience of time in mania or depression in comparison to schizophrenia, where disturbances in the passive temporal synthesis, especially in its protention feature, is thought to underlie some of its most prominent symptoms, such as thought insertion or delusions (Fuchs, 2013). Thus, phenomenological analyses focusing on the temporal experience in bipolar disorder by itself, including in mixed states, are particularly rare. We will briefly present here phenomenological findings relative to temporal experience in mania, depression and mixed states, and how they might be interpreted in terms of implicit and explicit timing processes.

Time experience in mania

In manic states, patients' subjective time was qualified by Minkowski (1933/2013) as 'instantaneous', 'limited to the immediate now', 'superficial', 'degraded and deformed compared to true atunement' (p. 275). That is, the manic subject's 'now' is restricted to the immediate now (or in Husserl's terms, impressions), with the subject "absorbing the world so avidly, he does not penetrate it at all" (p. 276). Interestingly, Minkowski (1933/2013) made use of a clinical example of racing thoughts provided by Kraepelin (1899/2008) to illustrate his assumptions and conclude that, in such individuals with racing thoughts, "contact with reality is narrowed, although present, leading the subject to constantly depend on the 'now', always variable and always changing, from a moment to the other" (p. 276). Because of this narrowing of the temporal experience to the immediate 'now', manic individuals were unable to fully 'unfold in time', i.e., to experience the past, the present and the future. Minkowski (1933/2013) suggested that the basic aspects of temporality, i.e., the temporal synthesis in Husserl's terms (when past, present and future information are integrated within the same time window), were not structurally disrupted in manic patients with racing thoughts, but they differed qualitatively from the 'now' experienced in 'true atunement'. More recently, Northoff et al. (2017, p. 2) argued that "…rather than showing disruption or fragmentation of time (as in schizophrenia), they (patients with bipolar disorder) experience abnormal shift or focus of time towards either the past ("past-focus" as in depressive episodes) or the present/future ("present/future-focus" as in manic episodes)". Indeed, if the temporal synthesis were completely disrupted in mania, this would result in a fragmentation of time, i.e., manic patients would have been unable to carry out simple daily activities in an organized and ordered fashion, such as preparing coffee or even uttering organized and coherent sentences (Bowden, 2013). Yet, such is only the case in severe cases of mania and possibly in mixed states, but we will develop this point later. Instead, the over-reliance on the immediate now described by Minkowski (1933/2013) could correspond to a *weakening* of the tripartite structure, and especially of its retention feature, on the one hand, and an acceleration of the flow of time (conative drive), on the other hand (Bowden, 2013). The disruption to the synthesis between the immediate past (retention) and the present now (impression) means that "…the manic person would not base actions on the tasks previously held to be important, but rather on that which is available in the immediate moment" (Bowden, 2013, p. 148). This is manifest in the distractible nature of racing thoughts and flight of ideas, where attention is grasped by whatever is occuring at the present moment. Whether distractibility might give way to fragmentation and confusion is probably related to the velocity of the flow of time, i.e., conative drive. When the flow of time is mildly accelerated, the patient might be distractible and verbose but thinking and language retain coherence and overall organization because each immediate now, through its intact anticipatory (protention) feature, might still be semantically connected to the subsequent one. In contrast, in severe mania, extreme acceleration might lead to fragmented and disjointed thinking and behavior. As Jamison (1997, p. 82) puts it: "My thoughts were so fast that I couldn't remember the beginning of a sentence halfway through.".

Consistent with this view, Binswanger (1933/200) argued that "where everything and everyone is 'handy' and 'present', where distance is missing, there is no future either, but everything is played off 'in the present', in the mere here and now." (p. 131). In other words, because they rely less on just-past goals, things seem more attainable (closer at hand), entailing the characteristic carefree and overly optimistic outlook towards the future of manic individuals (Biswanger, 1933/2000). Interestingly, using psychological paradigms, recent studies have suggested that thinking in hypomanic states is characterized by increased future-oriented (or 'fastforward') mental imageries, which are usually related to a goal that seems immediately attainable and positive to the individual (Ivins et al., 2014; Di Simplicio et al., 2016). Furthermore, Gruber et al. (2012) found that history of full-blown or temperamental mania was associated with an increased present and decreased long-term future focus, self-assessed via the Zimbardo Time Perspective Inventory (Zimbardo & Boyd, 1999), which they linked to the elevated impulsivity characteristic of these states. These results based on self-reports point thus to disturbances of the temporal structure of manic thinking, characterized by its over-reliance on the present-now and on short-term future features. To account for descriptions of fragmented thinking in severe mania, which, according to our phenomenological model (cf. figure 3), are a subtype of crowded thoughts, philosopher Hannah Bowden (2013) has recently suggested that the temporal synthesis itself, especially its retention feature, might be weakened in mania. In hypomania, such abnormalities in the temporal synthesis combined with increased conative dynamism might underlie the over-focus on the 'immediate now' (or the impressions, in Husserl's terms) characteristic of racing thoughts. In severe mania, an overwhelming increase in conative drive and disruption of the temporal synthesis might in turn underlie the experience of fragmented thinking and crowded thoughts in these patients.

In addition to the weakening of the temporal synthesis, essentially of its retention feature (Bowden, 2013), the flow of time itself seems to be accelerated in mania. Manic patients typically perceive time as sped up while others and the world are perceived as 'slowed down', e.g., "people do not go fast enough", which might be linked to feelings of hostility and irritability (Lam et al., 1999; Bschor et al., 2004; Fuchs, 2013; Northoff et al., 2017). According to Fuchs (2013), the speed of the flow of time, i.e., its conative drive, is an integral part of implicit subjective time. When it is synchronized with outer-time (or world-time – the world of those around us), the flow of time remains implicit. For example, while we dance, our movements are in-tune with the music around us. However, when there is a desynchronization, attention is directed towards this discrepancy, and subjective time goes faster or slower than usual. Psychiatrists, e.g. Fuchs (2013) and Northoff et al. (2017), recently proposed that this discrepancy, or desynchronization between inner-time (‘time flies’) and world-time (‘people are too slow’), was one of the core mechanisms involved in the psychopathology of manic and depressive episodes. From a neurofunctional perspective, Northoff et al. (2017) suggested that temporal desynchronization in mania and depression was due to a disbalance at the neuronal level between activity in the somatomotor and sensory cortical areas, involved in inner and outer time processing, respectively. These authors also attempted at translating self and world time to psychological terms by suggesting that self and world time corresponded respectively to passage of time judgments – i.e., how subjects feel that the time passed -- and estimation of durations – i.e., how long the interval seemed to last -- in psychological studies of time perception (see section 1.4.2; Northoff et al., 2017). In their study, this hypothesis is backed up by some empirical findings in bipolar disorder (e.g., Bschor et al., 2004). However, this conceptual overlap is speculative and, at least from a psychological perspective, the mechanisms underlying ‘felt-time’ as in passage of time judgments have yet to be completely elucidated (see section 1.4.2). In line with Fuchs (2013), Bschor et al. (2004) speculated that the subjective acceleration of the flow of time was related to racing thoughts but, to our knowledge, this assumption has not been empirically assessed thus far.

All in all, phenomenological analyses of first-person accounts of temporal experience in mania are particularly rare. Our brief review points however to temporal experiences characterized by an increase in conation leading to a desynchronization between inner and outer time. Within this framework, racing thoughts are intrinsically related to increased conative dynamism in manic episodes, regardless of their severity.

Time experience in depression

In depressive states, Minkowski (1933/2013) identified profound temporal disturbances in which subjective time "seemed slower than world time" (p. 278), hence suggesting a desynchronization between inner and outer time. This is manifest in the relative slowing of the passage of time often reported by depressed patients (e.g., Braden & Ho, 1981), but also in the ability to process incoming information from the world (Minkowski, 1933/2013; Gallagher, 2012). Thus, in contrast to manic states whereby 'time speeds up', and the world 'slows down', in depression, inner time is characterized by time retardation (time slows down or even stands still), and a world that moves 'too fast' (Northoff et al., 2017). Figures 5 and 6 illustrate the conceptual relationship between inner-time and world-time in manic and depressive episodes, as theorized by Northoff et al. (2017).

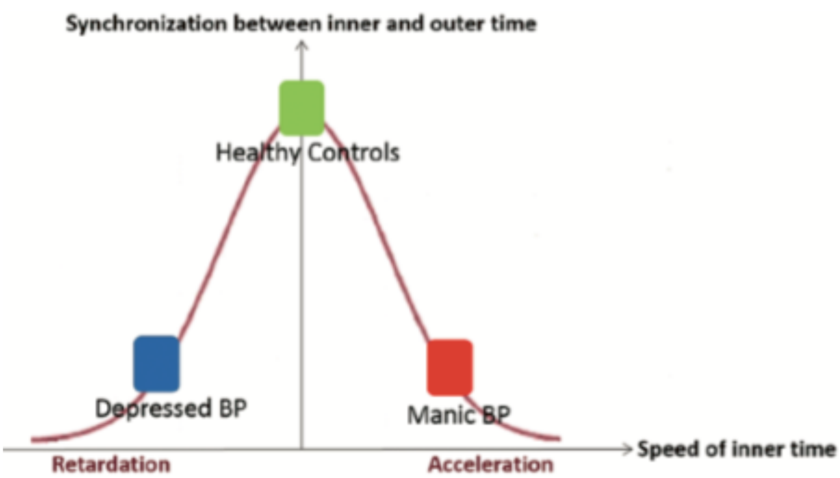

Figure 5: Relationship between inner-time and world-time. Source: Northoff et al. (2017).

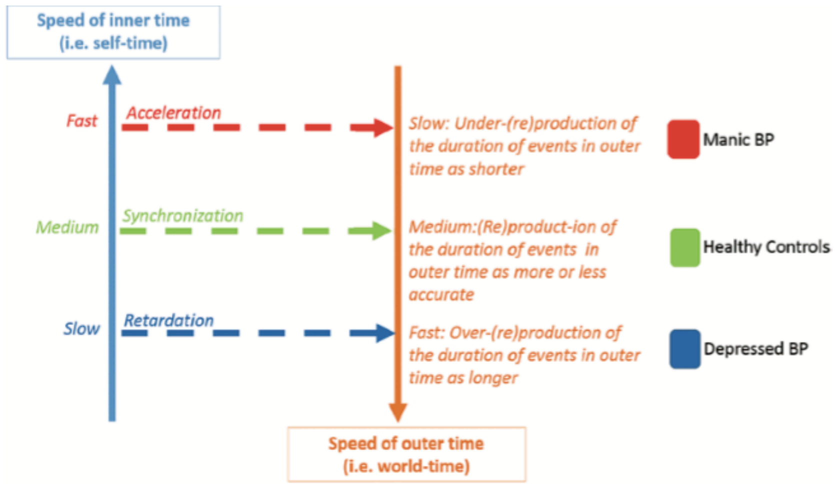

Figure 6: Relationship between inner-time and world-time, and how these concepts translate to psychological tasks. Source: Northoff et al. (2017).

Because time slows down in depression, Gallagher (2012) suggested that the time-structure of depression is similar to the time-structure of boredom, which is also intrinsically linked to the feeling that time 'drags'. However, unlike boredom experieced by non-depressed individuals, which is underlain by the desire that things be otherwise, depressed individuals seem to lack this desire, or the ability to contemplate a future where things might be different. Thus, one of the distinguishing features between 'healthy' boredom states and depression rely on the ability to contemplate the future – in boredom states, future might hold stimulating possibilities one can pursue, whereas in depression, the future closes down (Gallagher, 2012). Compared to manic states, where thinking may lack orientation toward the past, in depression, thinking lacks orientation toward the future, although the temporal continuity of oneself and one's behavior remains intact. In other words, in depression there is a durable decrease of the future-oriented drive towards perceptual or practical possibilities, i.e., conative drive, but the tripartite temporal structure is not disrupted (Fuchs, 2013). Of interest to our work, 'past-orientedness' and slowing of the passage of time in depression have been hypothesized to be related to rumination, a thinking pattern characterized by a repetitive analytical negative focus on past experiences (Droit-Volet, 2013; Marchetti et al., 2014). However, to our knowledge, the relationship between the experience of time and rumination, in depressed patients and in healthy individuals, has not been assessed empirically.

Temporal experience in mixed states

While it is a relatively easy task to conceptualize opposite time experiences in opposite 'pure' mood states – i.e., mania and depression –, phenomenology has failed thus far to provide a comprehensive framework enabling to explain temporal experience in mixed states. This might be due to the aforementioned limits of the phenomenological method itself (i.e., if disturbances occur beyond the consciousness level, patients may be unable to report them), but also to the lack of empirical and phenomenological studies in mixed states.

We have outlined above that thinking in mixed states might be characterized by 'crowded thoughts'; personal accounts further highlighted that thinking becomes fragmented and might lose its coherence in such states, an experience described as extremely distressing. For instance, Jamison (1997, p. 82-83) claimed that in a severe mixed manic episode: "…I could not follow the path of my own thoughts. Sentences flew around in my head and fragmented first into phrases and then words; finally, only sounds remained."

Although it is beyond the scope of our work to fill the gaps in the phenomenological literature, based on the aforementioned analyses of pure mania and depression, as well as first-person narrative accounts of mixed states, it seems likely that fragmentation of experience is at least partially underlain by disturbances in implicit timing, especially conation. This is manifest in the heterogeneous increased or decreased energy/drive, activity and mood levels manifest in these episodes (Kraepelin, 1899/2008). In pure depressive and manic episodes, disturbance in conative dynamism is thought to be homogeneous, leading to subjective experiences of either fluid racing thoughts or rumination, and to desynchronization of inner- and outer-time. In mixed states, however, energy might be increased, while level of activity is low, suggesting that disturbances in 'conation' might result in different and somewhat paradoxical symptoms. As we have outlined above, conation remains a philosophical concept, and it is still unkwnon how it translates to neuroscience. Sass (2013) has suggested that conation refers to the velocity of physiological processes, but this definition is vague and does not clarify how conation disturbances might underlie symptoms found in mixed episodes. Empirical research on timing in mixed episodes is thus particularly needed in order to elucidate the mechanisms involved in fragmented thinking, and crowded thoughts.

Like severe manic episodes, we speculate that temporal synthesis is weakened in mixed episodes (Bowden, 2013), leading to the fragmentation of higher-order cognitive activities, such as that of uttering a sentence or performing daily activities. On an explicit level, it is unkwown whether this experience, especially in the case of mixed episodes with crowded thoughts, might lead to a subjective desynchronization of inner and outer time, hence to an acceleration or slowing of the passage of time.

Summary

Most phenomenological studies on the temporal experience of individuals with bipolar disorder have put forward a desynchronization of inner time and world time, with a relative acceleration of subjective time in mania and, conversely, a slowing of subjective time in depression (Fuchs, 2013; Northoff et al., 2017). Recently, the retention feature of the temporal synthesis has been suggested to be weakened in hypomanic and manic episodes, and to play a role in structural abnormalities of the 'now' in these states (Bowden, 2013). These abnormalities are particularly manifest in the distractible and fleeting nature of racing thoughts. At the phenomenal level, desynchronization of inner and outer time in bipolar disorder might result from conative and temporal synthesis disturbances. However, ultimately, desynchronization means that, in depressive and manic episodes, time is explicitly acknowledged, as a content of experiences. Relevant to our work, racing thoughts (speeded thinking) and rumination (retardation of thinking), usually associated with manic and depressed states, have been suggested to be respectively implicated in the acceleration and slowing of subjective time (Bschor et al., 2004). We investigated this assumption in individuals with bipolar disorder, including mixed episodes, in article 4; and in healthy individuals in article 3. Psychological models and findings related to the temporal experience of individuals with mood disorders will be further outlined in the section 1.4.2.

1.3.3 Linguistic experience

"Flight of ideas is a torrent of near-unstoppable speech; thoughts bracchiate from topic to topic, held only by a thin thread of discernible association. Ideas fly out, and as they do, they rhyme, pun, and assemble in unexampled ways. The mind is alive, electric."

Kay Redfield Jamison (2017, p. 278)

From the perspective of philosophy, language refers to both its private use in thought, or inner-speech, as well as its public use to communicate thoughts. Philosophy thus acknowledges that language and thought are particularly intertwined and, at times, overlapping phenomena. The relationship between human thought and language has long been a focus in philosophy. A number of philosophical accounts claim that language is a prerequisite for conceptual thought (e.g. Wittgenstein, 1982), while others argue that highly complex behaviours occur in the absence of language, such as in non-human primates, but also in those who present with language impairment such as patients with aphasia (Carruthers, 2001). For instance, patients with severe forms of aphasia might still be capable of solving arithmetic problems (for a review on the distiction between 'thought' and 'language', see Fedorenko & Varley, 2016). However, even for those authors, language is necessary for some kinds of ‘thinking’ to occur. With the exact delineation between human thought and language still tentative, philosopher Peter Carruthers (2001) defined thoughts as “…discrete, semantically-evaluable, causally-effective states, possessing component structure, and where those structures bear systematic relations to the structures of other, related, thoughts”. Similar to the definition of the subjective present provided by Pöppel (2009; see section 1.4.2), for Carruthers (2001), conscious thoughts occur over time, as discrete structures in a stream of other thoughts, and have meaning (or, as he puts it, are semantically-evaluable). If such is the case, as we will further develop in section 1.4.3, through the study of meaning, we might gain access to how discrete thoughts are semantically tied to each other over time. Language, in turn, functions as both a communication system and, through its syntax, as an amodal structure responsible for shaping human thought (Carruthers, 2001). It is syntax that allows structured and compositional mental representations to emerge (Fodor & Pylyshyn, 2015 for more detailed arguments). Of interest to our subject matter, thought disturbances found in psychiatric illnesses such as bipolar disorder are usually manifest, at the behavioral level, in language and communication. As reviewed in section 1.3.1, psychiatry has long considered language and thought disturbances as correlated, if not indissociate phenomena. This is manifest in the history of the concept of flight of ideas – the term initially encompassed both racing thoughts and its verbal equivalent – and the scales subsequently developped to assess thought disturbance in both schizophrenia and mania, e.g. Scale for the assessment of Thought, Language and Communication (TLC; Andreasen, 1979), which focus heavily on language disturbances. Because language and thought disturbances are deeply intertwined in bipolar disorder, and since our goal is to have a broad picture of the racing and crowded thoughts phenomena, we provide here a brief review of phenomenological and linguistic accounts of language in bipolar disorder. Although philosophy and linguistics have different methods and theoretical grounds, both kinds of studies were included here because they address language in its natural environment (natural discourse) in a descriptive manner. Results from both accounts informed the development of our empirical research (section 1.4.3) and are thus reviewed in this section.

Definitions used in linguistics and philosophy of language display some overlap, and we will draw on definitions from both fields. It is beyond the scope of this work to provide an exhaustive report on language in these domains. Regarding philosophy, we will mainly focus on phenomenology, because it has inspired psychiatrists' accounts of language disorders in psychiatry. Phenomenology emphasizes the *subjective experience* of language, either as inner speech or as a form of communication, and it is these aspects that we will develop below. We will first briefly define some of the basic structural aspects of language from the point of view of philosophy of language and linguistics. Linguistic competence is thought to rely on a finite set of stored lexical units or complexes and combinatorial principles (Jackendoff, 2003). In other words, as Chomsky (1965) famously put it: languages make infinite use of finite means, meaning that, through its finite combinatory use (or syntax) of equally finite representations (semantical and phonological), language is eminently flexible and creative. Philosophy of language usually distinguishes three aspects of language or its use: syntax, semantics and pragmatics (Martinich, 2006). In linguistics, at least one additional structural aspect is usually considered: phonology (Jackendoff, 2003). We define these aspects in turn hereafter, by starting with the most elementary one, i.e. phonology, as defined in linguistics.

Phonology consists of the study of the sound structure of verbal output: e.g., how discrete speech sounds (or phonemes) constitute strings of segments, but also the prosodic features of a given syllable or phrase (Jackendoff, 2003). Prosody is concerned with sound-related features of large units of speech (syllables and phrases), and is involved in intonation, tone, stress and rhythm of speech – i.e., variable, accelerated or slowded down (Jackendoff, 2003).

Syntax is involved in the way words and other elements of language can be strung together to form grammatical units, regardless of the meaning of words (Martinich, 1996). For instance, sentences such as "atomic cats are cloudless" are syntactically correct, but have no literal meaning.

Semantics instead focuses on the meaning of words and sentences. Meaning, from the standpoint of a number of philosophical traditions, is built upon the relationship (or reference) between words and the world. From the standpoint of cognitive psychology, semantic knowledge refers to a memory system (Tulving, 1986). We will further develop this point in section 1.4.3 which focuses on the neuropsychological aspects of language.

Pragmatics is the study of how language is used in the interaction between speakers and hearers (Martinich, 1996). Pragmatics encompasses therefore aspects involved in language embedded in interpersonal communication, but not in inner speech.

The distinction between inner speech and communicative speech is crucial in Husserl's outlook on the phenomenology of language (Mensch, 2001). According to Husserl (1970), only when language is embedded in communication are words both 'expressive' and 'indicative', since they convey meaning (a unique sense) but, through communication, they also reference an object in real world. When communicating with someone else, the auditor must "take the speaker to be a person, who is not merely uttering sounds but is speaking to him, who is accompanying those sounds with certain sense-giving acts ... " (LI, 277). Since these acts (or meanings), however, cannot be directly experienced (e.g., the hearer cannot directly read the intentions of the speaker), for sounds to become meaningful to the hearer, they have to be intuitively attached to a referent. In Husserl's words, "... all expressions in communicative speech function as indications. They serve the hearer as signs of the 'thoughts' of the speaker, i.e., of his sense-giving inner experiences" (LI, 277). However, in interior monologue, the expressive function lingers, but the indicative one does not. In his words, "... expressions also play a great part in uncommunicated, interior mental life." They "continue to have meanings as they had before" (LI, 278). They do not, however, function as indications. "In monologue, words can perform no function of indicating the existence of mental acts, since such indication would there be quite purposeless. For the acts in question are themselves experienced by us at that very moment" (LI, 280). Speaking to ourselves, we have no need of indications since our meaning is immediately present to us in consciousness (Mensch, 2001). Inner speech thus relies on the meaning carried out by the structure of consciousness taken as a field of intuitive self-presence: i.e., the reference of a sign terminates in another sign, one which passes on this reference to yet another sign, and so on indefinitely (Mensch, 2001). In this sense, we can assume that, if his distinction between 'expression' and 'indication' applies, inner-speech is distinct from communicative speech insofar as it does not require the indicative function, or pragmatic interpersonal anchoring required by communicative speech. Syntax, phonology and semantics are instead required in both inner speech and communicative speech.

1.3.3.1 Linguistic experience in bipolar disorder

Whereas phenomenological and linguistic studies focusing on communicative and inner speech in schizophrenia are numerous, in bipolar disorder the literature is scarce. As an example, in schizophrenia, defective self-monitoring of inner-speech has been suggested to underlie voice-hearing hallucinations (e.g., Langdon et al., 2009). Studies reviewed here only investigated natural discourse embedded in interpersonal communication since, to our knowledge, no study thus far has focused on inner speech[9] in bipolar disorder. Inner speech

[9] Inner-speech is conceptualized here strictly in philosophical grounds. From the perspective of cognitive and developmental psychology, inner speech has been associated with the phonological loop of Baddeley et al.'s (1986) working memory model (e.g., David & Lucas, 1993) and to overall executive functioning (e.g., Cragg & Nation, 2010).

can only be retrospectively assessed via introspection, and this method of course holds methodological problems, as outlined in section 1.3. It is important to note that methodological issues in studies with natural discourse are also numerous; for example, it is difficult to control for interpersonal prosodic and pragmatic parameters involved in face-to-face contexts – e.g., the gestures or priming questions provided by the interviewer (Traxler & Gernsbacher, 2006). Moreover, vocabulary size, potentially involved in verbal production in this context, is rarely acknowledged.

In a recent review comparing the linguistic experience of manic, depressed and schizophrenic individuals, Sass & Pienkos (2015) highlighted that language disturbances in mania and depression have been described mostly in terms of decrease or increase in amount or rate of speech, rather than as alteration of semantic coherence, clarity, syntactic complexity or interpersonal anchoring, which is usually the case in schizophrenia. As mentioned previously, this characterization suggests that speed of thinking is central to the language anomalies found in bipolar disorder. However, we argue here that increased velocity of speech rate (prosody) and semantic disturbances might co-occur in manic and mixed episodes. For instance, during a mixed manic state, Kay Redfield Jamison (1997) stated that inner speech was characterized by increased velocity, which ultimately led to the disintegration of meaning "…I could not follow the path of my own thoughts. Sentences flew around in my head and fragmented first into phrases and then words; finally, only sounds remained." Thus, linguistic and temporal abnormalities are intrinsically connected, possibly via racing and crowded thoughts and rumination, and play a central role in the psychopathology of bipolar disorder.

Manic Speech

In addition to verbosity and rapid speech rate, the extremely 'combinatory thinking' and increased associations based on the sound features of words (clang associations) have been outlined as distinguishing features of manic speech by numerous authors, e.g., from Kraepelin (1899/2008) and Binswanger (1933), until, more rencently, Esmaeelpour & Sasani (2016) and Jamison (2017). Kraepelin (1899/2008 *in* Jamison 2017) noted that in mania "ideas become unbridled… associations with external impressions and rhyming frequently occur in the conversation of the patients… many develop a veritable passion for writing, cover innumerable sheets." (p. 260). He also noted that "…the associations show a characteristic change is the manic excitement. In these cases for the most part the tendency to clang associations comes out very distinctly, especially rhymes, citations, and word completions, which may surpass all other forms." (p. 260).

Interestingly, consistent with Binswanger (1933/2000), Sass & Pienkos (2015) suggested that clang associations were actually context-embedded, that is, clang associations were likely to be ambiguous, and take one into a new context different from the original, but they remained semantically coherent and anchored in interpersonal communication (Holzman et al., 1986). Thus, despite its rapid, shifting and often playful or humorous features, manic speech has been characterized by relatively intact pragmatics – i.e., the manic patient is likely to experience at least some awareness of the social aspects of speech and concern for the needs of the interlocutor (Sass & Pienkos, 2015). Comparing manic and schizophrenic speech, Wykes & Leff (1982) highlighted better abilities in mania of conveying meaning: "manic patients provided the listener with more ties to relate his sentences together than the schizophrenics did" (p. 123).

Still focusing on the difference between manic and schizophrenic speech, Hoffman et al. (1986) found, via the analysis of linguistic features in the natural discourse, that individuals with mania displayed greater quantities of speech, syntax complexity and more deviance within that speech, than those with schizophrenia and controls; however the coherence of manic speech was greater than that observed in those with schizophrenia, where there was "diminished discourse planning abilities." Of particular interest to our work, these authors also implied that the peculiarities of manic speech were due to increased shifts from one discourse structure to another, which was attributed to increased distractibility and overactivation, i.e., racing thoughts.

Recently, Mota et al. (2014) reported similar findings, using graph analysis to model patients' natural discourse – i.e., participants were asked to report their last dream. Here again the authors used linguistic methods. In this study, the authors found increased verbosity and tangentiality in manic speech, compared to controls and patients with schizophrenia. Figure 7 illustrates the graphs obtained in this study.

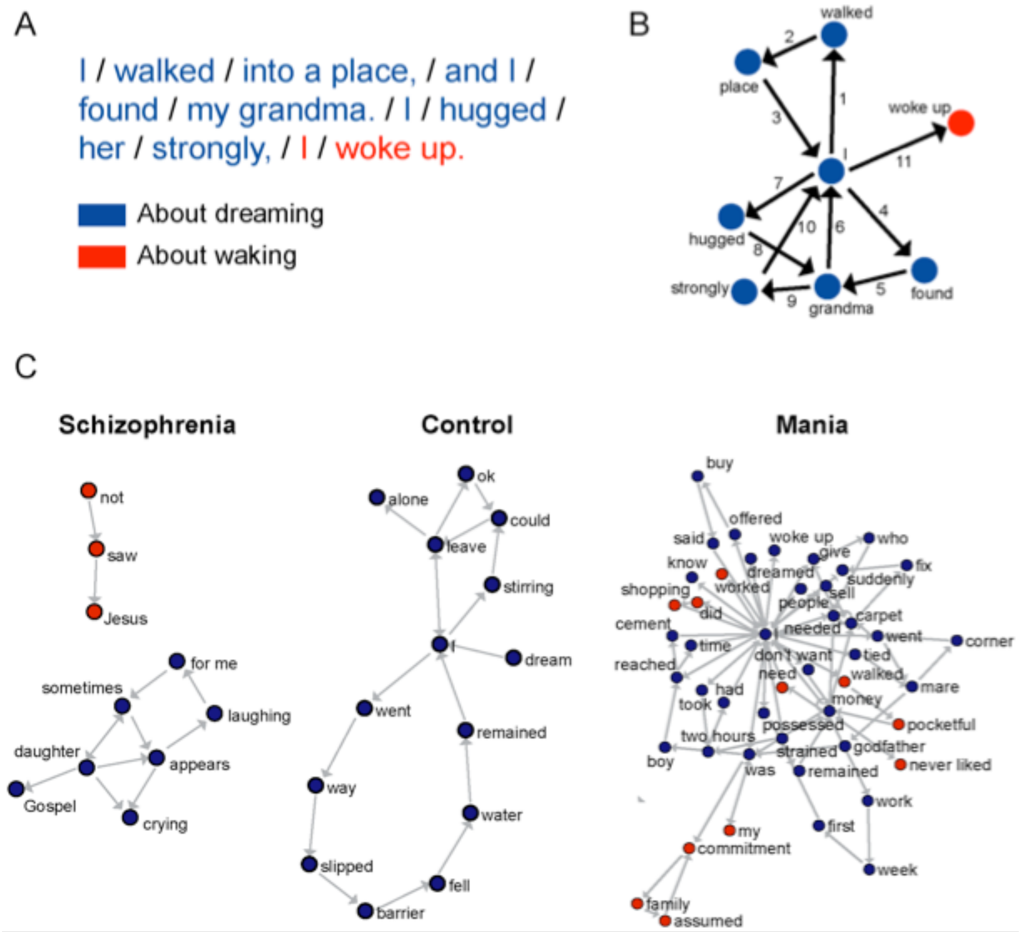

Figure 7: Graphs of natural discourse in patients with mania, schizophrenia, and controls. Digressions are represented in red. (Source: Mota et al., 2014).

Although manic speech has been typically linked to pressure of speech, talkativeness, and increased speech rate, as noted by Binswanger (1933/2000) and Kraepelin (1899/2008), in individuals with mixed symptoms, fluidity and talkativeness may proceed to disjointed thinking and laconic, telegraphic speech, with 'brutal conceptual shifts' (Binswanger, 1933/2000). Esmaeelpour & Sasani (2016) investigated the characteristics of written speech of the persian writer Sadegh Hedayat in euthymic, manic, depressed, and mixed states. This represents the only study on written language, to our knowledge. Esmaeelpour & Sasani (2016) noted that most letters (40/82) were written during hypomanic episodes, consistent with pressure of speech. During mixed episodes, there was also an increased amount of letters (36/82), but the quantity was more variable over the years. Only one letter was written during a depressive episode, which the authors found suggestive of poverty of speech. Topics evoked in the letters were also more numerous in hypomania, with more topic shifts, than those observed during mixed and typical depressive episodes.

Speech in depression

In depressive episodes, as suggested by Kraepelin (1899/2008) and mentioned previously, associations have been described to rely more on the meaning of words rather than on sound and outside stimuli, and to be restricted to few negative topics. Based on first-person accounts of individuals with depression, Sass & Pienkos (2015) concluded that the main linguistic feature found in depression, poverty of speech, was related to the profound isolation individuals with depression felt from others, who seemed to them to be operating at an entirely different pace and energy level, and the impossibility of translating with words the painful feelings associated with depression. In an example cited by Sass & Pienkos (2015) the patient described the ineffability of his experience in the following way: "I was not able to talk coherently for any length of time; I was too vague about the causes of my discomfort to make myself understood…" (Kaplan 1964, p. 164, in Sass & Pinkos, 2015). Thus, like manic speech, speech in depression seems to have interpersonal anchoring and is somewhat meaningful to the listener, but the linguistic manifestations found in each pole are opposite – i.e., pressured and playful speech in mania and inhibited and painful experience of speech in depression.

Comparison of speech in mania and depression

Surprisingly few studies have compared the linguistic structure of natural discourse samples in patients with depression and mania. In one of these studies, Andreasen & Pfohl (1976) found that manic speech was colorful, concrete, concerned with things rather than people while depressive speech was more vague, qualified and personalized (self-preoccupations). According to Andreasen & Pfohl (1976), this was manifest in the tendency to use qualifying adverbs and first-person pronouns in depression, whereas manic individuals used more actions verbs and adjectives. Interestingly, consistent with the concrete quality of manic speech reported by Andreasen & Pfohl (1976), a growing number of studies indicate that intrusive future-oriented (or 'flashforward') mental images are higher in hypomania compared to depression, which is more often accompanied by verbal thoughts than images (e.g., Ivins et al., 2014). Like racing thoughts and flight of ideas in mania, we speculate that rumination, typically defined as abstract and analytical self-focused thinking (Marchetti et al., 2014), might be considered the subjective equivalent of the linguistic peculiarities found in depression. To our knowledge, this assumption has not been throughly investigated thus far.

Summary

In sum, linguistic experiences are widely varied in bipolar disorder, but have been poorly investigated across different episodes. Structurally, syntax and pragmatics seem to be mostly intact in both mania and depression; that is, sentences are syntactically complex and convey meaning to the listener. This does not imply however that language is unimpaired in bipolar disorder, since prosodic and semantic peculiarities have been described. Generally speaking, pressured, verbose, combinatory and playful speech is characteristic of mania, whereas inhibited, vague, self-focused, and painful speech has been reported in depression. In addition, clang associations are a feature particularly prominent in manic states, indicating that speech segments, and possibly thoughts, are tied to each other in an idiosyncratic sound-based, but coherent, manner. In mixed episodes, classical accounts by Binswanger (1933/2000) and Kraepelin (1899/2008) suggest that laconic and disjointed speech might be characteristic of these states, which have received little attention from researchers in phenomenology and linguistics. First-person accounts are however suggestive of increased inner speech velocity, leading to a colapse of meaning and coherence, e.g., "Sentences flew around in my head and fragmented first into phrases and then words; finally, only sounds remained" (Jamison, 1997). As we will further review in section 1.4.3, from a neuropsychological standpoint, semantic and executive dysfunction might be considered potential mechanisms involved in these disturbances. Moreover, although linguistic anomalies have been linked to racing thoughts and rumination (Hoffman et al., 1986), the relationship between linguistic and thought patterns across mood states in bipolar disorder is still speculative.

1.4 – The psychology and neuropsychology of racing thoughts

1.4.1 Psychopathological aspects: development of the Racing and Crowded Thoughts Questionnaire (RCTQ)

In quantitative psychology and psychiatry, racing thoughts have been mainly investigated through the use of clinician-rated questionnaires that broadly assess manic symptoms, such as the Young Mania Rating Scale (YMRS, Young et al., 1978). Through this method, one or few questions focus specifically on racing thoughts, hence not allowing a fine-grained analysis of its polymorphous phenomenology. Furthermore, as outlined by Zimmerman (2017), clinician-rated questionnaires are time-consuming and difficult to implement in routine clinical practice. With the increasing acknowledgement of racing thoughts in depression and in subsyndromal bipolar conditions, the development of questionnaires able to assess this phenomenon seems particularly important for two reasons: first, in clinical settings, it might aid the detection of racing thoughts in depression and in individuals at-risk for the development of bipolar illness; second, it might improve empirical research focusing on this phenomenon, particularly neglected thus far.

To our knowledge, only the 9-item *Subjective Thought Overactivation Questionnaire* (STOQ-9, Keizer et al., 2014) has been validated to assess racing thoughts in patients with mood disorders. This questionnaire was developed by a team in Geneva led then by one of the supervisors of our work (Gilles Bertschy) based on the expertise of a sample of clinicians. In addition to the development and validation of the STOQ-9, in their study, Keizer et al. (2014) investigated the qualitative features of racing and crowded thoughts found in the reports of 45 patients with mood disorders. The authors found six underlying semantic themes in these reports: (i) pressure of thoughts (e.g., "I pass from one thought to another so fast that I don't even remember what I was thinking about"), (ii) articulation of thoughts (e.g., as either simultaneous or sequential), (iii) information processing load (attention characteristics of racing thoughts, such as lack of filtering or saturation), (iv) onset and context of thought overactivation (e.g., "Each thing I come to see or hear triggers lots of thoughts"), (v) effects of thought overactivation, (vi) interface thought activation-emotion (i.e., relationship with specific moods, such as anxiety or depression). Thus, consistent with phenomenological accounts of racing thoughts (cf. section 1.3.1), the qualitative findings of Keizer et al. (2014) suggested that racing thoughts was a multi-faceted concept.

In the same study, the authors investigated the psychometric properties of a 16-item questionnaire conceived prior to their qualitative study. This questionnaire included items belonging to racing and crowded thoughts but also rumination items that were developed based on a consensus among clinicians (Keizer et al., 2014). This scale was applied to 82 patients presenting with a mood episode, and 38 healthy controls. A principal component analysis of the initial 16-item scale indicated that a single component explained 55.9% of the variance, with major and exclusive contributions from 9 items. Rumination items were not part of this component. The final 9-item self-rating scale was called *Subjective Thought Overactivation Questionnaire* (STOQ; Keizer et al., 2014), 'thought overactivation' refering here to both racing and crowded thoughts. Scores on the STOQ correlated with both activation and depression indices of the ISS (Bauer et al., 1991) in patients with mood disorders, suggesting that it was able to capture a thought pattern associated with both depressive and manic mood. Elevated STOQ scores were also significantly associated with decreased well-being and higher anxiety levels. Interestingly, in a recent study, Ferrari et al. (2016) reported preliminary findings indicating that STOQ scores were significantly higher in euthymic individuals compared to controls, hence suggesting that subthreshold mood symptoms might be associated with mild, but significant rates of racing and crowded thoughts. However, this scale did not address the numerous facets found in he qualitative analysis of patient reports, which was performed after designing the first draft of the STOQ, nor did Keizer et al. (2014) consider that racing and crowded thoughts might also be observed in association with subthreshold mood symptoms. Another limitation is related to how their sample of patients was assessed. Ineed, aside from visual analog scales (ISS; Bauer et al., 1991), patients' clinical status was not assessed in depth. Since most of their patients were outpatients, they were likely to be in a depressive episode, which might be another limitation to the their findings.

To address the multi-faceted nature of racing and crowded thoughts in association with pathological and 'healthy' mood, we (Gilles Bertschy, Ineke Keizer and Luisa Weiner) developed a new questionnaire, the 34-item Racing and Crowded Thoughts Questionnaire (RCTQ), which included the nine items of the STOQ, and 25 additional items refering to specific aspects of the phenomenology of racing and crowded thoughts and to the qualitative findings of Keizer et al. (2014). If some items of the RCTQ were clearly related to the phenomenology of racing thoughts or crowded thoughts, others were more related to the consequences of thought overactivation and less exclusively linked to the racing versus crowded distinction (e.g., 'My mental overactivity is exhausting'). Items that refered to racing thoughts conveyed the notion of an acceleration and an increased amount of thoughts that are linked to each other in a sequential manner (e.g., my thoughts race at 200 km/hour); clinically these thoughts are usually associated with positive emotions, and are not perceived as being emotionally overwhelming. In contrast, items that refered to crowded thoughts were related to an increased amount of thoughts that are linked to each other in a simultaneous manner, as if thoughts were accumulating in one's mind (e.g., thoughts accumulate in my head); these thoughts are usually associated with an increased information processing load, and the feeling of being emotionally overwhelmed. Both racing and crowded thoughts items portrayed thoughts as arising in one's mind involuntarily (e.g., my thoughts take off on their own). Figure 8 and 9 portray the final versions of the RCTQ in English[10] and in French.

[10] The English version was translated and back-translated.

This questionnaire refers to the last 24 hours. If your thought activity varied in the last 24 hours, please refer to the average thought activity in this period of time.

Item No	RCTQ Question
1	*I have too many thoughts at the same time.*
2	My thoughts race at 200km/h
3	*My thoughts get twisted and mixed up.*
4	*Thoughts accumulate in my head.*
5	*My thoughts keep changing topics.*
6	When I speak, I feel less distressed by the stream of thoughts in my mind.
7	*My thoughts take off on their own.*
8	There is a succession of thoughts in my mind, racing from one to the other with incredible ease.
9	*Many thoughts come up and cross my mind at the same time.*
10	The intensity of my mental activity is unbearable.
11	My mind 'jumps ' from one thought to another ceaselessly.
12	Each object, each detail surrounding me gives rise to a new thought.
13	My brain cannot manage all these thoughts that arise at the same time.
14	I feel distressed in my everyday life by the great number of thoughts or by the velocity of the thoughts in my mind.
15	I cannot seem to stop the mechanism that generates all of these thoughts in my head.
16	At any given moment, a great number of thoughts come and go in my head.
17	My thoughts race when my attention is not captured by an activity
18	My thoughts overflow : it is like an overload.
19	My brain moves faster than my body.
20	At any given moment, new thoughts burst from nowhere in my mind.
21	Everything I hear or see immediately gives rise to a new thought.
22	There is not enough time to grasp the meaning of a thought, as new ones immediately arise.
23	Keeping focused in the middle of this thought overload is a constant struggle.
24	Thoughts pile up in my head.
25	A thought immeadiately leads to another, which leads to another, then another…
26	*My thoughts fly in all directions.*
27	I find it difficult to express myself because of the amount or the speed of my thoughts.
28	My thoughts race much too fast.
29	My mental overactivity is exhausting.
30	I cannot slow down or reduce the stream of thoughts in my head.
31	*My thoughts often take me very far away from my initial idea.*
32	When my thoughts race, I disconnect from everything around me.
33	*My thoughts bump into each other in my head*
34	There is a permanent parade of thoughts in my mind : one after the other, ceaselessly.

Italics: items from the 9-item STOQ

Figure 8: 34-item RCTQ (English version)

Item No	RCTQ Question
1	J'ai trop de pensées en même temps.
2	Mes pensées vont à 200 à l'heure.
3	Mes idées se mélangent et s'embrouillent.
4	Les pensées s'accumulent dans ma tête.
5	Mes pensées changent trop souvent ou trop vite de sujet.
6	Quand je parle je suis moins gêné(e) par le flot de pensées dans ma tête.
7	Mes idées s'emballent toutes seules.
8	J'ai une succession de pensées qui filent l'une derrière l'autre avec une incroyable facilité.
9	Une multitude de pensées me viennent à l'esprit en même temps.
10	L'intensité de mon activité mentale est insupportable.
11	Mon esprit saute sans arrêt d'une pensée à une autre.
12	Chaque objet, chaque détail autour de moi fait surgir une nouvelle pensée.
13	Mon cerveau n'arrive pas à gérer toutes les pensées qui arrivent en même temps.
14	Je suis gêné(e) dans ma vie quotidienne par mes pensées nombreuses ou rapides.
15	Je n'arrive pas à stopper le mécanisme qui produit des flots de pensées dans ma tête.
16	A chaque instant de nombreuses pensées vont et viennent dans ma tête.
17	Mes pensées s'emballent dès qu'une activité capte moins mon attention.
18	Mes pensées débordent : ça fait comme un trop-plein.
19	Mon cerveau va plus vite que mon corps.
20	A tout instant de nouvelles pensées, semblant venir de nulle part, jaillissent dans mon esprit.
21	Tout ce que je vois ou entends déclenche immédiatement une nouvelle pensée.
22	Je n'ai pas le temps de saisir une pensée qu'une autre arrive déjà.
23	Rester concentré au milieu de ce trop-plein de pensées est une lutte permanente.
24	Les pensées s'empilent les unes sur les autres dans ma tête.
25	Une pensée en induit instantanément une autre, qui en induit une autre, puis une autre, puis une autre…
26	Mes pensées vont dans tous les sens.
27	J'ai de la peine à m'exprimer en raison de l'abondance ou de la vitesse de mes pensées.
28	Mes pensées vont à toute vitesse.
29	Mon hyperactivité mentale m'épuise.
30	Je n'arrive pas à ralentir ou réduire le flot de mes pensées.
31	Mes pensées m'amènent sans arrêt très loin de mon point de départ.
32	Quand mes pensées s'emballent, je me déconnecte de ce qui se passe autour de moi
33	Mes idées se bousculent dans ma tête.
34	C'est le défilé permanent des pensées :l'une chasse l'autre, sans fin

Figure 9: 34-item RCTQ (French version)

In line with the phemenological literature reviewed in section 1.3.1 and the new model we have proposed linking subsyndromal and full-blown low and elated mood symptoms to racing and crowded thoughts (cf. Figure 3), in our work, we aimed at investigating the psychometric properties of the RCTQ in individuals with mood disorders (article 2), but also in healthy individuals with sub-affective temperament traits and subsyndromal symptoms (article 1).

1.4.2 Time and racing thoughts: neuropsychological frameworks

Phenomenal time, as outlined in section 1.3.2, encompasses at least two aspects of experience, that may seem incompatible: the feeling of the present moment (or 'nowness', as a discrete moment) and the flow of time (the continuity of time; Husserl, 1913/2014). In section 1.3.2, we indicated how Husserl tried to solve this paradox by proposing that the feeling of the present moment resulted from a passive temporal synthesis, including the just-past and the about-to-come. Passive synthesis thus leads to the sense of continuity, i.e. time as a flow, by linking past, present and future events. The passive synthesis is an implicit aspect of time, which structures our conscious experiences in an incidental way. Wittmann (2011) nicely re-formulated this idea by writing that one's sense of 'nowness' is "an island of presence in the continuous flow of time related to what is happening right now". Whether this sense of 'nowness' is a discrete durationless point or an interval containing a duration has been a matter of philosophical debate (Pöppel, 2009; Wittmann, 2011). We will show here experimental evidence that allowed authors to categorize different types of temporal windows, and to reconcile, from a neurocognitive standpoint, the discreteness of moments and the continuity of subjective time.

Temporal windows

Reconciling discrete moments and the continuity of time: the hierarchical model of Pöppel

From the standpoint of psychology and neuroscience, a wide range of empirical data suggests that perception, cognition and motor behavior occur in discrete temporal windows or epochs (Wittmann, 2011; van Wassenhove, 2009). Events are perceived as co-temporal within discrete temporal windows, forming snapshots of experience (temporal units) or psychological presents (van Wassenhove, 2009; Wittmann, 2011). The assumption of discrete temporal windows is supported by numerous psychophysical accounts suggesting that, regardless of the sensory modality, minimal durations or thresholds of tens of milliseconds are necessary for specific events to be experienced as successive, and not simultaneous (Pöppel, 2009). For instance, in vision, the threshold is approximately 20 ms for static visual stimuli in the same location (Exner 1875 in van Wassenhove, 2009); that is, successive visual input occurring below the threshold are subjectively experienced as a single event, whereas if the lag between successive events is above the threshold, temporal asynchrony and temporal order may be experienced as such. For disparate events from different sensory modalities (e.g., visual and auditory information), events occurring within approximately 100ms are more likely than not to be fused into a single multisensory perceptual segment (van Wassenhove, 2009). Temporal integration of more complex stimuli, such as dynamic ones, occur instead below the threshold of approximately 200-300 ms (van Wassenhove, 2009). For instance, in a simultaneity task whereby participants had to judge whether visual and auditory speech events were asynchronous or not, Conrey & Pisoni (2006) reported that events were judged to be synchronous within a temporal window of approximately 200–300ms. As outlined by Wittmann (2011), these data imply that perceptual moments, within which events are fused together, are experienced as durationless snapshots of the world.

Like phenomenal time, psychological time has to account for the existence of discrete moments which needs to be reconciled with the notion of temporal continuity. To bridge the gap between perceptual temporal units and the perceived continuous flow of time, Pöppel (1997) developed a model consisting of three overlapping hierarchical temporal windows – i.e., (i) the functional moment, (ii) the experienced moment and (iii) mental presence (Wittmann, 2011) -- corresponding to processing levels at different time scales – i.e., from tens of milliseconds up to minutes. **The functional moment** refers to temporal windows of some tens of milliseconds whereby spatial and temporal information are binded together and perceptual units with no perceivable duration emerge (Pöppel, 1997); the functional moment is usually assessed via asynchrony detection tasks – i.e., the subject has to judge whether two stimuli are simultaneous or not. **The experienced moment** is defined as the state of being conscious, i.e., an extended unit of subjective presence within the flow of consciousness, which arises from the temporal integration of functional moments (Pöppel, 2009); the experienced moment can be assessed, for instance, via bistable images paradigms (see below). On the third level of temporal processing, termed as '**mental presence**' by Wittmann (2011), one may experience extended durations and temporal continuity – from several seconds up to minutes and hours (Pöppel, 1997); mental presence can be assessed via, for instance, duration estimation tasks.

Both the stationary and dynamic features of temporal experience are addressed within this framework: during their respective intervals the identity of a percept (the functional moment) or a thought (the experienced moment or subjective now) is maintained, and a new experiential moment may enter consciousness when the interval is over (Pöppel, 2009). Mental presence, in turn, encloses a sequence of extended moments or nows that underlie the representation of a unified experience of presence (Wittmann, 2011). The functional and the experienced moment shape and maintain respectively the content (identity) of percepts or concepts over time. In this sense, the integration of information within temporal windows is a container rather than a content. It is the hierarchy of temporal windows that helps to avoid discontinuities, each discrete event being embedded and integrated within a larger scale window.

Distinction between implicit/explicit processing and sub-second/supra-second timing

It could be noted here that several experimental approaches measuring time windows are based on temporal judgements, e.g. judging whether two events are simultaneous or asynchronous. This is problematic when the aim is to evaluate windows that structure our consciousness rather than temporal contents. There are however several means to evaluate temporal windows. Timing can be implicitly assessed when an overt report is not required: time is “just there” as a by-product of a non-temporal task, or as a container of experiences, e.g., the rythmicity of language or movements. In psychological tasks, implicit timing can be measured for instance meanwhile the subject makes a perceptual judgment about stimulus features or performs a motor task (Coull & Nobre, 2008). Yet, it is also possible to experience time as a content, and such is the case especially for explicit judgments of durations. In psychological tasks, this means that an overt report of a temporal quantity is required, e.g., when estimating a duration. A typical everyday example of implicit and explicit time judgments is that of listening to music: explicit timing is manifest when one tries to estimate how long a song lasted, while implicit timing is involved in the ability to sing at the right moments during the song (Piras & Coull, 2011).

Although there is a frequent overlap in the literature between the explicit and implicit distinction and respectively suprasecond and subsecond interval durations, these definitions are not interchangeable, and explicit duration judgments can concern for instance subsecond intervals. Moreover, at the neural level, distinct neural substrates have been shown to be associated with explicit and implicit interval timing, on the one hand, and explicit subsecond and suprasecond interval estimation, on the one hand. In a recent meta-analysis of fMRI studies, Wiener et al. (2010) reported that sub-second timing tasks showed a higher propensity to recruit subcortical networks, such as the basal ganglia and cerebellum, whereas supra-second timing tasks were more likely to activate cortical structures, such as the supplementary motor area (SMA) and the prefrontal cortex. Regarding the implicit and explicit distinction, in a review of fMRI studies, Coull & Nobre (2008) showed that the basal ganglia was actived by explicit timing tasks, whereas during implicit interval tasks, the inferior parietal and premotor areas were more likely to be recruited. Hence, different neural substrates seem to be selectively involved in explicit and implicit interval timing, but also in sub-second and supra-second duration estimations. From the standpoint of cognitive psychology, however, whether they share the same representation of time, thus reference the same psychological models, is still a matter of debate.

Studies focusing on duration judgments have usually used stimuli in the multiple seconds range, and, unlike other timing studies presented here, they usually refer to internal clock conceptual frameworks (Treisman, 1963). We describe them in the section corresponding to the 'mental presence' level of processing (1.4.2.3).

We already provided definitions for each type of temporal windows described by Pöppel to reconcile discrete 'present moments' and the sense of time continuity. Hereafter we will focus on each type of temporal window. This knowledge determined our strategy regarding the investigation of timing abnormalities in bipolar disorders.

1.4.2.1 The functional moment

As outlined previously, the functional moment can be assessed explicitly via simultaneity or order detection tasks: in these tasks, subjects are asked to judge whether stimuli are simultaneous or successive. If the lag between two stimuli is above the threshold, then two discrete perceptual experiences may arise. For instance, acoustically, [bæ] and [pæ] differ mainly in terms of the delay between the consonantal burst and the vowel onset. If the delay is below approximately 30ms, a [bæ] is perceived; if the delay is above approximately 30ms, a [pæ] is perceived. Here the categorical threshold which defines two discrete perceptions is approximately 30 ms. (van Wassenhove, 2009). At the neural level, because their time scales echo that of perceptual integration, periodicities of brain oscillations especially in the gamma range (more than 30 Hz) have been put forward as a putative mechanism underlying tens of ms integrative windows (Pöppel, 1997). That is, synchronization of neuron populations can then occur at a level that can be distinguished from spurious synchronization, leading to the processing of disparate sensory information as a multi-dimensional perceptual unit (Singer, 1999; Elliott & Giersch, 2015).

However, a number of studies have pointed to the fact that events occurring beyond the asynchrony threshold are also temporally structured (e.g., Elliott & Giersch, 2015). This has been shown essentially when asynchronies are assessed implicitly, i.e., independent of a conscious judgment, via, for example, priming paradigms (e.g., Poncelet & Giersch, 2015) or the Simon effect (Simon, 1969); the latter corresponds to the tendency to respond to the side of a stimulus independent of the task at hand. For instance, in a visual simultaneity task, for asynchronies as short as 17 ms, a bias to the side of the second stimulus has been reported in healthy individuals, hence suggesting that information below the asynchrony detection threshold (30-50 ms for visual stimuli in distinct locations) is not homogeneously processed as co-temporal (Lalanne et al., 2012a,b). This might mean either that the functional moment needs to be better defined, or that there is an additional window within the functional moment that is based on unconscious mechanisms.

1.4.2.2 The experienced moment

On a higher level of processing, the experienced moment, functional moments are linked together, and the subjective present or feeling of 'nowness' may be experienced as such. Nowness is defined as the state of being conscious, i.e., an extended unit of subjective presence within the flow of consciousness, which arises from the temporal integration of perceptual moments (Pöppel, 2009). Correspondingly, at the neural level, van Wassenhove (2009) suggested that long-range neural projections accessing sets of distributed and specialized neural populations are involved in the emergence of the subjective present.

In terms of the duration of such intervals, drawing from a number of empirical studies, Pöppel (1997, 2009) suggested that feeling of nowness corresponds to a temporal integration mechanism evolving at around 3s. For instance, Pöppel (e.g., 1971 in Pöppel, 1997) found that explicit reproduction of durations of approximately 2-3 seconds was usually precise with small variance, but performance decreased considerably for longer intervals, leading to shorter reproductions. In an incidental manner, spoken language, whether in its spontaneous form or in poetic form through verse segmentation, has also been reported to be embedded in temporal windows of up to 3 s duration, giving speech its rhythmic structure (Pöppel, 2009).

Another paradigm providing insights into the temporal integration at the basis of the subjective present is that of temporal reversal of ambiguous figures or bistable perception (Pöppel, 1997). Ambiguous figures, such as the Necker Cube or binocular rivalry paradigms (Figure 10 (a) & (b) respectively, taken from Ngo et al., 2011), can be perceived alternatively in two different ways, e.g., for the Necker cube, either from above with the lower right face in the front or from below with the upper left face in the front. These two perceptions are exclusive, meaning only one can be accessed at a time. It is this constraint that implies that the two perceptions alternate, each perception having a duration. The interval between perceptual changes, i.e., 'dwell times' or 'switch rates', can be measured via self-report. During continuous presentations, perceptual switches spontaneously occur every 2-3 seconds on average (Wittmann, 2011).

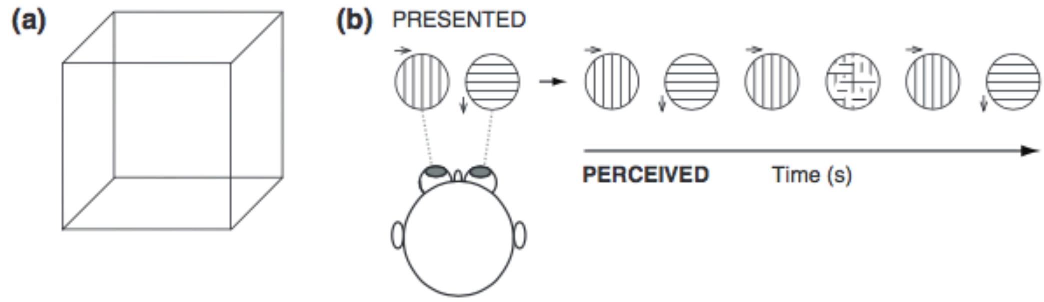

Figure 10: (a) The Necker cube: percepts alternate between two different depth perspectives. (b) binocular rivalry, two dissimilar images are presented, one to each eye. Percepts alternate over time. Source: Ngo et al., 2011.

The peculiarity of bistable stimuli is that over time they elicit two distinct conscious representations, while the actual stimulus remains completely unchanged, akin to mindwandering in contexts of sensory deprivation (van Wassenhove, 2009). As noted by Kornmeier & Bach (2012) in their review, psychophysical studies which manipulated low-order features of stimuli, such as color and size, support the idea that bottom-up processes are involved in the spontaneous switching of percepts of ambiguous figures. Consistently, electroencephalography (EEG) studies using bistable stimuli have found a chain of event-related pontentials beginning with an early occipital positivity at around 130 ms, hence suggesting the contribution of early visual processing in perceptual reversal (Kornmeier & Bach, 2005; Kornmeier, Pfäffle, & Bach, 2011). However, subjects may also exert, to a certain extent, volitional control over perception switches, for instance through eye blink or by looking at specific parts of the figure, suggesting that top-down processes are also involved in perceptual alternation. A number of neuroimaging studies in healthy subjects have further supported this view by pointing to the crucial role of the frontoparietal cortex in perceptual transitions during bistable perception (e.g., Weilnhammer et al., 2013). To disentangle bottom-up from top-down processes involved in perceptual switches, some studies have administered, in addition to the passive viewing of ambiguous figures, conditions whereby subjects were instructed to vonlutarily either inhibit or accelerate perceptual switches (e.g., Windmann et al., 2006). Of note, in an ongoing study we are investigating, using passive and 'controlled' viewings of Necker cube (akin to Windmann et al., 2006) whether (i) patients with racing and crowded thoughts report greater number of perceptual switches in spontaneous conditions compared to controls, and (ii) whether and how they are able to exert some control over perceptual switches [11].

1.4.2.3 Mental presence

Finally, on the third level of temporal processing, termed as 'mental presence' by Wittmann (2011), one may experience extended durations (i.e., longer than 3 s) and temporal continuity over a longer time range (Pöppel, 1997). According to Pöppel (1997), at this level temporal continuity is made possible by the semantic connections between what is represented within each subjective present. In other words, temporal continuity is based on "…the mental content and its ongoing representation within the neurocognitive machinery masking the discontinuity of the 3 s segments." (Pöppel, 1997, p. 60). Hence temporal continuity is subtended by declarative memory processes – semantic and episodic – which allow for the creation of personal identity and, as a consequence, of self-reference (Pöppel & Bao, 2014). Within this context of self-reference, mental presence relies on the ability to maintain mental representations of current and past goals in an active state for a certain period of time, i.e., working memory (Wittmann, 2011). Here again time is the container but not the content, inasmuch as mental presence is involved in the ability to maintain mental representations across short 'experienced moments' and thus to avoid a sense of discontinuity.

[11] Preliminary findings were reported in Causin, Weiner, Bertschy & Giersch (2016). Since these results are being further analyzed, they will not be discussed here.

Extended windows can be assessed via recall of specific events, but it can also be evaluated by measuring the passage of time, for example when we say that time goes quickly or too slowly during supra-seconds intervals.. This refers to our experience of time and implies a sense of continuity. These expressions also imply that durations have been estimated. Such aspects of time are relevant in the present work because they might account for reports of patients during acute mood states of bipolar disorder – for instance, time may seem to drag or stand still in depression, while it is accelerated in mania (see section 1.3.2). Part of our work thus focused on duration experience.

1.4.2.3a Duration experience

One of the most striking features of time perception is how it can be modulated by contextual factors relatively independent of the actual physical time. That is, for the same time lapse, one might feel that time 'flies' or, instead, that time 'drags', according to extrinsic and intrinsic contextual factors such as, respectively, how stimulating the activity taking place is and one's psychological state while experiencing it. In the literature, the experience of duration has been usually assessed via six types of task: (i) verbal estimation, (ii) reproduction of durations, (iii) production of durations, (iv) temporal generalization, (v) temporal bisection, and (vi) passage of time judgments. With the exception of passage of time judgments, which usually rely on visual analog scales assessing how time 'feels', in the other tasks, a quantification of duration is required. In verbal estimation tasks, participants experience the target duration and then are required to translate it into chronometric units. In time reproduction tasks, participants are required to reproduce the duration of the stimulus that was previously presented (Mioni et al., 2016). In production tasks, subjects have to produce a given interval by signalling when the duration has been reached. An under-production of an interval is indicative of an overestimation of time: if more time has passed subjectively for an individual he/she will indicate that a given duration has passed too early. In temporal generalization tasks, subjects are presented with standard durations (e.g., 5 s), and comparison durations – either the same interval (e.g., 5 s), longer or shorter --; they have to judge whether each compairison duration corresponds or not to the standard duration. Finally, temporal bisection tasks consist of attributing a given target duration to previously learned 'short' or 'long' sample durations (Droit-Volet, 2016).

The most influential psychological timing model to date is based on the hypothesis of an internal clock – in humans and in animals -- underlying the ability to estimate durations rather accurately in everyday situations (Treisman, 1963). The internal clock would thus be responsible for transforming objective time into subjective time. According to the clock model, pulses emitted by an internal pacemaker are transferred via a switch into an accumulator whose content grows as a linear function of real time. The switch allows for the definition of an onset and offset for a given interval. This model account for fundamental properties of time perception in humans, i.e., scalar properties. In time perception, scalar properties are based on the fact that the variability of temporal estimates increases with the standard duration to be timed – the longer the actual duration, the more variable the estimates (Matell & Meck, 2004; Wearden & Lejeune, 2008). A wide range of data in humans and animals are supportive of the linear and scalar properties of the model in both implicit and explicit interval timing (e.g., Piras & Coull, 2011). However, internal-clock models have been criticized for their lack of neurobiological plausibility – i.e., such internal clock has not been localized in the brain (e.g. Karmarkar & Buonomano, 2007; Buonomano, 2014; chapter in Arstila & Lloyd, 2014) --, and for their inability to account for more elementary timing processes occurring in the tens of ms range (Buonomano, 2014). Moreover, in terms of experiences of duration, they do not account for dissociations between passage of time judgments and duration estimation found in numerous studies (Wearden, 2015). We will further develop the latter point in section 1.4.2.3c. Other models have evolved in order to address these limitations. Some of them avoided the notion of a dedicated clock system altogether (Ivry & Schlerf, 2008; Wittmann, 2013). For instance, Karmarkar & Buonomano (2007) suggested that neural circuits are inherently capable of temporal processing at the ms range due to the oscilatory properties of neurons[12]. Staddon (2005) proposed that short-term memory decay is linked to interval timing: when memory trace decays below a threshold value, it means that the target interval has elapsed and responding can begin (as in conditioning studies). Similarly, in the "dual klepsydra model" (Wackermann & Ehm, 2006) memory-loss is also an intrinsic component: subjective duration is represented by the state of a lossy accumulator which receives continuous inflow for the constitution of duration presentation of a stimulus that has to be judged. A simultaneous outflow reflects the loss of representation, indicative of underestimation of durations in psychological tasks. Recently, Matell & Meck (2004) elaborated a model, i.e., the Striatal Beat Frequency model, based on a wide range of neurobiological evidence indicating that the basal ganglia plays a central role in interval timing. Matell & Meck (2004) suggested that temporal judgments rely on the monitoring activity of the basal ganglia in the thalamo-cortico-striatal circuits, which acts as a coincidence detector that signals particular patterns of activity. Put more clearly, this model posits that durations are encoded when spiny neurons in the striatum detect a synchronous pattern of neuron activity in the beginning and in the end of a given interval, leading to a coincidence between the perceived duration and a standard duration.

Despite the aforementioned weaknesses of internal-clock models, they remain influential because, with recent developments (e.g., Gibbon, Church, & Meck, 1984), they can acount for the modulation of durations estimations, and they allow for the distinction of each type of modulation mechanism (i.e. arousal, attention, memory or decisional) involved in the

[12] This model is also state-dependent inasmuch as time is represented based on the general properties of a specific neural network, i.e., its previous activity (Karmarkar and Buonomano, 2007).

observed behavioral data (Droit-Volet & Gil, 2009). Because of their relevance as a psychological model, we will reference them specifically in the next sections to review findings relative to how contextual factors influence duration estimation.

1.4.3.2b Contextual factors and duration estimation

Theoretically speaking, to account for the influence of contextual factors on time perception, internal clock models have evolved and integrated memory and decision-making as putative mechanisms involved in temporal distortions (Droit-Volet & Gil, 2009). To date, the scalar expectancy theory model (SET, Gibbon, Church, & Meck, 1984), which incremented the initial clock model proposed by Treisman (1963), has been the most widely referenced in psychological studies focusing on time perception. According to the SET model (figure 11; Gibbon et al., 1984), when a subject processes an interval, an attentionnally modulated switch between pacemaker and accumulator closes. At this level, enhanced arousal may increase the frequency of pacemaker signals – the more arousing the event, the more pulses are emitted (Mioni et al., 2016). The clock pulses emitted by the pacemaker can then reach the accumulator, which starts counting these pulses. The more attentional resources are allocated for timing, the more pulses are "allowed" to pass through the gate (Zakay, 2014)[13]. The more pulses accumulated, the longer the perceived duration. The pulses accumulated are temporally stored in working memory and compared to long-term memory representations of durations. The subject can then decide whether the perceived duration corresponds to the short or the long standard duration (in temporal bisection tasks) or press a button when the elapsed interval corresponds to the duration subjects were required to produce (in production tasks).

[13] This attention-switch system has been integrated into the model more recently (for a review, Zakay & Block, 2004); attention has an effect on the switch that closes and opens at the onset and the offset, respectively, of the stimulus to be timed.

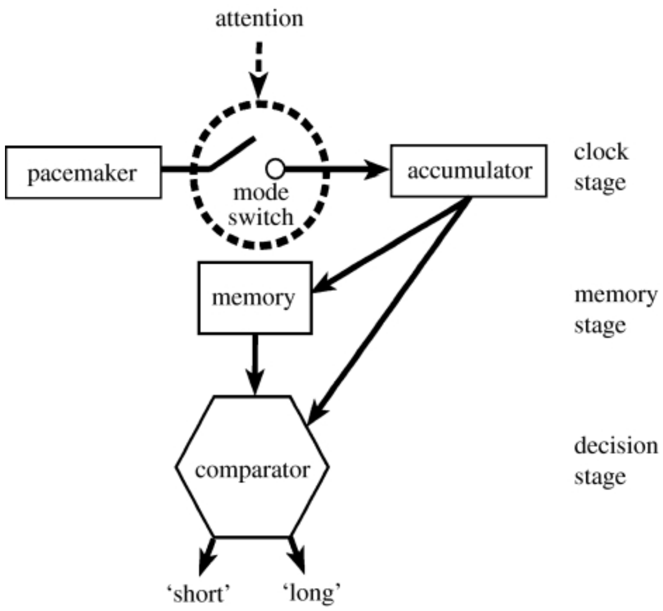

Figure 11: The temporal model outlined by Gibbons et al. (1984). Source: Droit-Volet & Gil (2009)

According to the SET model, if the relative number of pulses accumulated is high, then overestimation of durations accompanied by the feeling that time is slowed down should be observed. Put in other words, if events seem to last longer then, logically, time seems "slowed down" rather than "speeded up" (Wearden, 2015). Yet duration estimation and passage of time judgments are dissociated in a number of studies (e.g., Bschor et al., 2004; Droit-Volet & Wearden, 2016), and contextual factors seem to have different effects on duration estimation and passage of time judgments (Wearden, 2015). Among these contextual factors, the amount and the type of information processed during the interval, as well as the emotional/arousal state of the individual are the most prominent. In this section, we will focus on how contextual factors affect duration estimates. The impact of contextual factors on passage of time judgments will be reviewed in the following section (1.4.2.3c).

The amount and the kind of events, i.e., the information processing load, presented during an interval affect how boring the event is judged to be; thus how duration is quantified (Zakay, 2014). Furthermore, whether duration judgments refer to past or prospective intervals also influences how the amount of information is processed during the interval (Zakay & Block, 2004). When subjects are unaware that they are going to be asked questions about time (i.e., retrospective timing), they have to retrieve the events flow from memory. The more events are encoded (i.e., the less 'boring' the interval), the longer the duration is judged to be (Zakay, 2014). In contrast, when subjects are informed that the task they are going to perform is related to time (i.e., prospective timing), duration is estimated based on the attentional resources allocated to the non-temporal concurrent task. The more attention resources are allocated to the non-temporal concurrent task (and not to time itself), the shorter the duration is judged to be (Zakay & Block, 2004). As an example, Zakay and Fallach (1984 cited in Zakay & Block, 2004) used either an easy or a difficult Stroop (1935) task and found that prospective estimates made immediately after the interval were lengthened if the non-temporal concurrent task was easier. In addition to such contextual factors related to the nature of the ongoing activity, intrinsic personality and mood factors might play a role in how one subjectively experience durations (Watt, 1991; Rammsayer, 1997; Wittmann et al., 2014). For instance, Rammsayer (1997) found that healthy individuals with exacerbated extraversion traits tended to overestimate time and to make less accurate time judgments relative to introverts. Other personality dimensions that have been linked to time perception include impulsivity (e.g., Wittmann & Paulus, 2008), mindulness (e.g., Wittmann et al., 2014) and boredom-proneness (e.g., Watt, 1991). Aside Watt's (1991) study, reports have focused mainly on quantification of duration. Yet, as pointed out by Watt (1991), individuals may accurately estimate durations, and report that time passed slowly during the interval. We will further develop this point in section 1.4.2.3c. Given these results, it seems fair to conclude that both intrinsic and extrinsic contextual factors play a role in duration estimation in healthy individuals. Of note, studies have mostly focused on either personality or task-related (i.e., the amount of events processed during the non-temporal task) factors, and few studies have investigated the effects of their interaction on duration experience.

Emotion is another aspect involved in the experience of durations particularly relevant in the context of mood disorders. In healthy subjects, discrete emotions – e.g., sadness, happiness, anger, fear, shame –, usually depicted in facial pictures have been shown to have different effects on time perception (in such tasks, subjects have to determine how long the face stimuli were presented). For instance, Droit-Volet et al. (2004) found that angry faces (range of the interval 400 ms – 1600 ms) were associated with an overestimation of durations relative to neutral faces in a temporal bisection task, i.e. a given target duration has to be attributed to either a 'short' or a 'long' sample duration. To a lesser extent, overestimation of durations was also reported for sad and happy faces compared to neutral ones. The authors attributed these effects to the high arousing nature of these emotional stimuli, especially anger, leading to an acceleration of the internal clock, and thus an overestimation of durations (Droit-Volet et al., 2004; Droit-Volet & Gil, 2009). Because sadness is usually associated with a loss of energy, Droit-Volet (2013) argued that its moderate effect on time perception results from a relative slowing down of the internal clock rather than the unambiguous speeding up of the internal clock elicited by other discrete emotions, such as disgust and anger. Nevertheless, generally speaking, studies have found that negative high-arousal pictures (faces, affective images) are perceived as lasting longer than neutral low-arousal ones, although the temporal dynamics as well as the neural substrate of the lenghtening of durations varies according to the nature of the discrete emotional stimuli, e.g., fear and sadness (Droit-Volet, 2013). Inter-related arousal and attention mechanisms, but also specific body states elicited by a given emotion, have been suggested to play a role in how emotion affects temporal processing (Droit-Volet, 2013).

1.4.2.3c Passage of time judgments

Perhaps counterintuitively, passage of time judgements – i.e., how time feels --, and actual duration estimation – i.e., how long the interval lasted – might be dissociated in everyday situations (Droit-Volet & Wearden, 2016). For instance, individuals may feel that the time passes slowly while waiting at a bus stop, and still be able to give a relatively precise estimation of their wait. In cognitive psychology, whereas mechanisms involved in duration quantification have been widely studied, fewer studies have focused on the mechanisms involved in judgements of the passage of time (Wearden et al., 2014 chapter *in* Arstila & Lloyd, 2014; Wearden, 2015). Yet, a number of empirical studies have found that passage of time judgments and duration quantification can be dissociated (for a review, Wearden, 2015). As an example, in a study involving retrospective and prospective judgements, Wearden et al. (2014) investigated the effect of information-processing load on duration estimates and passage of time judgements. During 181-second intervals, subjects were asked to indicate the number that was missing in a 3x3 matrix of numbers from 0 to 9. In the low information-processing condition the numbers were arranged in ascending order, whereas in a the high information-processing condition their order was scrambled. In the high information-processing condition, the retrospective duration estimate was longer than the prospective one, and in the low information-processing condition the result was the other way around, which is consistent with Zakay & Block (2004). However, in both prospective and retrospective timing, high information-processing load produced faster passage of time judgements than the low information-processing conditions. Less demanding non-temporal concurrent tasks led instead to a relative slowing of the passage of time, which, according to Zakay (2014), is intrinsically related to the feeling of boredom. Thus, during less stimulating (or more boring) activities, healthy individuals might feel that the time passes slower, on the one hand, and overestimate prospective durations, on the other hand (Zakay, 2014). Consistently, Wearden et al. (2014) reported that the repeated viewing of a film produced increasing boredom and this was related to the feeling that time passed slower. Another recent study has also showed that boredom was the main predictor of passage of time judgments (Tanaka & Yotsumoto, 2017).

In everyday situations, using an experience sampling methodology (ESM), Droit-Volet et al. (2017) recently found a relationship between passage of time judgements and the level of difficulty as well as the attention that the ongoing activity required: The more difficult the activity was and the more attention it captured, the faster time seemed to pass. Although ESM may be well-suited for capturing how time 'feels' in an ecological manner – subjects perform the tasks in their everyday environment --, it can also explain why activity-related results differ across studies, probably due to the wide diversity of daily activities (Droit-Volet & Wearden, 2015).

The emotion and the arousal experienced during the interval are also involved in passage of time judgments. Using ESM, Droit-Volet & Wearden (2016) and Droit-Volet et al. (2017) recently showed in two consecutive studies that the passage of time was associated with self-reported affective states and arousal. Indeed, participants judged the time to go faster when happiness and arousal increased, and the opposite was found for sadness and relaxation. However, in the first study, passage of time judgments were unrelated to duration estimation of short intervals (< 2 seconds) in everyday situations, whereas in the second one passage of time judgments were related to duration estimates only when the intervals were long (in the minutes range). In the latter case, the faster the passage of time, the shorter the duration estimates. According to the authors, the dissociation between duration estimation and passage of time judgments for short intervals implied different underlying mechanisms in each type of time experience: estimation of world-time (or clock time) being dependent on the number of pulses accumulated by a potential internal clock, whereas such does not seem to be the case for 'felt time' (Droit-Volet & Wearden, 2016). By contrast, for longer intervals, passage of time judgments were related to duration estimation because in everyday situations people usually become aware of time during activities that last several minutes, and such is especially the case when a discrepancy between expected durations and actual durations occur, e.g., during waits (Droit-Volet et al., 2017). Interestingly, Tanaka & Yotsumoto (2017) found in a recent study that passage of time judgments were proportional to the difference between expected and actual duration. More specifically, prior to a working memory task (n-back) whose actual duration ranged from 3 to 7 minutes, subjects were informed that the task would last 5 minutes. After the task, subjects were asked to judge how fast the time passed. The authors found that the longer the task durations were compared to the initial instructions, the slower the passage of time was judged to be. Thus, both expectation and estimation processes were involved in passage of time judgments. These results led them to conclude that passage of time judments are "always "about" or "defined in relation to" certain external events" (p. 10). This might be in line with phenomenological accounts which have suggested that the feeling of the passage of time resulted from the comparison between a "time of self" -- the "time of the being" - and an external time – world time (Minkowski, 1933; Fuchs, 2013; Northoff et al., 2017)[14]. From a psychological standpoint, Tanaka & Yotsumoto (2017) suggested that memory is implicated in expectation processes, but the mechanisms involved in expectation and estimation discrepancies remain for the most part elusive, since few studies have addressed passage of time judgments, and methods vary greatly among studies.

Taken together, these results suggest that contextual factors such as the amount of events occuring during the interval, on the one hand, and the emotion elicited by the task and/or the emotional state during the interval, on the other hand, modulate the experience of time. Moreover, recent studies have suggested that these contextual factors have distinct effects on how time feels – assessed via passage of time judgments – , and how long intervals seem to have lasted – assessed via duration estimation tasks --, suggesting that different cognitive mechanisms might be at stake. However, to date, very few studies have investigated the

[14] See section 1.3.2.

mechanisms involved in the dissociations between passage of time and duration estimation judgments.

1.4.2.4 Findings in bipolar disorder

1.4.2.4a The functional moment

While explicit and implicit temporal alterations relative to the perceptual moment have been reported in schizophrenia (e.g., Lalanne et al., 2012 a,b; Giersch et al., 2016), in bipolar disorder, studies investigating timing at this elementary level are still lacking. From the perspective of phenomenology, since elementary temporal anomalies have been recently suggested to underlie the fragmentation of experiences, and possibly some aspects of the racing and crowded thoughts phenomena (Bowden, 2013)[15], it seems likely that, at least in a subgroup of patients, some kind of alteration at this time scale might be observed. In an ongoing study, we are currently investigating whether such is the case.

1.4.2.4b The experienced moment

Given their temporal dynamics, spontaneous perceptual switches of ambiguous images have been suggested to reflect the stimulus-independent dynamics of mental states, i.e., the inter-individual durations of the 'subjective present' (Pöppel, 2009). Because of this, they have been increasingly used in conditions whereby the temporal dynamics of the subjective present and the flow of time might be altered, i.e., in healthy individuals who are mindfulness meditators or under hallucinogens, but also in individuals with psychiatric disorders (Wittmann, 2015). In bipolar disorder, studies dating back from 1933 have reported a

[15] Bowden (2013) suggested that the retention feature of the passive synthesis was weakened in patients in manic and mixed episodes, and possibly subtended, from a phenomenological perspective, the experience of racing and crowded thoughts. See section 1.3.2.

significant slowing of switch rates for ambiguous figures in medicated and unmedicated[16] euthymic patients compared to controls and patients with schizophrenia (Hunt & Guildford 1933 in Miller et al., 2003; Pettigrew & Miller 1998; Miller et al., 2003; Krug et al., 2008). For instance, Pettigrew & Miller (1998) found that controls experienced perceptual switches every 1–2 s in a binocular rivalry task (cf. Figure 10, b), whereas for patients with bipolar disorder this occurred every 3–4 s with some perceptual periods as long as 7–10 s. This led authors to hypothesize that 'sticky switches', i.e., longer intervals between switches, were an endophenotype of the disorder (Pettigrew & Miller, 1998; Krug et al., 2008; Nagamine et al., 2009; Ngo et al., 2011; Vierck et al., 2013). Interestingly, in healthy individuals, Schmack et al. (2013) found that carriers of the DRD4-2R, a dopamine system polymorphism frequently reported in subjects with bipolar disorder (Douglas et al., 2016), showed slower perceptual switching than did non-carriers, hence suggesting that dopaminergic neurotransmission might be involved in the 'sticky switches' found in bipolar disorder. In the only study to our knowledge which has investigated perceptual stability in mania, Hoffman et al. (2001) found that manic patients had a spontaneous alternation rate of the Necker cube perspectives that was twice as fast that of control subjects and patients with schizophrenia. Hence, an acceleration of switching rates was found in manic patients, in contrast to the 'sticky switches' reported previously in euthymic bipolar patients.

Moreover, Hoffman et al. (2001) considered that increased perceptual instability in mania was likely to be related to the fleeting nature of racing thoughts and flight of ideas, although 'thought disorder', as measured by the *Comprehensive Assessment of Symptoms and History* (Andreasen, 1986), was not correlated to perceptual switches in their study. Interestingly, in a later review, Mellerup & Kristensen (2004) speculated that increased perceptual switches in

[16] Psychotropic medication for bipolar disorder, such as lithium and antipsychotic drugs, became widely available by the late 1960s. Thus, in early studies dating from 1933, patients were not under medication. Most patients included in more recent studies are medicated.

mania corresponded to faster synaptic transmission leading to faster emergence of functional clusters (i.e., synchronous activities between different neuronal groups), and thus of a conscious state or 'subjective present'. According to this model, faster than usual emergence of 'subjective presents' would thus underlie racing thoughts in mania (Mellerup & Kristensen, 2004).

1.4.2.4.c Mental presence

While studies on the experience of durations in depression are numerous, a very small amount of research has focused on bipolar disorder. In this section we will review findings relative to estimation of durations and passage of time judgments in bipolar disorder. However, we provide a more thorough review of findings on time perception in bipolar disorder, including exclusively motor tasks, in table 2.

In a particularly insightful and wide-ranging early study, Mezey & Knight (1965, p. 184) hypothesized that "…psychic acceleration in hypomania is accompanied by a faster personal time leading to an asynchronism between subjective and clock-measured time". Hence, Mezey & Knight (1965) highlighted that racing thoughts are key to the dissociation between passage of time judgments and duration estimations in mania. Although this assumption was not empirically investigated in their study, the authors did find that, compared to depressed subjects, hypomanic patients overestimated durations, on the one hand, and judged that time passed faster, on the other hand. In a later study, Tysk (1984) also found an overestimation of durations in manic subjects, and the opposite in bipolar depressed patients. Similarly, Bschor et al. (2004) found that depressed patients underestimated durations compared to manic ones in a verbal estimation task (109s), whereas manic and depressed patients equally underproduced (overestimated) durations in a production task compared to controls. By contrast, depressed patients reported a subjective slowing of the passage of time compared to manic patients and healthy controls, whereas manic patients reported a significant acceleration of the passage of time compared to both groups. Thus, manic patients overestimated durations, but they felt that the time passed faster, while in depression, time passsed slower, and estimates of durations differed according to the type of task (relative underestimation in a verbal estimation task and overestimation in production tasks). It is important to note that in Bschor et al's (2004) study, passage of time judgments refered to how fast the time seemed to pass during the day of the assessment, and not during the temporal tasks. Since subjects might have participated in a great number of different activities and experienced different emotional states during the day, passage of time judgments are difficult to interpret in this study. Nevertheless, these results point to the fact that manic and depressed subjects feel that the time passes respectively faster and slower during everyday situations, and that temporal distortions – i.e., how duration is quantified -- might be found in both cases.

Like Mezey & Knight (1965) before them, Bschor et al. (2004) speculated that racing thoughts were involved in the dissociation between estimation and passage of time judgments in mania, since overproduction of ideas might be arousing, giving the impression of longer durations, and faster passage of time. None of these papers investigated however the experience of durations in patients with mixed states or euthymic patients. If racing thoughts are involved in the acceleration of the passage of time and overestimation of durations in mania, it is likely that crowded thoughts also affect both aspects involved in the experience of durations.

Table 2: Brief review of time perception studies in bipolar disorder

Study	Task	Interval	Findings in mania	Findings in depression	Finding in euthymia
Mezey & Knight (1965)	Production (30s by counting) Reproduction (30s by tapping) Passage of time (during experiment) Duration estimation (of the experiment)	Several seconds range	- Overestimation of duration in production and reproduction* '- Underestimation long duration** '- Faster passage of time	- Underestimate less than mania	---
Tysk (1984)	- Metronome adjustment - Production (10, 20, 30s) - Verbal estimation (7.5, 17.5, 27.5s) '-Verbal stimation (experiment)	Several seconds range	'- Overestimation of duration in the production task ***	'- Underestimation in the estimation task (17.5 and 27.5s)***	- Non significant***
Bschor et al. (2004)	- Production (7, 35, 90s) - Verbal estimation (8, 43, 109s) - Verbal estimation (movie 12 min 40s) - Passage of time (during the day)	Several seconds range	- Overestimation of duration (production) - Overestimation movie duration - Slower passage of time	- Overestimation *** - Underestimation (estimation)** - Slower passage of time	---
Malhberg et al. (2008)	- Reproduction (1, 6, 37s)	Seconds range	- Under-reproduction (37s)***	- Over-reproduction (1s)***	---
Bolbecker et al. (2011)	- Paced finger-tapping (500 ms intertap)	Subseconds range	- Faster tapping*** - Increased variability***	---	- Faster tapping*** - Increased variability***
Bolbecker et al. (2014)	- Temporal bisection task (300 and 600 ms)	Subseconds range	---	---	- Non significant*** - Increased variability***

Legend: *Longitudinally, acute vs. Mild hypomania; **Hypomania vs. Depression;***Compared to controls estingly, in patients with unipolar depression, unlike the results found in individuals with bipolar depression, duration estimates are, in most studies, accurate compared to that of controls. Indeed, a recent meta-analysis by Thönes & Oberfeld (2015) found that depressed patients judged that time passed slowlier, but had no deficit in the duration estimation compared to healthy controls. This suggests that mood may influence passage of time judgments due to boredom and sadness among other symptoms, but, unlike emotion, it might be insufficiently intense to induce significant estimation distortions (Droit-Volet et al., 2017). It is noteworthy that, although the meta-analysis by Thönes & Oberfeld (2015) focused on time perception in depression, it also included studies conducted in individuals with bipolar disorder. Yet it is still unclear whether depression is associated with the same experiences of duration regardless of the longitudinal diagnosis (i.e., either as a part of bipolar or unipolar disorder). Indeed, in the only study that compared duration estimation in subjects with bipolar depression and unipolar depression, Tysk (1984) found that underestimation of durations was only observed in the bipolar group, hence suggesting that the characteristics of the depressive episode matter when it comes to time perception.

Gil & Droit-Volet (2009) and Droit-Volet (2013) suggested that verbal reports of a slowing of the passage of time in depression might actually refer to the feeling of boredom and be related to clinical symptoms such as rumination and psychomotor retardation. In other words, akin to healthy individuals who experience sadness and feel that time passes slower (Droit-Volet & Wearden, 2016), individuals with depression are aware of their own internal state (i.e., psychomotor retardation, lack of energy and drive) and may ruminate on their inability to take part on everyday trivial activities like they used to, and like others around them do (Droit-Volet, 2016). The slowing of the passage of time would thus result from symptoms like psychomotor retardation, boredom, decreased attention abilities, and rumination.

According to Northoff et al. (2017), discrepancies between target intervals and duration estimates are supportive, at the phenomenal level, of inner and outer-time desynchronization since the inner-time serves as a template for estimating and reproducing the duration in outer-time. Thus, if the subject's inner-time is accelerated in comparison to outer-time, i.e., the time of those aroud us, then actual duration of intervals should be overestimated (in estimation and production tasks) and under-reproduced (in reproduction tasks). Moreover, these authors suggest that the velocity of the passage of time is the basis of duration estimates in bipolar disorder and in healthy individuals – durations are estimated with reference to the velocity of 'inner-time'. While this approach seems plausible at the phenomenal level (cf. section 1.3.2), it does not provide any indication of putative cognitive processes involved in such dissociations. Moreover, it fails to acknowledge empirical data that one may feel that time passes slowly, and still accurately estimate durations (e.g., Watt, 1991; Wearden et al., 2014). To account for these divergent findings, we speculate that, if duration estimates and passage of time judgments are related (Droit-Volet et al., 2017; Tanaka & Yotsumoto, 2017), dissociations between passage of time and estimation judgments might be due to selective impairments of either expectation and/or estimation processes[17] (Tanaka & Yotsumoto, 2017), but also to the differential effects of mood on passage of time judgments and duration estimates (Droit-Volet et al., 2017). Interestingly, for long durations only, Droit-Volet et al. (2017) reported that acceleration of the passage of time was associated with underestimation of durations, which is consistent with the idea that if events seem to be shorter then time should be "sped up" (Wearden, 2015). However, this is not what has been reported in mania – i.e., overestimation of durations and faster than usual passage of time (e.g., Bschor et al., 2004). We speculate that this might be due to symptoms like racing thoughts and elated mood, which might be arousing, and lead to an overestimation of durations and faster than usual

[17] Probably related to memory functions, see 1.4.2.3.c.

passage of time judgments. Since few studies have investigated time perception in mania, and the methodologies differed among studies (see above), it is difficult to draw definitive conclusions on the pattern of results found in mania; thus, the mechanisms involved the experience of time in these patients are for the most part speculative.

Taken together, in the small number of studies conducted in bipolar disorder, the most robust findings in manic and depressive episodes are the acceleration of the passage of time accompanied by an overestimation of durations in mania, whereas in depression divergent findings have been reported according to the task (e.g., Tysk, 1984; Bschor et al., 2004). In mania, a relative shortening of the subjective present, measured by the spontaneous switching rate of the Necker cube (Hoffman et al., 2001), and faster tapping rate in the subsecond range (Bolbecker et al., 2011; table 2) have also been reported. Although Northoff et al. (2017) only acknowledged time perception in their phenomenological model, it is likely that the relative shortening of the subjective present, as measured by bistable perception paradigms, might also be involved, at the phenomenal level, in the acceleration of inner-time in manic states. Interestingly, racing thoughts were put forward by several studies as a putative mechanism involved in the acceleration of the flow of time in mania (e.g., Mezey & Knight, 1965; Hoffman et al., 2001), and its desynchronization relative to world-time (Mezey & Knight, 1965). We expect racing thoughts to be involved in time perception for two reasons: (i) racing thoughts are often associated with elated mood, which can be arousing, and (ii) racing thoughts have been associated with increased distractibility (e.g., Braden & Ho, 1981), and attention mechanisms play a role in time perception (Zakay & Block, 2004). By contrast, rumination is associated with (i) low mood, which has been linked to slower than usual passage of time judgments (Droit-Volet et al., 2017), and (ii) decreased working memory resources, which can impact duration estimates (e.g., figure 11). Both assumptions have not been assessed empirically thus far.

Furthermore, studies in individuals with mixed depression are lacking, and it is unknown how the co-occurrence of manic and depressive symptoms might affect time perception. In euthymic subjects[18], most findings refer to other temporal windows and are suggestive of a lengthening of the subjective present (i.e., sticky switches), which has been considered a trait of the disorder (Pettigrew & Miller, 1998). If the subjective present is lenghtened in euthymia due to a slowing of the internal clock (Pettigrew & Miller, 1998), it is possible that durations are perceived as shorter than they are in explicit interval timing tasks. However, to our knowledge, the experience of durations has not been thoroughly investigated in euthymic patients, whether from a phenomenological or an empirical perspective[19].

1.4.3 Language and racing thoughts: verbal fluency

"For those who are manic, or those who have a history of mania, words move about in all directions possible, in a three-dimensional 'soup', making retrieval more fluid, less predictable."

Kay Redfield Jamison (2017, p. 279)

In section 1.3.3, we provided a brief review of phenomenological and linguistic descriptive accounts of language experience in bipolar mood episodes. The studies reviewed found that, whereas syntax and pragmatic aspects were relatively unimpaired in mania and depression, peculiarities at the lexico-semantic and prosodic levels were prominent in the speech of patients. These anomalies were reflected by changes in the velocity of speech rate in mania and depression, but also in verbosity, and patterns of association between speech segments. Importantly, as outlined in section 1.1.3, from a psychopathological perspective, early

[18] Bolbecker and colleagues conducted two studies in euthymic patients (cf. table 2), with different timing task, and found somewhat disparate results (Bolbecker et al., 2011; Bolbecker et al., 2014).
[19] To our knowledge, only one study by Tysk (1984) included a group of patients in remission, and found that duration estimates did not differ from that of controls.

descriptions provided by Kraepelin (1899/2008) and Binswanger (1933/2000) had already highlighted similar speech peculiarities in mania, depression, and mixed episodes. Thus, like time, language has long been considered a core domain involved in the psychopathology of bipolar disorder, and particularly in racing thoughts. Believing that "language was the royal road to cognition"[20], some of the contemporaries of Kraepelin (1899/2008) tried to capture empirically the racing thoughts and flight of ideas phenomenon via verbal fluency tasks assessing how subjects associated words, beginning with a given inductive word, over time. However, and rather logically, these early studies were conducted without any reference to the cognitive processes involved in verbal fluency performance. Although some of these early results are consistent with descriptions of speech in depression and mania (results are further reviewed subsequently), the exact methods and frameworks were not described, and potential confounding factors were most probably not accounted for. For example, it is unknown how factors such as vocabulary size, age, and years of study might have influenced the results. Moreover, since the exact methods of these studies were not presented, it is unclear how the scores of interest were computed, and how the cue-words in associational tasks were selected.

This led Binswanger (1933/2000) to rightfully point to the fact that the number of words produced in word generation tasks might not reflect the flight of ideas phenomenon in patients with bipolar disorder. We will further expand on this point in subsequent sections. Since language is a vast cognitive domain, and since it is beyond the scope of the present work to be exhaustive on language production, we will focus here specifically on the cognitive aspects involved in verbal fluency performance. Then, we will review empirical findings in bipolar disorder.

[20] To paraphrase and recontextualize Aaron Beck et al.'s (1987) "emotion is the royal road to cognition", which underlies some of the principles of cognitive therapy in depression.

In our work, language was addressed via verbal fluency tasks for the following reasons. Verbal fluency tasks are now well-validated neuropsychological tests targeting how subjects generate thoughts over time. Theoretical models allow us to consider and control for a number of cognitive processes involved in free speech – i.e., executive, lexico-semantic and temporal processing. Indeed, we are now in a position where it is possible to isolate cognitive processes involved in verbal fluency performance through a number of methods. Thus, as Estes (1974 *in* Lezak, 2004) suggested, word fluency tests provide an excellent means of finding out whether and how subjects organize their thinking. This is not the case for natural discourse which encompasses a number of other linguistic parameters that are difficult to control for in empirical psychological studies – e.g., pragmatics and syntax. Although pragmatics and syntax are supposedly unimpaired in bipolar disorder (see section 1.3.3), the influence of these parameters has to be taken into account in natural speech conditions, and less so when producing individual words in verbal fluency tasks.

1.4.3.1 Verbal fluency tasks

Verbal fluency is a widely used neuropsychological procedure to evaluate the spontaneous production of words within an allotted time, usually one or two minutes. Traditionally, verbal fluency is measured in clinical and experimental neuropsychology by word counts during unrestricted – e.g., free word generation –, and restricted speech conditions – e.g., words beginning with a given letter or belonging to a semantic category (Lezak, 2004). More specifically, in the first unrestricted case, subjects are asked to produce orally as many words as possible, and in the latter cases, research criteria – orthographic, beginning with a given letter, or semantic -- are provided by the examiner. Another kind of fluency task is associational fluency. Probably because of its linkage with psychoanalysis, associational fluency has been underused in neuroscientific contexts (Rozin et al., 2002). In associational tasks, subjects are instructed to orally produce words following an inductive cue word.

Associational fluency is based on the assumption that words stored in semantic memory are linked to other words, and the associational strength between them vary according to the probability that one word, e.g., table, might lead to the recall of another word, e.g., chair (Nelson et al. 2004). Generally speaking, in order to avoid the implication of executive processes in word production, subjects are instructed to produce only one or two words, the first that come to mind, following the presentation of a cue word – for instance, the cue word 'table', and the two associated words 'chair' and 'dinner' (Nelson, McEvoy, & Dennis, 2000). Associational measures have been applied in the study of how semantic representations are organized in memory (Nelson et al., 2000), and performance has been found to be defective in case of hippocampal dysfunction (Kircher et al., 2008). However, single word associations do not allow studying the temporal characteristics of associative behavior, such as those involved in one's stream of thoughts (Deyne & Storms, 2008). Moreover, it is the continuous nature of associations that forms the empirical basis of various models of semantic processing including, for example, the dynamics of verbal clustering or free recall (e.g., Wixted & Rohrer, 1994; Troyer et al., 1997). In its continuous form (i.e., associational fluency), subjects are instructed to associate words following a cue word during a limited amount of time. Associational fluency might thus provide additional information regarding how word associations affect subjects' verbal output, in a relatively unrestricted way (Nelson et al., 2000; Baror & Bar, 2016). Hence, because a research criterion is not provided by the examiner, akin to the free condition of the verbal fluency test, associational tasks might provide a different means, closer to natural discourse, of assessing one's flow of thoughts (Levine et al., 1996). Yet associational tests cannot be studied without taking into account the cognitive functions that affect verbal output during fluency tasks. As already emphasized, different cognitive mechanisms are involved in verbal fluency performance. Most studies in the neuropsychological literature have focused on the cognitive underpinnings of the semantic and letter conditions of verbal fluency taks in patients with neurological or neurodevelopmental conditions. In the next section, we will review provide a brief review of these studies.

1.4.3.2 Cognitive components involved in verbal fluency performance

Regardless of the condition of the task – letter, semantic, free or associative --, in verbal fluency tests, participants need to retrieve and produce words of their language, hence verbal fluency performance undoubtely requires verbal abilities – e.g., the size of one's mental lexicon (or vocabulary), and the ability to access it can affect performance (Lezak et al., 2004). Indeed, letter fluency was originally developed as a measure of verbal intelligence quotient (VIQ; Thurstone, 1941), and correlations of .67 (Crawford, Moore, & Cameron, 1992) and even .87 (Miller, 1984) have been reported between letter fluency performance and VIQ. However, unlike naming tasks whereby subjects have to name a picture at a time, in verbal fluency tasks, participants need to strategically retrieve words stored in memory over the allotted time, hence to focus on the task, select specific words and avoid repetition, which certainly involves executive control processes (e.g., Rosen & Engle, 1997; Henry & Crawford, 2005). Thus, impairment in either lexico-semantic processes or executive control should lead to poor performance in fluency tasks. Given its hybrid nature, before we present how our work was conducted in patients with bipolar disorder, in the subsequent sections, we will first present the theoretical cognitive frameworks of the two main components involved in verbal fluency performance: lexico-semantic and executive processes (sections 1.4.3.2a and b, respectively). Then, in section 1.4.3.2c, we will present neuropsychological findings relative to verbal fluency tests, and how new methods can address the different cognitive facets involved in the overall number of words produced.

1.4.3.2a Semantic and lexical access

As formulated by Caramazza (1997, p.177) twenty years ago, theories of speech production are in agreement on two fundamental points: (1) semantic, syntactic, and lexical form information constitute independent levels of representation, and (2) these levels of representation are probably accessed sequentially in the course of language production. More specifically, most models are suggestive of at least two successive stages[21] of processing (Caramazza, 1997; Roux & Bonin, 2011). The first corresponds to the selection, at the conceptual stage (or semantic memory), of a semantic target representation; when accessing the target conceptual representation (e.g., dog), it is generally assumed that other semantically related conceptual representations (e.g., cat, horse) become activated as well through spreading activation (e.g., Caramazza, 1997; Levelt, 1999). We will further develop this point in subsequent paragraphs. The first stage also includes the selection of the syntactically specified lexical representation (the abstract word form or 'lemma'). The second stage involves the selection of its lexical-phonological representation (the word with its sound form or 'lexeme'). Thus, when turning a thought into a pronounced word, the result of the first stage is an abstract form of the word with its meaning and syntax (whether it is a noun or a verb, for instance). It is only in the second stage that information about the sounds that will have to be uttered are integrated into the word form – e.g., syllabification and prosody (Levelt, 1999).

[21] There is some divergence in the literature regarding the number of stages of processing. Caramazza (1997) suggested the existence of only two sequential stages: the first lexico-semantic, and the second phonological. Other models distinguish the conceptual (semantic) from subsequent lexical retrieval or 'lemma' and phonological retrieval or 'lexeme', and include a fourth articulatory stage (e.g., Levelt, 1999; Navarrete & Costa, 2005).

However, word production models disagree on mostly everything else. Such is the case for instance for whether they assume componential or holistic representations for meaning, and whether stages of processing are serial-discrete or cascading-interactive, a controversy arising partly from the methods favored by each model – either chronometric, speech-errors, or neuropsychology-based (Caramazza, 1997; Levelt, 1999). Partisans of the discrete model argue that, once information has been selected at the conceptual stage, it follows a fast-forward mechanism which does not allow for feedback from the subsequent stages (Levelt, 1999). Hence the discrete model implies that the first step must be completed before any activation of phonological forms takes place. As an example, during the first step of retrieval of the word "cat", the lemmas for CAT and DOG may both be active, but the phonological forms of these will not be. By contrast, cascade theories assume that any activated representation at a given processing level spreads a proportion of its activation to its immediately linked representation at the subsequent level (Navarrete & Costa, 2005). Thus, cascade models imply that phonological forms of potential lemmas (e.g., the forms of both "cat" and "dog") may be activated before the first, conceptual, step has been completed. Cascade models have been conceptualized as either partially (Caramazza, 1997) or fully interactive; only the latter permits bottom-up and top-down feedback (Dell, 2013; see figure 12 for a schematic representation of discrete-serial and cascade models). Currently, there is a considerable amount of evidence for cascading (for a review, Roux & Bonin, 2011), but little consensus on the degree to which the system is interactive (see Harley, 2007, for review).

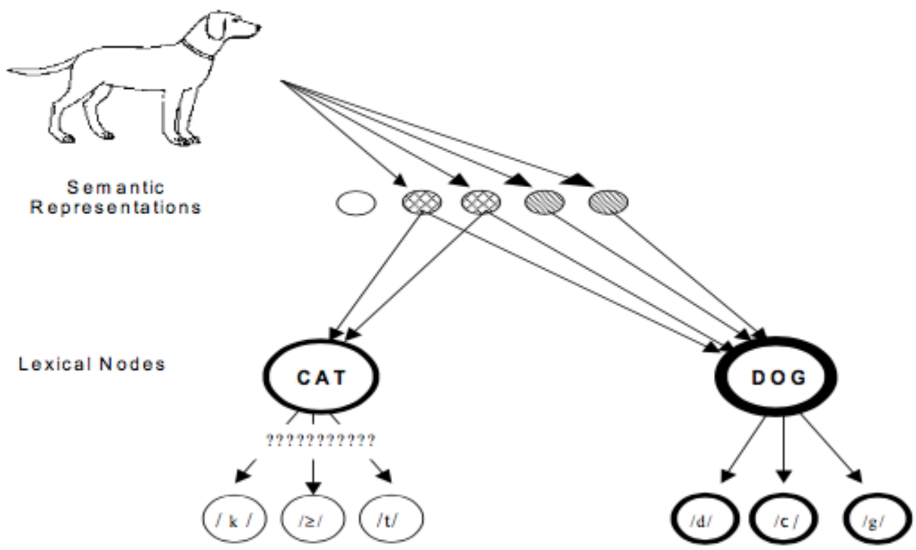

Figure 12: Representation of the cascaded and discrete view of lexical access. The arrows represent the flow of activation and the thickness of the circles the level of activation of the representations. The question marks represents the debate as to whether sublexical information of the non-selected lexical node (cat) is (cascaded view) or is not (discrete view) activated. Source: Costa et al. (2000).

Findings supportive of the serial-discrete model arise mostly from 'chronometric' studies using Stroop-like picture-word interference paradigms. In these tasks, subjects are instructed to ignore the word and name the target object which is simultaneously or asynchronously presented to them. In a much cited study, Schriefers, Meyer, & Levelt (1990) found an interference effect of semantically related words (for instance, word 'cat' and picture of a dog) on picture naming latencies at an early stimulus onset asynchronies (SOA; < 150 ms), and a facilitatory effect of phonologically related words (for instance, word 'dot' and picture of a dog) at later SOAs (0 ms, > 150 ms). These results were interpreted as supportive of a serial model of lexical access where meaning is first activated, and it is followed by a stage where only its form is activated. Since then, a large amount of studies using somewhat similar paradigms have found that distractor stimuli activate their phonological content, thus challenging the discrete-serial theory (e.g., Navarrete & Costa, 2005; Roux & Bonin, 2011). For instance, Cutting & Ferreira (1999) asked participants to name pictures that had homophone twins (e.g., a picture depicting a toy ball) and ignore distractor words. Distractors were either semantically related to the meaning of the target homophone twin (e.g., dance) or unrelated (e.g., table). Naming latencies were faster in the related condition than in the unrelated condition, indicating that distractors semantically related to the non-depicted, sound-based, meaning of the picture (dance) led to faster responses than unrelated distractors (table). This effect was explained based on cascading and spreading activation within different levels of processing. According to the authors, distractor word 'dance' activates its semantic representation along with other semantically related concepts, including BALL (dance). The activation of these concepts spreads in a cascaded manner to the lexical system, thereby activating the lexical node 'ball' (dance). This activation further spreads to the phonological level, activating the same phonological content of the target picture's name [e.g., ball (toy)], thus speeding up naming latencies. This means that unselected semantically processed material can affect phonological processing, even when lemmas are semantically unrelated to the target material (here, toy ball and dance).

Another divergence among models is related to how meaning is structured and accessed within the conceptual stage or semantic memory. From the standpoint of cognitive neuropsychology, semantic memory is one of the two long-term explicit memory systems outlined by Tulving (1986) – the other being episodic memory. Semantic memory refers to a person's conceptual knowledge about the world, and includes knowledge of the meaning of words, objects and other perceptual stimuli, as well as facts and associated information (Snowden et al., 2001). There has been a lively debate regarding the structure of semantic representations as to whether they are single and amodal or plural and category-specific, but also to whether they are componential or holistic. We will not address these matters in much detail, but single-case studies in patients with brain-damage are supportive of category-specific componential semantic stores[22].

Several cognitive models have been developped to address the question of how semantic knowledge is acquired, stored and accessed. The most prominent ones emphasize either the conceptual structure of knowledge by focusing on relations among concepts – i.e., the connectionist approach --, or the associative distance between words and concepts in natural language use – i.e., the semantic space approach (for a review, Griffiths, Steyvers, & Tenenbaum, 2007). Roughly, in the connectionist approach, words are represented as nodes, and edges indicate semantic relationships. By contrast, in a semantic space, words are represented as points, and proximity indicates semantic association within a multidimensional semantic space where each word is represented by specific coordinates (Griffiths et al., 2007). These models are not mutually exclusive: semantic space approaches acknowledge that spreading activation takes place within semantic networks, but each node is a holistic word, whereas such is not necessarily the case in connectionist models (e.g., Collins & Loftus, 1975; Griffiths et al., 2007). In the aforementioned discrete and cascade word production models, a connectionist semantic network approach is assumed. Based on latencies in sentence verification tasks (subjects have to decide whether a statement is true or not), earlier connectionist models conceptualized semantic memory as a tree-like hierarchical structure (Collins & Quillian, 1969), in which specific concepts are embedded in more general ones (for instance 'dog' is embedded in the broader 'animal' category). According to this model,

[22] A large number of double dissociations – i.e., patients displaying selectively one of two kinds of impairment -- have been reported in the neuropsychological literature for living and non-living things, regardless of the sensory input (i.e., naming pictures or answering questions such as "do whales have legs"?, which are independent from visual processing; for a review, Mahon & Caramazza, 2009). The living *vs.* non-living dissociation has been mainly attributed to the fact that conceptual knowledge of living things is constituted of its perceptual features (e.g., cats have whiskers) whereas inanimate objects (e.g., a spoon) have more functional features (e.g., we use it to eat), suggesting that semantic representations are not holistic, but feature-based (Harley, 2007).

participants produce responses by starting off from the node in the network that is the subject in the sentence (here "dog", if the sentence is "a dog is an animal"), and travelling through the network until they find the necessary information. The closer the concept is to the node, the faster the reponse latencies. Hence the sentence "a dog is an animal" should entail faster responses than the sentence "a dog is a living being". However, this model fails to explain some divergent findings (e.g., slower latencies for sentences involving subordinates, such as "a dog is a *mammal*" compared to superordinates, "a dog is an *animal*") and to conceptualize how more abstract concepts could be represented (for a review see Harley, 2007). These theoretical limitations brought about network models where the structure is no longer primarily hierarchical: nodes are linked as many times as relations found between their underlying concepts. Hence, any single concept can be defined in terms of its links to other concepts. Within such connectionist models, a semantic representation does not correspond to a particular semantic unit, but to a pattern of activation across semantic units or features, which have no symbolic meaning by themselves (Harley, 2007). Access and priming in the network occur through a mechanism of spreading activation, i.e., information is processed through activation, beginning at a given point of the network and spreading to adjacent nodes following a decreasing energy gradient (Collins & Loftus, 1975; Anderson & Pirolli, 1984)

Overall, these theoretical frameworks suggest that impairment in word production might arise from lesions at different sites of the speech architecture – e.g., degradation of semantic storage, semantic network anomalies and/or access to the following, phonological, stage. Typically, from the perspective of cognitive neuropsychology, lexico-semantic storage and access disorders can be distinguished through naming tasks and priming effects – e.g., semantic storage deficits are related to consistent errors across naming trials (Rossell, 2006). In verbal fluency tasks, however, subjects do not have to name a specific picture, but instead they are instructed to retrieve a number of words from semantic memory in a restricted or unrestricted fashion – thus requiring some kind of cognitive control. Moreover, cognitive demands differ according to the type of constraint required by the task: in the case of letter fluency, search strategies have to be generated based primarily on lexical representations, whereas in tests of semantic fluency, semantic extensions of a target superordinate (for instance, names of different animals) have to be searched, and thus depend intrinsically upon the integrity of semantic associations within the lexicon (Rohrer et al. 1999). Consistently, neuropsychological findings in patient populations suggest that, unlike the semantic task, which relies on a more familiar meaning-based search strategy, the letter fluency task prompts a less familiar 'word representation' search strategy through the lexicon; hence it relies more on executive functions (see section 1.4.3.2 c) (Ho et al., 2002). In this sense, given the multifaceted nature of verbal fluency tasks, the amount of words produced during the task is probably not sufficient to distinguish between semantic storage (Rossell & David, 2006), network idiosyncrasies (for example, related to activation/inihibition within the semantic network; e.g., Neely, 1977), and controlled retrieval deficits (Henry & Crawford, 2005). Several research strategies have been devised to investigate the different processes involved in fluency tasks. To take into account the storage issue, some studies using verbal fluency tasks also controlled for vocabulary size via, for example, cognitive tests which assess how subjects define words (e.g., Ross et al., 2007). Others focused on the organization and activation of concepts in semantic memory, and considered both the number of words in fluency tasks, but also the dynamics (e.g., Mayr, 2002) and/or the semantic organization of word output (Troyer et al., 1997; Sung et al., 2013). Indeed, when asked to freely generate words, healthy participants tend to produce clusters of successive semantically or phonemically related words (e.g., Wixted & Rohrer, 1994). Such spontaneous grouping of words has been attributed to the fact that, in structured semantic networks, the activation of a given word may automatically activate or prime a local network of related associates through spreading activation (Wixted & Rohrer, 1994; Anderson & Pirolli, 1984). There are at least two ways of addressing the semantic contribution to performance in verbal fluency tasks. The first is to control for the influence of baseline lexico-semantic skills, and the second is to investigate how words are clustered together in such tasks, either through their temporal dynamics or their semantic similarity. We will further address the latter point in section 1.4.2.3.d .

1.4.3.2b Executive functioning

Executive functions are intrinsic to the ability to respond in an adaptive manner to novel situations, and usually encompass a set of functions that regulate one's thoughts and direct behavior toward a general goal (Lezak et al., 2004). In this sense, *executive* in 'executive functions' refers to the fact that an overarching entity is thought to control and coordinate performance of complex non-routine cognitive tasks (Shallice, 1982). Among the first to elaborate on this matter, Luria (1976) conceptualized a system specialized in the programming, regulation and evaluation of non-routine activities that was particularly affected by frontal lobe damage. Other early studies distinguished between automatic and controlled processes (e.g., Shiffrin & Schneider, 1977); the latter being closely related to attention monitoring. It was Norman and Shallice (1980 *in* Shallice & Burgess, 1996) that first proposed a cognitive framework whereby a specified cognitive module, the Supervisory Attentional System (SAS)[23], was designated to override automatic responses in favour of scheduling behaviour on the basis of plans or intentions. According to the model developed by Norman & Shallice (1980 in Shallice & Burgess, 1996), routine thought or action schema are processed by a contention scheduling module; they are automatic and fast (e.g. drinking from a cup). By contrast, in novel situations, the SAS is responsible for the selection and

[23] Baddeley & Hitch (1974) proposed a conceptually similar module, the central executive, within their working memory model.

short-term storage of relevant schema to the task at hand and the inhibition of irrelevant ones; thus processing is flexible and slow (Shallice, 1982). In later studies, the model was refined, and the executive processes subtended by the SAS were further delineated – namely, the generation of solutions, their implementation, which encompasses holding relevant schema available in working memory, and the monitoring of performance (Shallice & Burgess, 1996).

The contribution of executive functions to verbal fluency performance has been long recognized in the neuropsychological literature (see section 1.4.3.2c). Indeed, in such tasks, subjects have to generate a search strategy, temporarily store both the instruction and the words already pronounced, inhibit repetitions, and flexibly change search strategies when adequate. Thus, impairment in at least one of these executive processes might result in reduced verbal output and/or increased errors, such as perseverations or intrusions (Ho et al., 2002). Another approach to understanding speech generation in verbal fluency tasks implies that automatic word production processes are intrinsically related to executive functions. In other words, this view suggests that each cognitive level involved in word production – conceptual and lexical -- requires a 'control module' comprising four functions: initiate, operate, check, and terminate (Butterworth, 1992). At the conceptual level, 'initiate' would thus involve response generation and 'terminate' may be crucial to prevent errors or idiosyncratic associations from arising that result in rhyming or tangential disinhibited speech (Robinson & Ceslis, 2014). Consistent with the assumption that verbal fluency tasks are multi-faceted, Moscovitch (1994) suggested that executive processes regulating semantic retrieval (i.e., 'working-with-memory') are located in frontal regions, whereas the actual access to semantic representation is dependent of temporal brain regions. We will further review the neuropsychological evidence to this claim in the next section.

1.4.3.2c Neuropsychological findings

There is a wide range of data in healthy controls and patients with neurological conditions indicating that verbal skills and executive functions are differentially involved in the number of words produced in verbal fluency tests (e.g., Borkowski et al., 1967; Crawford et al., 1992; Ross et al., 2007; Shao, Janse, Visser, & Meyer, 2014). For instance, in a princeps study in healthy and brain-damaged individuals, Borkowski et al. (1967) assessed the associative value of each letter of the alphabet, except X and Z, via the number of total words produced starting with each letter, in one-minute time. The authors found that controls with low VIQ, measured via vocabulary and verbal reasoning tests, produced fewer words than brain-damaged individuals with high verbal premorbid skills. More recently, Sauzéon et al. (2011) reported that older healthy adults with larger vocabulary sizes also produced more words in verbal fluency tests than those with smaller vocabulary sizes. Hence, as suggested in section 1.4.2.3a, vocabulary size may play a role in verbal fluence performance.

In patients with neurological conditions, while deficits in the overall verbal output have been reported in a number of different illnesses, the contribution of lexico-semantic processes and executive function seems to vary according to the type and location of brain damage. For instance, in patients with Alzheimer's disease, deficits in the letter condition of the verbal fluency test have been attributed to decrement in verbal IQ, whereas in patients with focal frontal lobe lesions they seem to rely on executive dysfunction, indicating that reduced verbal output in verbal fluency tests may arise from different types of cognitive impairments and damage to specific brain regions – here, the temporal lobes in Alzheimer's disease and frontal lobes in brain-damaged individuals (Miller, 1984; Henry & Crawford, 2004).

Moreover, the type of search criterion required by the task – e.g., letter or semantic – seems to tap distinct cognitive and neural mechanisms. In a meta-analytic review that included 31 studies, Henry & Crawford (2004) investigated the relative magnitude of cognitive deficits on tests of letter and semantic fluency for patients with temporal and prefrontal cortical lesions. The pattern of results suggested that the two types of fluency imposed comparable demands upon executive processes -- that is, letter and semantic fluency performance were equally impaired in patients with frontal and temporal lesions. However, semantic fluency was relatively more dependent upon the integrity of semantic memory – i.e., performance was relatively more impaired in patients with temporal lesions. These effects were not explained by VIQ nor psychomotor speed.

To summarize, cognitive neuropsychological findings suggest that verbal fluency performance is multi-faceted, involving at least two cognitive processes – i.e., semantic memory and executive functioning. Moreover, while executive function seems to play a role in category and letter conditions, semantic memory seems relatively more involved in semantic fluency performance. These results thus point to two directions: first, in order to gain a better understanding of the nature of verbal output, it is important to address both cognitive processes; second, studies should use different conditions of verbal fluency tasks, since they impose different demands upon executive functions and semantic memory. Here we focused on semantic and letter conditions because they have been abundantly studied in the literature. It is noteworthy that other task conditions exist and seemingly rely on specific neural and cognitive mechanisms. Such is the case for instance for verb generation (e.g., Thompson-Schill et al., 1998), and rhyme fluency (Nagels et al., 2012). In a more unrestrictive fashion, recent studies have used free word production (e.g., Kircher et al., 2008; Tremblay et al., 2010), and associational fluency (Levine et al., 1996; Benedek, Könen, & Neubauer, 2012), but also emotion fluency, whereby subjects are instructed to produce words associated with an emotional word cue, such as 'joy' and 'fear' (e.g., Gawda et al., 2017). We will quickly review in the next section the theoretical underpinnings of methods addressing the lexico-semantic and executive components of verbal fluency performance.

1.4.2.3.d Addressing the hybrid nature of verbal fluency tasks

Although fluency performance is traditionally measured by the number of words generated, there have been attempts to characterize other aspects of the data, such as the temporal structure and the meaning of individual responses (Troyer et al., 1997; Raskin, Sliwinski, & Borod, 1992). Most of these attempts rely on the fact that word production in verbal fluency tasks is unevenly distributed over time, that is, they are produced in temporal clusters containing words that are semantically and/or phonologically related and, during each pause, the participant is engaged in a search process to access appropriate words from lexico-semantic store (e.g., Gruenewald & Lockhead, 1980). Moreover, the rate of words retrieved in the beginning and by the end of task vary, suggesting that distinct cognitive mechanisms are involved at different moments of the task (e.g., Woods et al., 2016). To our knowledge, there are three types of methods for decomposing fluency performance into cognitive processes: (i) qualitative, (ii) chronometric, and (iii) automated or statistical methods.

Qualitative methods evolved based on findings relative to the dynamics of word retrieval in fluency and semantic memory tasks. Indeed, it has been long known that semantically related words occur together as part of a burst of responding in recall protocols (Wixted & Rohrer, 1994). Bursts of recall or 'clusters' are thought to reflect the dynamics of lexical entries within the semantic network, as one node is activated during retrieval, other related nodes will be accessed through a spread of activation. It was Raskin et al. (1992) that first proposed a structured framework for assessing clusters of sequentially related words in semantic and letter fluency tests. Within their framework, both the number of words and clusters were taken into account. Given that the absolute amount of clusters was intrinsically related to the number of words produced, the authors calculated a cluster ratio, which consisted of the number of clusters divided by the number of words in each condition. Two types of clusters were distinguished: task-consistent clusters and task-discrepant clusters. Task-consistent clusters refer to words semantically related in semantic fluency and phonemically related in letter fluency. By contrast, task-discrepant clusters acknowledge that words can be phonemically related in semantic fluency and vice-versa. Semantic and phonemic relatedness were defined as successive words sharing semantic (i.e., semantic subcategories such as 'domestic animals' within the category 'animals') and/or phonemic (i.e., first two phonemes or words that rhyme) features. Raskin et al. (1992) reported good inter-rater reliability with their qualitative scoring criteria (range from .80 to .95 for the four types of cluster). As expected, the authors found that task-consistent clustering was more common that task-discrepant clustering. Some years later, Troyer et al. (1997) further refined the scoring criteria in both semantic and letter fluency conditions, and suggested that two strategic processes were involved in verbal fluency performance – i.e., clustering and switching. The authors discarded however the distinction between task-consistent and task-discrepant clustering, arguing that task-discrepant clusters were infrequent. In addition, unlike Raskin et al. (1992), the score of interest in Troyer et al.'s (1997) procedure was cluster size, i.e., the number of words within a cluster beginning with the second word (or n – 1) – for example, in the sequence '**lion tiger monkey** *dog*', there are two semantic clusters: one cluster of size two, and one cluster of size zero, hence the mean cluster size is one in this subject's production. To account for the search strategies involved in verbal output, Troyer et al. (1997) operationalized 'switching' as the ability to shift from one cluster, including single words or clusters of size zero, to another; in the example provided above, there is thus one switch. Troyer et al. (1997) suggested that temporal-lobe mediated processes such as semantic memory are represented in mean cluster size scores, whereas frontal-lobe-mediated processes such as cognitive flexibility and inhibition are reflected in switch scores. There is some support for this position, as patients with Alzheimer's disease demonstrate poor clustering performance relative to switching, whereas the reverse pattern has been observed in patients with Parkinson's disease and Huntington's disease (e.g., Tröster et al., 1998; Ho et al., 2002). According to Troyer et al.'s (1997) account, damage to the temporal lobes thus may impair access to lexical information due to reduced automatic spread of activation, degradation of semantic storage, or a combination of the two. On the other hand, impaired switching in patients with frontal and/or subcortical damage might be due to executive dysfunction. More recently, Abwender et al. (2001), but also Mayr (2002), criticized both measures put forward by Troyer et al. (1997), arguing that (i) cluster sizes of zero and multiple word cluster sizes could actually refer to different processes, (ii) 'switching', as defined by Troyer et al. (1997), was highly correlated to the number of clusters, and (iii) task-discrepant clustering was relatively frequent. To account for these limits, recent studies (Ledoux et al., 2014; Helmes & Hall, 2016) have developed combined scoring procedures, including task-discrepant clustering, cluster ratio, and the exclusion of cluster sizes of zero. These procedures yielded more psychometrically sound results than the scoring procedure provided by Troyer et al. (1997) (Ledoux et al., 2014; Helmes & Hall, 2016). For instance, Ledoux et al. (2014) found that the number of task-consistent clusters obtained through their scoring criteria was similar to those of Troyer et al. (1997). Moreover, the application of computational and temporal analyses of the verbal output further validated the approach. Latent semantic analysis (LSA; Landauer, Foltz, & Laham, 1998) is a computational tool that permits the automatic quantification of the semantic relatedness of words and clusters of words in a high-dimensional semantic space. In this semantic space, individual words are represented as vectors and the cosine between word vectors provides an objective measure of the semantic similarity or coherence between words (a more detailed description of LSA is provided below; e.g., Pakhomov et al., 2016). This method allowed Ledoux et al. (2014) to show that, in letter and semantic fluency, semantic similarity was higher and inter-word timing was shorter within clusters than within non-clustered words, hence providing additional validity to this combined scoring system. It is noteworthy that such was not the case for phonological clusters. The authors suggested the primacy and automaticity of semantic processing in the lexicon, whereas phonological processing supposedly involves the inhibition of semantically-related concepts in favor of an alphabetic retrieval. This might explain why healthy subjects usually produce more words in the semantic fluency compared to the letter fluency test (Ross et al., 2007; Ledoux et al., 2014). What the study of Ledoux et al. (2014) also shows is that, aside qualitative methods, other approaches can be used to address the cognitive mechanisms involved in verbal fluency performance.

It is also possible to explore word output by evaluating its temporal structure. Most studies have focused on two types of data in verbal fluency tasks: interword intervals and the dynamics of retrieval during the task. As outline above, the bursts of responses over the time-course of verbal fluency and memory tasks (e.g., Gruenewald & Lockhead, 1980) led to the operationalization of clusters and switches (Raskin et al., 1992; Troyer et al., 1997), consistent with findings suggesting that interword latencies are shorter within such bursts or cluster of words, compared to non-clustered words. These approaches appear to be useful for clinical purposes as well. Rorher et al. (1995) found reduced number of words and shorter interword intervals in semantic fluency (but not letter fluency) in patients with Alzheimer's disease compared to controls, which was due, according to the authors, to a degradation of the semantic store. The theory behind this interpretation is that degradation of semantic store leads to smaller and less competitive pool of information, hence to less conflict and faster retrieval. By contrast, poor controlled retrieval, as measured in the same article via dual task compared to single verbal fluency test performance in healthy individuals, resulted in longer interword intervals. These data thus suggest that shorter and longer interword latencies in semantic fluency are due to different cognitive mechanisms: respectively, degradation of semantic memory and executive dysfunction. Another branch of research consists of investigating the temporal dynamics of words produced during the task. With focus on individual word production over the allotted time, studies have found that verbal performance usually follows an exponential decline as a function of time: the amount of words produced is highest during the initial stages of the task (for example, the first 15 or 30 seconds), and as time increases, production decreases (e.g., Crowe, 1998). Interestingly, using factor analysis, Fernaeus and Almkvist (1998) found that two main factors seemed to underlie the production decline in letter fluency: the first factor loaded on the initial intervals and was associated with rapid semi-automatic word retrieval, whereas the second loaded on the later intervals and was interpreted as reflecting effortful word retrieval.

Lastly, in recent years, computational tools based on specific theories of how knowledge is acquired and stored in semantic memory have been applied to the analysis of verbal fluency performance. Among them, LSA posits that meaning is acquired through its use in context, and that two words are semantically related in a specific semantic space (e.g. *Le Monde* newspapers of the whole year) to the degree that they appear in the same documents (e.g. chapters, paragraphs or sentences) within that chosen semantic space (Landauer et al., 1998). In this context, the meaning of a word in a given semantic space is represented by a high dimensional vector where each entry corresponds to the number of times the given word appears in each document. The semantic similarity between two words is calculated as the cosine of the angle between their respective vectors. Hence semantically related words will have a semantic similarity close to 1; and unrelated words, close to 0. In most cases, the dimension of the vectors is reduced using a method similar to factor analysis (i.e., singular value decomposition), both for facilitating the computational aspect and for filtering misrepresented or irrelevant words (Pakhomov et al., 2016). Thus, LSA can provide an objective measure, based on relatedness within the semantic space, of what is usually described as an inaccessible phenomenon (i.e., the content and organization of thoughts) (Holshausen et al., 2014). Since verbal output in verbal fluency tasks usually occurs in bursts or clusters, studies using LSA have increasingly attempted at designing clusters based on semantic relatedness (e.g., Ledoux et al., 2014; Nicodemus et al., 2014).

In sum, there are different approaches — qualitative, temporal and automated — to tackle the cognitive processes involved in verbal fluency performance, and ultimately gain a better understanding of how, in these tasks, thoughts are tied together over time. We will present in the next section results in patients with bipolar disorder, then, in article 5, how we assessed verbal fluency performance in our work.

1.4.3.2e Findings in bipolar disorder

As outlined in previous sections, verbal fluency paradigms have been used in patients with bipolar disorder since at least the nineteenth century. In his historical review of the concept of flight of ideas, Binswanger (1933/2000) pointed to the considerable contribution of these early experiments to the description and understanding of flight of ideas of the time. For instance, Aschaffenburg (cited in Binswanger, 1933/2000) developed the theory that increased 'psychic movement' or 'pressure of speech' was the main psychopathological mechanism involved in flight of ideas, since he did not find an acceleration of speech (i.e., diminished inter-word latencies) in associational fluency tasks. The same author also reported increased sound-based associations in manic patients, which led him to suggest that flight of ideas could be defined as "first and foremost a disorder of conceptual thought" (Binswanger, p. 15, 1933/2000). Since we could not find the original text, it is unclear however how Aschaffenburg measured sound-based associations and inter-word intervals, as well as the exact characteristics of his sample of patients. The same applies to other studies of the same period, but given their clinical relevance to the phenomenon studied here, and also for the sake of exhaustivity, in table 3, we present the results from these early studies compiled by Kraepelin (1899/2008) and Binswanger (1933/2000). Subsequent studies found that manic patients produced greater number of words in associational fluency tasks than controls (Giehm, 1933; Levine et al., 1996), akin to highly creative healthy individuals (Benedek et al., 2012). Consistent with the idea that mania enhances verbal fluency, two later studies found that associational fluency increased after patients with bipolar disorder discontinued lithium (Kocsis et al., 1993; Shaw et al., 1986).

Table 3: Results from studies using associational fluency tasks in mania (Krapelin, 1899; Binswanger,1933)

	Speech rate	Distractibility	Repetition cue word	Word length	Clanging
Aschaffenburg	Slowing	/	/	/	++
Isserlin	Acceleration	++	++	1s*	++
Franz	Slowing	/	/	/	/
Kilian & Gutmann	/	/	++	/	/

Legend: *Word duration in healthy subjects was estimated by Isserlin to range between 1.2-1.4 seconds

While early studies focused mostly on associational fluency as a measure of cognitive functioning, creativity, and thinking style in manic patients, more recent studies have favored the use of semantic and letter fluency tasks. This is probably due to the fact that, instead of aiming to characterize a psychopathological phenomenon such as racing thoughts, these studies aimed at addressing trait-like cognitive dysfunction in patients with bipolar disorder and its relation to functional impairment and/or potential neural substrates. Since letter and semantic fluency have been the most studied verbal fluency tests in the neuropsychological literature, those were the tasks of choice to this aim. Relatedly, because the aim was to characterize cognitive impairment in patients with bipolar disorder, the vast majority of these studies investigated verbal fluency performance in euthymic individuals and, most importantly, they only took the overall number of words produced into account. To illustrate this point, Raucher-Chéné et al. (2017) recently conducted a systematic review and meta-analysis of studies using semantic and letter fluency tests in patients with bipolar disorder. Strikingly, most studies included were conducted in euthymic patients (in their meta-analysis, 30 out of 39 studies), and only one study (Basso et al., 2002) included a group of patients in a mixed episode. Similar to most studies reviewed in their meta-analysis, this study did not focus specifically on verbal fluency but on cognitive tests as a whole, and only the number of words in the letter condition was analyzed (Basso et al., 2002).

Despite the little amount of data in patients with acute episodes, the authors reported some valuable results. First, the number of words in letter and semantic fluency was equally reduced in patients with bipolar disorder compared to controls, with medium effect sizes. Second, verbal fluency performance was not correlated to IQ, illness duration and number of previous episodes, but it was negatively correlated to mean education level. Third, impairment was greater in semantic relative to letter fluency tasks in euthymic patients compared to manic ones. Given that this was only observed in the semantic fluency task, the authors argued that semantic memory dysfunction – i.e., storage and/or functional organization – could explain these results (Raucher-Chéné et al., 2017). More specifically, akin to formal thought disorder in schizophrenia (e.g., Kerns et al., 1999), they speculated that the relative "manic advantage" in the semantic fluency task was related to an over-activation of the semantic network (i.e., faster spreading of activation), which supposedly underlie thought and language disturbances in mania, and compensate for trait-like semantic anomalies in bipolar disorder (Raucher-Chéné et al., 2017). To support this interpretation, the authors cited the two studies which investigated verbal fluency performance through process-oriented approaches – i.e., automated analysis similar to LSA and hierarchical cluster analysis (respectively, Sung et al., 2013 and Chang et al., 2011). In these studies, results suggested less knowledge-based categories (Chang et al., 2011) and less coherent clusters while the number of words in the semantic task did not differ in euthymic patients relative to controls (Sung et al., 2013). Given that the overall number of words produced was unimpaired in the latter study, the authors suggested that idiosyncratic clustering in semantic fluency was linked to functional aspects of the semantic system (i.e., spreading activation) rather than to any degradation of semantic knowledge (Sung et al., 2013). However, this interpretation is somewhat inconsistent with other findings suggesting that semantic fluency is relatively impaired in euthymic patients (e.g., Raucher-Chéné et al., 2017), on the one hand, and with functional neuroimaging findings suggesting that prefrontal lobes hypoactivity is involved in performance in fluency tasks in euthymic patients, on the other hand (Allin et al., 2010). Given the very small amount of data obtained through process-oriented approaches – either qualitative, temporal or automated --, additional studies are needed to clarify whether and how lexico-semantic and executive processes are involved in verbal fluency performance in patients with bipolar disorder. Moreover, the relationship between clinical symptoms, such as racing thoughts and rumination, and verbal performance has not been directly assessed in any of these studies, although they have been suggested to be related to performance in both depressed (e.g., Fossati et al., 2003) and manic patients (e.g., Raucher-Chéné et al., 2017).

2 Articles

We present in this section the studies we conducted in healthy individuals and patients with bipolar disorder in order to investigate the psychopathological and cognitive underpinnings of racing and crowded thoughts.

In **study 1 and 2**, we investigated racing and crowded thoughts, via the RCTQ, in healthy subjects and patients with bipolar disorder. In **study 3**, we focused on the extrinsic and intrinsic contextual factors that could influence time perception in healthy subjects, including racing and crowded thoughts (article 3 Appendix). In **study 4**, we investigated time perception in patients with bipolar disorder (short report). Lastly, **in study 5**, we addressed the linguistic anomalies found in mood episodes of bipolar disorder via a qualitative process-oriented approach. Analyses with other process-oriented approaches are ongoing (Article 5 Appendix).

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Measuring racing thoughts in healthy individuals: The Racing and Crowded Thoughts Questionnaire (RCTQ)

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ABSTRACT

Racing thoughts refer to an acceleration and overproduction of thoughts, which have been associated with manic and mixed episodes. Phenomenology distinguishes 'crowded' from 'racing' thoughts, associated with mixed depression and mania, respectively. Recent data suggest such thoughts might also be present in healthy individuals with sub-affective traits and symptoms. We investigated this assumption, with a 34-item self-rating scale, the Racing and Crowded Thoughts Questionnaire (RCTQ), and evaluated its reliability, factor structure, and concurrent validity. 197 healthy individuals completed the RCTQ, the Temperament Evaluation of Memphis, Pisa, Paris, and San Diego – autoquestionnaire (TEMPS-A), the Beck Depression Inventory (BDI), the Altman Self-Rating Mania scale (ASRM), and the Ruminative Response Scale (RRS). Exploratory factor analysis yielded a three-factor solution, labeled 'thought overactivation', 'burden of thought overactivation', and 'thought overexcitability'. Internal consistency of each of the three subscales of the RCTQ was excellent. The TEMPS-A cyclothymia score was associated with the three factors, suggesting good concurrent validity. Each factor was selectively associated with low and/or elated mood symptoms. In contrast, rumination was not a significant predictor of RCTQ subscores. These results suggest that racing and crowded thoughts, as measured by the RCTQ, are particularly associated with mood instability even in its milder forms.

Keywords: racing thoughts; crowded thoughts; affective temperament; cyclothymia; thought overactivation; distractibility

1. Introduction

Racing thoughts refer to a subjective acceleration and overproduction of thoughts. They are mainly associated with manic/hypomanic episodes in bipolar disorder (BD) and also belong to the "with mixed features" specifier criteria of major depression [1]. On a phenomenological level, recent models have conceptualized racing thoughts as related to depressive and manic mood [2], and also to creativity [3]. However, these models only concern individuals with full-blown mood disorders, and do not take into account the broad kraepelinian notion of mood disorders including subclinical temperamental forms [4]. Yet cyclothymic and hyperthymic traits have been widely described in healthy populations, e.g., [5, 6], suggesting that mood, and possibly thought activity, might be conceptualized as a continuum. In addition, Dodd et al. [7] reported that the 'cognitive and behavioral activation' subscore of the Internal States Scale (ISS) [8], which measures experience of racing thoughts and elevated energy [7], was particularly associated with dysfunctional hypomanic attitudes in a sample of healthy students. It seems thus plausible that healthy individuals experience racing thoughts.

To the best of our knowledge, racing thoughts have not been described in healthy volunteers, and only two studies have investigated racing thoughts in patients with mood disorders [9, 10]. In both studies, racing thoughts, as measured by the Subjective Thought Overactivation Questionnaire (STOQ) [9], were significantly increased in patients with mood disorders compared to healthy controls. The broad term 'thought overactivation' refers to the fact that racing thoughts were conceptualized differently from the unitary definition found in the Diagnostic and Statistical Manual of mental disorders – 5th edition (DSM – 5) [1].

Indeed, although in the DSM-5 thought overactivation is solely described by the unitary term 'racing thoughts' [1], at least two types of racing thoughts have been identified in phenomenological studies in patients with mood disorders, i.e., 'crowded' and 'racing', associated with low and elated mood, respectively [2, 11]. Moreover, the phenomenology of crowded and racing thoughts seems to differ: crowded thoughts are usually associated with a very unpleasant and tense feeling related to thoughts of all kind accumulating in one's mind [2, 11, 12]. In contrast, racing thoughts are characterized by a rapid flow of thoughts usually associated with positive emotions, that may be accompanied by increased creativity and productivity [3, 13].

To our knowledge, only one qualitative study [9] investigated the phenomenology of thought overactivation in patients with mood disorders. Thirty-four categories that were clustered in six main themes emerged from the reports of 45 patients, such as those related to the pressure of thoughts, which included racing and crowded thoughts, the consequences of thought overactivation (e.g. "I find it difficult to express myself because of the amount or the speed of my thoughts"), and how thoughts involuntarily arise in one's mind. These results suggested that numerous mechanisms may be at stake in the overall concept of thought overactivation. In the same study, based on the expertise of clinicians, the authors subsequently developed a self-report questionnaire composed of 16 items that included racing, crowded, and ruminative thoughts [9]. This scale was applied to 82 patients presenting with a mood episode, and 38 healthy controls. A principal component analysis of the initial 16-item scale indicated that a single component explained 55.9% of the variance, with major and exclusive contributions from 9 items. Rumination items were not part of this component. The final 9-item self-rating scale was called Subjective Thought Overactivation Questionnaire (STOQ) [9]. Scores correlated with both activation and depression indices of the ISS [8] in patients with mood disorders, suggesting that they assessed a thought pattern associated with both depressive and manic mood. However, this scale did not address the numerous facets found in the qualitative analysis of patient reports. Thus, in order to determine whether or not thought overactivation is a multi-faceted concept, as qualitative and phenomenological data suggest [2, 9], it is necessary to develop new scales allowing a fine-grained analysis of the phenomenology of thought overactivation in patients with mood disorders, but also, from the perspective of a continuum spanning from mood disorders to subclinical temperament traits, in healthy individuals.

In healthy volunteers, data regarding the phenomenology of thought overactivation are still lacking. It is thus unknown whether racing and crowded thoughts are found in healthy individuals, and how they relate to mild mood variations.

An interesting issue is the comparison of thought overactivation and rumination. Rumination could be easily confused with racing or crowded thoughts, inasmuch as it has been defined as a repetitive, and analytical pattern of thinking associated with the onset and the maintenance of depression [14]. According to the Response Styles Theory (RST) [15], rumination includes both self-reflection, considered to be an adaptive form of rumination, and brooding, i.e., a repetitive focus on one's negative emotions, considered to be maladaptive [16]. Brooding and crowded thoughts are therefore both accompanied by low mood. Yet the two types of thought pattern also differ, since rumination, unlike crowded thoughts, is repetitive in nature and is associated with a decreased amount of thoughts [3, 17]

Whereas there is a large amount of evidence suggesting that rumination is a trait of unipolar depression, e.g., [18], data on rumination in euthymic individuals with BD and in healthy populations with sub-affective presentations are scarce [19]. However, unlike racing thoughts, there is a wide-array of validated questionnaires enabling the assessment of rumination in healthy individuals, e.g., [16]. In at-risk populations, Pavlickova et al. [20] found increased levels of rumination in offspring of bipolar parents compared to offspring of healthy controls, but they did not control for the presence of racing and crowded thoughts.

The aim of the present study is to evaluate the factor structure, validity and reliability, in a sample of healthy subjects, of a new 34-item self-report questionnaire – the Racing and Crowded Thoughts Questionnaire (RCTQ). To evaluate its concurrent validity in healthy individuals, measures evaluating affective temperaments and current mood were administered in addition to the RCTQ. If the RCTQ is able to capture a phenomenon specifically associated with mood instability, then we should find significant correlations between the RCTQ and measures of cyclothymia, as well as current elated and low mood. Moreover, racing and crowded thoughts, measured with the RCTQ, were expected to be distinct and independent from rumination.

2. Methods

2.1 Participants

For this cross-sectional study, 215 individuals were recruited among the staff and students of the University Hospital of Strasbourg. Eighteen participants were excluded because they had a personal history of psychiatric or neurological disorders or were taking psychotropic medication. The study sample thus included 197 healthy individuals aged 19 – 56 (M = 26, SD = 7.3). Women constituted 65% of the sample. Participants had on average 16.3 years of education (cf. table 1 for detailed demographic information). The majority of participants were university students, mostly in psychology and medical schools (74.1%). This study was part of a larger protocol involving time perception; results obtained on the time perception tasks were published elsewhere [21]. Participants provided written informed consent prior to inclusion in the study, in accordance with the Declaration of Helsinki.

2.2 Materials and procedures

Participants filled-out five self-report questionnaires assessing mood and thought patterns. Questionnaires were administered in a fixed order. All measures were completed in a quiet room as part of a wider testing session.

2.2.1 *Racing and Crowded Thoughts Questionnaire (RCTQ) scale development*

The RCTQ is a 34-item self-report questionnaire that assesses thought overactivity during the past 24 hours (Figure 1). Nine items of the RCTQ belong to the STOQ [9], of which 4 underwent very minor wording adaptations, whereas the remaining 25 items were developed by three experienced clinicians (GB, IK and LW) based on the six themes that emerged in the qualitative reports of patients with mood disorders in the study of Keizer et al. [9], i.e., (i) pressure of thoughts, (ii) articulation of thoughts, (iii) information processing load, (iv) onset and context of thought overactivation, (v) effects of thought overactivation, (vi) interface thought activation-emotion. If some items were clearly related to the phenomenology of racing thoughts or crowded thoughts, others were more related to the consequences of thought overactivation and less exclusively linked to the racing versus crowded distinction (e.g., 'My mental overactivity is exhausting'). Items that refer to racing thoughts convey the notion of an acceleration and an increased amount of thoughts that are linked to each other in a sequential manner (e.g., my thoughts race at 200 km/hour); clinically these thoughts are usually associated with positive emotions, and are not perceived as being emotionally overwhelming. In contrast, items that refer to crowded thoughts are related to an increased amount of thoughts that are linked to each other in a simultaneous manner, as if thoughts were accumulating in one's mind (e.g., thoughts accumulate in my head); these thoughts are usually associated with an increased information processing load, and the feeling of being emotionally overwhelmed. Both racing and crowded thoughts items portray thoughts as arising in one's mind involuntarily (e.g., my thoughts take off on their own). Items are rated on a scale from 0 ("not at all") to 4 ("completely agree").

Figure 1: The 34-items of the RCTQ

2.2.2 *Other measures*

The brief Temperament Evaluation of Memphis, Pisa, Paris, and San Diego – autoquestionnaire (TEMPS-A)[22] is a self-report, 39-item, yes-or-no type questionnaire designed to assess affective temperaments in psychiatric patients and in healthy subjects, e.g., [23, 24, 25]. The TEMPS-A was conceptualized based on the Kraepelinian notion of a broad manic-depression syndrome extending from subclinical temperamental manifestations to type I BD [22]. Five affective temperaments are assessed via five subscales: (i) items 1 to 12 assess cyclothymic temperament, (ii) items 13 to 20 assess depressive temperament, (iii) items 21 to 28 assess irritable temperament, (iv) items 29 to 36 assess hyperthymic temperament, and (v) items 37 to 39 assess anxious temperament. This scale has been validated in French [26].

The Beck Depression Inventory short-form (BDI-sf) [27] is a 13-item self-report scale that measures the severity of depressive symptoms during the past two weeks. Items are rated on a scale ranging from 0 (the symptom is absent) to 3 (maximum severity). This scale has been widely used in individuals with clinical depression [28], and in non-clinical healthy populations, e.g., [29, 16].

The Altman Self-Rating Mania scale (ASRM) [30] is a short 5-item self-report scale that measures the presence and the severity of manic symptoms during the past 7 days in subjects with BD [30], but also in healthy subjects [31]. Items are rated on a scale ranging from 0 (the symptom is absent) to 4 (maximum severity).

The Ruminative Response Scale State version (RRS-S) [16, 32, 33 for the state-version] is a 22-item self-report questionnaire which evaluates two aspects of rumination during the past 7 days, including the past 24 hours: ‘Brooding’ (5 items) taps passive rumination on negative mood and is considered to be maladaptive whereas ‘reflection’ (5 items) refers to active efforts to understand one’s negative feelings, and is considered to be adaptive. In their psychometric analysis of the reflection and brooding subscales, Treynor et al. [16] found that internal consistency was acceptable (Cronbach's alpha .72 and .77, respectively). A total score is also obtained *via* the sum of the 22 items. Items are rated on a scale from 1 (“almost never”) to 4 (“almost always”).

2.3 Statistical analyses

Descriptive statistics included frequencies and percentages for categorical variables, and means and standard deviations for continuous variables.

To investigate the underlying factor structure of the RCTQ, a principal components analysis with oblimin rotation was conducted. The goal of oblimin rotation is to simplify and clarify the data structure, when factors are correlated [34]. The number of retained factors was determined on the basis of the eigenvalue greater-than-one guideline and through visual inspection of the scree plot [35]. Only non-overlapping items with loadings of at least .50 were considered to be part of a given factor [34]. Items were considered as non-overlapping, when the loading difference between factors was at least .20 [34]. Internal consistency of each identified factor (i.e., to what extent items belonging to that factor are inter-correlated) was assessed with the Cronbach's alpha coefficient [36]. A coefficient of at least 0.7 was expected. To assess concurrent validity, associations between RCTQ factors, the five TEMPS-A subscales, the BDI-sf and the ASRM were investigated by computing Pearson’s correlation coefficients, with Bonferroni correction for multiple tests. Divergent validity was assessed by computing Pearson's correlation coefficients between the RCTQ scores and the two subscales of the RRS. In addition, multiple regression analysis was performed in order to partial out the effects of the different clinical dimensions (TEMPS-A subscales, BDI-sf, ASRM and RRS subscales) on the RCTQ scores. Statistical significance was set at 0.05 (two-sided tests). Analyses were performed using the Stata 14.1 software.

3. Results

3.1 Descriptive analyses

Mean scores, floor and ceiling percentage values for each of the 34 items of the RCTQ are presented in table 1. The distribution of scores on all of the 34 items of the RCTQ ranged from 0 to 4. As expected, ceiling values were seldom found in healthy subjects. With regards to the other questionnaires, the ASRM (manic symptoms) mean was 4.0 (SD = 3.5), which corresponds to scores reported in other non-clinical populations (M = 4.8; SD = 3.7) [31]. Fifty-eight individuals (29%) had scores above the cut-off of 6 [30]. Similarly, the BDI-sf mean was 3.3 (SD = 3.4), which is similar to scores reported in healthy populations (M = 4.4; SD = 4.1) [16]. Twenty-two subjects (12%) had scores above the cut-off of 8 [27]. Table 2 provides further descriptive characteristics of our sample.

3.2 Principal component analysis

The number of underlying dimensions was selected based on the scree plot and the eigenvalue greater-than-one criterion. Through this method, a 3-factor solution was retained (eigenvalues 16.9, 1.9 and 1.7, respectively), which explained 60.2% of the variance. Non-overlapping items with loadings > 0.5 were retained for each factor [34]. Factor 1 consisting of items 1, 2, 4, 5, 7, 8 & 9 corresponds to items initially conceived as both crowded and racing, i.e., this factor contains 5 of the 9 items of the STOQ [9]; this factor was labeled 'thought overactivation' with items conveying a notion of an increased amount and velocity of thoughts. Factor 2 consisting of items 10, 13, 14, 15, 18, 23, 29 & 30 was labeled 'burden of thought overactivation' and includes items initially conceptualized as crowded thoughts. Factor 3 consisting of items 12, 17, 20, 21, 22, 25, 31 & 32 is related to the 'overexcitability' nature of thoughts, and was therefore called 'thought overexcitability'. The mean scores are 9.29 (SD = 6.76) for factor 1 (thought overactivation), 4.87 (SD = 5.91) for factor 2 (burden of thought overactivation), and 8.93 (SD = 6.59) for factor 3 (thought overexcitability). Table 3 presents factor loadings for the 3-factor solution with oblimin rotation.

3.3 Reliability

Alpha coefficients were equally high for the three subscales of the RCTQ (0.92, 0.91 and 0.92, for factors 1, 2 and 3 respectively), suggesting excellent internal consistency.

3.4 Concurrent validity

We conducted pairwise correlation analyses in order to assess the relationship between RCTQ subscores and other psychological dimensions, namely affective temperaments (TEMPS-A), current depressive (BDI-sf) and manic symptoms (ASRM), and rumination, i.e., brooding and reflection (RRS). After Bonferroni correction for multiple tests, significant positive correlations were observed between RCTQ 'thought overactivation' subscore and score on the cyclothymic subscale of the TEMPS-A, depressive (BDI-sf) and manic (ASRS) current symptoms. For the factor 'burden of thought overactivation', significant positive correlations were found with scores on the cyclothymic and the dysthymic subscales of the TEMPS-A, depressive (BDI-sf) current symptoms, and the brooding subscore of the RRS. Regarding the 'thought overexcitability' factor, significant positive correlations were found with the cyclothymic, the irritable, and the depressive subscales of the TEMPS-A, depressive (BDI-sf) and manic (ASRS) current symptoms, and the brooding subscore of the RRS (cf. table 4).

In order to partial out the specific contribution of each of these dimensions on each one of the three components of the RCTQ, we conducted multiple regression analyses. Nine predictors – the five subscales of the TEMPS-A, the BDI-sf total score, the ASRM total score, and the two subscales of the RRS -- were simultaneously entered into the model. To investigate the presence of multicollinearity among selected measures, we calculated variance inflation factors (VIF). No VIF exceeded 2, meaning that multicollinearity was not a concern in our regression models. For all models, we examined the assumption of normality of the distribution of residuals. Residual plots revealed no breach of model assumptions. Regarding factor 1 ('thought overactivation'), predictors accounted for 24% of the variance, with significant contributions from (i) cyclothymic temperament ($\beta = .79$, $p < .01$), (ii) hyperthymic temperament ($\beta = .57$ $p = .01$), and (iii) ASRM score for manic symptoms ($\beta = .29$, $p = .04$). For factor 2 ('burden of thought overactivation'), the predictors accounted for 26% of the variance, with significant effects of (i) cyclothymic temperament ($\beta = .52$, $p < .01$), and (ii) BDI-sf score of depressive symptoms ($\beta = .44$, $p < .01$). Regarding factor 3 ('thought overexcitability'), 28% of the variance was explained, with significant contributions from (i) cyclothymic temperament ($\beta = .78$, $p < .01$), (ii) hyperthymic temperament ($\beta = .51$, $p = .02$), (iii) ASRM score of manic symptoms ($\beta = .28$, $p = .03$), and (iv) BDI-sf score of current depressive symptoms ($\beta = .40$, $p = .01$). Regression results are presented in table 5.

4. Discussion

Consistent with the qualitative and phenomenological descriptions of racing thoughts in patients with mood disorders [2, 9], our results show that the RCTQ is a multi-faceted scale, composed of three underlying factors that encompass specific thought patterns in healthy volunteers. Moreover, the evaluation of the psychometric properties of the scale suggests that the RCTQ is both valid and reliable when used in healthy subjects, and that it assesses a phenomenon distinct from rumination. Indeed, the internal consistency of each of the three subscales of the RCTQ is excellent, and the specific relationship between RCTQ subscores and cyclothymic and hyperthymic temperament, on the one hand, and current depressive and manic symptoms, on the other hand, suggests that it has good concurrent validity.

Our results add to those previously reported by Keizer et al. [9], which suggested that thought overactivation was associated with both depressive and manic symptoms in patients with mood disorders. Interestingly, our results indicate that racing and crowded thoughts are not only present in patients with full-blown mood disorders, but might also be observed in healthy subjects. Here racing and crowded thoughts were associated with subsyndromal symptoms and sub-affective trait expressions, suggesting a continuum between "normal" and "symptomatic" functioning.

In addition to the specific links between the subscales of the RCTQ and mood dimensions, the three subscales of RCTQ have good concurrent validity with the TEMPS-A cyclothymic subscale score. Indeed, the main predictor of all the three subscores of the RCTQ was elevated cyclothymic temperament traits, which has been found to be one of the main liability factors in the subsequent development of BD in healthy individuals [37, 38, 39]. Thus, racing and crowded thoughts, as measured by the RCTQ, seem to be particularly associated with mood instability even in its milder forms, such as that found in healthy individuals.

Importantly, our results indicate that the RCTQ is multi-faceted, with three underlying factors which were entitled: (i) 'thought overactivation', (ii) 'burden of thought overactivation', and (iii) 'thought overexcitability'. In addition to cyclothymic temperament, which was the main predictor of the three components of the RCTQ, each of these three factors was selectively associated with current elated and/or low mood symptoms and hyperthymic temperament traits. Moreover, each of them corresponds to a specific theme derived from the qualitative data reported in patients with mood disorders, i.e., factor 1 relates to the 'pressure of thoughts' theme whereas factors 2 and 3 refer to the 'effects and consequences of thought overactivity', and 'information processing load' themes, respectively [9].

According to Keizer et al. [9], pressure of thoughts corresponds to an increased amount of thoughts, which characterizes both racing and crowded thoughts. However, in our study, items retained in the 'thought overactivation' subscale of the RCTQ, which contains 5 out of 9 items of the STOQ [9], convey the notion of an increased amount of thoughts, but also of an acceleration of thoughts. Moreover, scores on this subscale were exclusively associated with elated mood and hyperthymic temperament traits, suggesting that it is more 'racing' in nature. This might be due to the fact that, in addition to the 5 items from the STOQ, the two other items found in the 'thought overactivation' subscale are the ones that most provide the notion of velocity and positive mood (i.e., "My thoughts race at 200 km/h"). Finally, increased amount of thoughts might be perceived as overwhelming by depressed patients [9], but this might concern to a lesser extent healthy individuals with milder forms of racing and crowded thoughts and subsyndromal symptoms. It remains to be tested whether the RCTQ leads to similar results in patients with BD during a (hypo)manic episode.

In contrast with factor 1 (thought overactivation), factor 2 (burden of thought overactivation) was exclusively associated with low mood. In other words, in healthy individuals, the excessive amount and velocity of thoughts is more elated in nature, whereas the unpleasant feeling of having too many thoughts at once is associated with low mood. Indeed, items retained in the 'burden of thought overactivation' subscale convey the overall notion of an increased amount of thoughts occurring at the same time, and a sense of uncontrollability (e.g., 'My brain cannot manage all these thoughts that arise at the same time'). This is consistent with the fact that most items in this subscale were initially conceived as 'crowded thoughts' items, i.e., an increased amount of thoughts occurring at the same time, which are perceived as unpleasant and difficult to grasp [2]. In sum, crowded thoughts, as reported by healthy subjects, seem to share similar features with those reported by patients; these thoughts are specifically linked to dysphoric mood, and a distressing feeling of lack of control.

Factor 3 (thought overexcitability), in turn, was associated with both elated and low mood, and was also highly correlated with factor 1 (thought overactivation) and factor 2 (burden of thought overactivation), suggesting that it is independent from the racing vs. crowded distinction. Indeed, items retained in this subscale (i.e., 12, 17, 20, 21, 32) are equally associated with racing and crowded thoughts, and reflect how thoughts involuntarily arise in one's mind, disrupting the ability to stay focused, i.e., distractibility. Distractibility is a clinical symptom frequently observed in both manic and mixed depressive episodes [40, 41, 42, 43]. In patients with mood disorders, it has been associated with racing thoughts [44], on the one hand, and irritability [42], on the other hand. Moreover, Benazzi [45] found in his study using factor analysis that distractibility, racing and crowded thoughts, and irritability belonged to the same cluster of core manic symptoms. Our study suggests that, in healthy individuals, distractibility is one of the hallmarks of both racing and crowded thoughts, on the one hand, and that it is associated with both elated, and low mood, on the other hand.

Given the paucity of data regarding racing thoughts in healthy individuals and in patients with BD, whether racing and crowded thoughts are a trait of BD, that is a predisposing factor to the subsequent development of BD, remains to be tested via studies with a longitudinal design. If such is the case, RCTQ could become a particularly useful tool in the detection of subthreshold manic symptoms in at-risk individuals [39]. Like rumination in unipolar depression, e.g., [46], we speculate that racing and crowded thoughts might be a trait of BD, present in individuals with sub-affective trait expressions and subsyndromal symptoms, but also in at-risk individuals and in euthymic phases of BD. In at-risk populations, longitudinal studies have identified racing thoughts, along with cyclothymic temperament, as one of the main predictors of the later BD onset [39, 47, 48]. In the only study that controlled for both rumination and racing and crowded thoughts in patients with BD, Ferrari et al. [10] showed that thought overactivation, measured by the STOQ, was higher in euthymic individuals compared to healthy controls. In contrast, the brooding subscore of the RRS did not differ between healthy individuals and euthymic subjects. In our study, rumination was not a significant predictor of RCTQ scores. Our results further support the view that racing and crowded thoughts are distinct from rumination, and that they are particularly associated with cyclothymic temperament traits in healthy individuals.

There are limitations to this study. Most of our sample was composed of young students. Future cross-sectional studies should include more individuals in other age groups, since the mechanisms associated with racing and crowded thoughts, e.g., distractibility, might evolve throughout the lifespan. Further, the instrument as a whole needs to be tested via a confirmatory factor analysis in a large sample of patients with mood disorders, in order to investigate its factor structure in patients with full-blown symptoms.

Here we found that thought overactivation is associated with temperamental affective characteristics and subclinical affective symptoms even in healthy subjects. Future studies with patients with mood disorders should thus take subthreshold mood symptoms into account, since they seem to matter when it comes to racing and crowded thoughts.

Conflicts of interest

None.

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None.

Authors' contributions

The article was written by LW, AG and GB. LW, SW and WSG collected and analyzed the data, with the help of IK and MGF. All authors have approved the final article.

REFERENCES

[1] APA. Diagnostic and Statistical Manual of Mental Disorders (DSM-5®). American Psychiatric Pub; 2013.

[2] Piguet C, Dayer A, Kosel M, Desseilles M, Vuilleumier P, Bertschy G. Phenomenology of racing and crowded thoughts in mood disorders: a theoretical reappraisal. J Affect Disord 2010;121:189–98. doi:10.1016/j.jad.2009.05.006.

[3] Desseilles M, Chang T, Piguet C, Bertschy G, Dayer AG. A three-dimensional model of thoughts: insight into depression. Psychopathology 2012;45:203–14. doi:10.1159/000335073.

[4] Akiskal KK, Akiskal HS. The theoretical underpinnings of affective temperaments: implications for evolutionary foundations of bipolar disorder and human nature. J Affect Disord 2005;85:231–9. doi:10.1016/j.jad.2004.08.002.

[5] Figueira ML, Caeiro L, Ferro A, Cordeiro R, Duarte PM, Akiskal HS, et al. Temperament in Portuguese university students as measured by TEMPS-A: implications for professional choice. J Affect Disord 2010;123:30–5. doi:10.1016/j.jad.2009.10.005.

[6] Vellante M, Zucca G, Preti A, Sisti D, Rocchi MBL, Akiskal KK, et al. Creativity and affective temperaments in non-clinical professional artists: An empirical psychometric investigation. J Affect Disord 2011;135:28–36. doi:10.1016/j.jad.2011.06.062.

[7] Dodd AL, Mansell W, Sadhnani V, Morrison AP, Tai S. Principal components analysis of the hypomanic attitudes and positive predictions inventory and associations with measures of personality, cognitive style and analogue symptoms in a student sample. Behav Cogn Psychother 2010;38:15–33. doi:10.1017/S1352465809990476.

[8] Bauer MS, Crits-Christoph P, Ball WA, Dewees E, McAllister T, Alahi P, et al. Independent assessment of manic and depressive symptoms by self-rating. Scale characteristics and implications for the study of mania. Arch Gen Psychiatry 1991;48:807–12.

[9] Keizer I, Piguet C, Favre S, Aubry J-M, Dayer A, Gervasoni N, et al. Subjective experience of thought overactivation in mood disorders: beyond racing and crowded thoughts. Psychopathology 2014;47:174–84. doi:10.1159/000354781.

[10] Ferrari M, Ossola P, Lucarini V, Accardi V, Panfilis CD, Tonna M, et al. Thought overactivation as a marker of bipolar disorder. Eur Psychiatry 2016;33:S264. doi:10.1016/j.eurpsy.2016.01.547.

[11] Koukopoulos A, Faedda G, Proietti R, D'Amico S, de Pisa E, Simonetto C. [Mixed depressive syndrome]. L'Encephale 1992;18 Spec No 1:19–21.

[12] Faedda GL, Marangoni C, Reginaldi D. Depressive mixed states: A reappraisal of Koukopoulos' criteria. J Affect Disord 2015;176:18–23. doi:10.1016/j.jad.2015.01.053.

[13] Johnson SL, Murray G, Fredrickson B, Youngstrom EA, Hinshaw S, Bass JM, et al. Creativity and bipolar disorder: touched by fire or burning with questions? Clin Psychol Rev 2012;32:1–12. doi:10.1016/j.cpr.2011.10.001.

[14] Aldao A, Nolen-Hoeksema S, Schweizer S. Emotion-regulation strategies across psychopathology: A meta-analytic review. Clin Psychol Rev 2010;30:217–37. doi:10.1016/j.cpr.2009.11.004.

[15] Nolen-Hoeksema S. Sex differences in unipolar depression: evidence and theory. Psychol Bull 1987;101:259–82.

[16] Treynor W, Gonzalez R, Nolen-Hoeksema S. Rumination Reconsidered: A Psychometric Analysis. Cogn Ther Res 2003;27:247–59. doi:10.1023/A:1023910315561.

[17] Marchetti I, Van de Putte E, Koster EHW. Self-generated thoughts and depression: from daydreaming to depressive symptoms. Front Hum Neurosci 2014;8:131. doi:10.3389/fnhum.2014.00131.

[18] Spendelow JS, Simonds LM, Avery RE. The Relationship between Co-rumination and Internalizing Problems: A Systematic Review and Meta-analysis. Clin Psychol Psychother 2016. doi:10.1002/cpp.2023.

[19] Grierson AB, Hickie IB, Naismith SL, Scott J. The role of rumination in illness trajectories in youth: linking trans-diagnostic processes with clinical staging models. Psychol Med 2016;46:2467–84. doi:10.1017/S0033291716001392.

[20] Pavlickova H, Turnbull O, Bentall RP. Cognitive vulnerability to bipolar disorder in offspring of parents with bipolar disorder. Br J Clin Psychol 2014;53:386–401. doi:10.1111/bjc.12051.

[21] Weiner L, Wittmann M, Bertschy G, Giersch A. Dispositional Mindfulness and Subjective Time in Healthy Individuals. Front Psychol 2016;7. doi:10.3389/fpsyg.2016.00786.

[22] Akiskal HS, Mendlowicz MV, Jean-Louis G, Rapaport MH, Kelsoe JR, Gillin JC, et al. TEMPS-A: validation of a short version of a self-rated instrument designed to measure variations in temperament. J Affect Disord 2005;85:45–52. doi:10.1016/j.jad.2003.10.012.

[23] Akiskal KK, Savino M, Akiskal HS. Temperament profiles in physicians, lawyers, managers, industrialists, architects, journalists, and artists: a study in psychiatric outpatients. J Affect Disord 2005;85:201–6. doi:10.1016/j.jad.2004.08.003.

[24] Siwek M, Dudek D, Drozdowicz K, Jaeschke R, Styczen K, Arciszewska A, et al. Temperamental dimensions of the TEMPS-A in male and female subjects engaging in extreme or/and high risk sports. J Affect Disord 2015;170:66–70. doi:10.1016/j.jad.2014.08.036.

[25] Park CI, An SK, Kim HW, Koh MJ, Namkoong K, Kang JI, et al. Relationships between chronotypes and affective temperaments in healthy young adults. J Affect Disord 2015;175:256–9. doi:10.1016/j.jad.2015.01.004.

[26] Morvan Y, Tibaoui F, Bourdel M-C, Lôo H, Akiskal KK, Akiskal HS, et al. Confirmation of the factorial structure of temperamental autoquestionnaire TEMPS-A in non-clinical young adults and relation to current state of anxiety, depression and to schizotypal traits. J Affect Disord 2011;131:37–44. doi:10.1016/j.jad.2011.01.008.

[27] Beck AT, Beamesderfer A. Assessment of depression: the depression inventory. Mod Probl Pharmacopsychiatry 1974;7:151–69.

[28] Beck AT, Steer RA, Carbin MG. Psychometric properties of the Beck Depression Inventory: Twenty-five years of evaluation. Clin Psychol Rev 1988;8:77–100. doi:10.1016/0272-7358(88)90050-5.

[29] Tanskanen A, Hibbeln JR, Tuomilehto J, Uutela A, Haukkala A, Viinamäki H, et al. Fish Consumption and Depressive Symptoms in the General Population in Finland. Psychiatr Serv 2001;52:529–31. doi:10.1176/appi.ps.52.4.529.

[30] Altman EG, Hedeker D, Peterson JL, Davis JM. The Altman Self-Rating Mania Scale. Biol Psychiatry 1997;42:948–55. doi:10.1016/S0006-3223(96)00548-3.

[31] Meyer B, Beevers CG, Johnson SL. Goal Appraisals and Vulnerability to Bipolar Disorder: A Personal Projects Analysis. Cogn Ther Res 2004;28:173–82. doi:10.1023/B:COTR.0000021538.34160.52.

[32] Nolen-Hoeksema S, Morrow J. A prospective study of depression and posttraumatic stress symptoms after a natural disaster: The 1989 Loma Prieta earthquake. J Pers Soc Psychol 1991;61:115–21. doi:10.1037/0022-3514.61.1.115.

[33] LeMoult J, Arditte KA, D'Avanzato C, Joormann J. State Rumination: Associations with Emotional Stress Reactivity and Attention Biases. J Exp Psychopathol 2013;4:471–84. doi:10.5127/jep.029112.

[34] Costello AB, Osborne JW. Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. Pract Assess Res Eval 2005;10:173–178.

[35] Floyd FJ, Widaman KF. Factor analysis in the development and refinement of clinical assessment instruments. Psychol Assess 1995;7:286–99. doi:10.1037/1040-3590.7.3.286.

[36] Cronbach LJ. Coefficient alpha and the internal structure of tests. Psychometrika 1951;16:297–334. doi:10.1007/BF02310555.

[37] Chiaroni P, Hantouche E-G, Gouvernet J, Azorin J-M, Akiskal HS. The cyclothymic temperament in healthy controls and familially at risk individuals for mood disorder: endophenotype for genetic studies? J Affect Disord 2005;85:135–45. doi:10.1016/j.jad.2003.12.010.

[38] Kochman FJ, Hantouche EG, Ferrari P, Lancrenon S, Bayart D, Akiskal HS. Cyclothymic temperament as a prospective predictor of bipolarity and suicidality in children and adolescents with major depressive disorder. J Affect Disord 2005;85:181–9. doi:10.1016/j.jad.2003.09.009.

[39] Correll CU, Hauser M, Penzner JB, Auther AM, Kafantaris V, Saito E, et al. Type and duration of subsyndromal symptoms in youth with bipolar I disorder prior to their first manic episode. Bipolar Disord 2014;16:478–92. doi:10.1111/bdi.12194.

[40] Benazzi F. Unipolar depression with racing thoughts: a bipolar spectrum disorder? Psychiatry Clin Neurosci 2005;59:570–5. doi:10.1111/j.1440-1819.2005.01416.x.

[41] Perugi G, Angst J, Azorin J-M, Bowden CL, Mosolov S, Reis J, et al. Mixed features in patients with a major depressive episode: the BRIDGE-II-MIX study. J Clin Psychiatry 2015;76:e351-358. doi:10.4088/JCP.14m09092.

[42] Prieto ML, Youngstrom EA, Ozerdem A, Altinbas K, Quiroz D, Aydemir O, et al. Different patterns of manic/hypomanic symptoms in depression: A pilot modification of the hypomania checklist-32 to assess mixed depression. J Affect Disord 2015;172:355–60. doi:10.1016/j.jad.2014.09.047.

[43] Van Meter AR, Burke C, Kowatch RA, Findling RL, Youngstrom EA. Ten-year updated meta-analysis of the clinical characteristics of pediatric mania and hypomania. Bipolar Disord 2016;18:19–32. doi:10.1111/bdi.12358.

[44] Young RC, Biggs JT, Ziegler VE, Meyer DA. A rating scale for mania: reliability, validity and sensitivity. Br J Psychiatry J Ment Sci 1978;133:429–35.

[45] Benazzi F. What is hypomania? Tetrachoric factor analysis and kernel estimation of DSM-IV hypomanic symptoms. J Clin Psychiatry 2009;70:1514–21. doi:10.4088/JCP.09m05090.

[46] Robinson MS, Alloy LB. Negative Cognitive Styles and Stress-Reactive Rumination Interact to Predict Depression: A Prospective Study. Cogn Ther Res 2003;27:275–91. doi:10.1023/A:1023914416469.

[47] Homish GG, Marshall D, Dubovsky SL, Leonard K. Predictors of later bipolar disorder in patients with subthreshold symptoms. J Affect Disord 2013;144:129–33. doi:10.1016/j.jad.2012.06.020.

[48] Zeschel E, Correll CU, Haussleiter IS, Krüger-Özgürdal S, Leopold K, Pfennig A, et al. The bipolar disorder prodrome revisited: Is there a symptomatic pattern? J Affect Disord 2013;151:551–60. doi:10.1016/j.jad.2013.06.043.

Figure

This questionnaire refers to the last 24 hours. If your thought activity varied in the last 24 hours, please refer to the average thought activity in this period of time.

Item No	RCTQ Question
1	*I have too many thoughts at the same time.*
2	My thoughts race at 200km/h
3	*My thoughts get twisted and mixed up.*
4	*Thoughts accumulate in my head.*
5	*My thoughts keep changing topics.*
6	When I speak, I feel less distressed by the stream of thoughts in my mind.
7	*My thoughts take off on their own.*
8	There is a succession of thoughts in my mind, racing from one to the other with incredible ease.
9	*Many thoughts come up and cross my mind at the same time.*
10	The intensity of my mental activity is unbearable.
11	My mind 'jumps ' from one thought to another ceaselessly.
12	Each object, each detail surrounding me gives rise to a new thought.
13	My brain cannot manage all these thoughts that arise at the same time.
14	I feel distressed in my everyday life by the great number of thoughts or by the velocity of the thoughts in my mind.
15	I cannot seem to stop the mechanism that generates all of these thoughts in my head.
16	At any given moment, a great number of thoughts come and go in my head.
17	My thoughts race when my attention is not captured by an activity
18	My thoughts overflow : it is like an overload.
19	My brain moves faster than my body.
20	At any given moment, new thoughts burst from nowhere in my mind.
21	Everything I hear or see immediately gives rise to a new thought.
22	There is not enough time to grasp the meaning of a thought, as new ones immediately arise.
23	Keeping focused in the middle of this thought overload is a constant struggle.
24	Thoughts pile up in my head.
25	A thought immeadiately leads to another, which leads to another, then another…
26	*My thoughts fly in all directions.*
27	I find it difficult to express myself because of the amount or the speed of my thoughts.
28	My thoughts race much too fast.
29	My mental overactivity is exhausting.
30	I cannot slow down or reduce the stream of thoughts in my head.
31	*My thoughts often take me very far away from my initial idea.*
32	When my thoughts race, I disconnect from everything around me.
33	*My thoughts bump into each other in my head*
34	There is a permanent parade of thoughts in my mind : one after the other, ceaselessly.

Italics: items from the 9-item STOQ

Fig. 1: The 34 items of the RCTQ

Table
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Table 1. Distribution of scores on the 34 items of the RCTQ

RCTQ item	Mean (SD)	% floor	% ceiling
1	1.56 (1.26)	26.90	9.14
2	1.29 (1.21)	35.03	5.58
3	0.98 (1.15)	44.16	5.58
4	1.49 (1.26)	29.44	6.6
5	1.13 (1.09)	35.53	3.55
6	1.41 (1.41)	38.07	11.17
7	0.97 (1.09)	43.65	3.05
8	1.49 (1.23)	26.90	6.60
9	1.36 (1.21)	32.49	4.06
10	0.45 (0.84)	71.07	1.52
11	1.02 (1.12)	41.62	3.55
12	1.15 (1.10)	34.01	4.57
13	0.48 (0.87)	69.54	1.52
14	0.64 (0.92)	60.41	0.51
15	0.92 (1.15)	49.75	3.05
16	1.10 (1.12)	41.62	1.52
17	1.44 (1.24)	29.95	5.58
18	0.54 (0.85)	62.44	0.51
19	1.35 (1.33)	37.56	9.14
20	0.86 (1.00)	48.22	0.51
21	1.12 (1.06)	35.53	2.03
22	0.60 (0.82)	57.36	0.51
23	0.62 (0.95)	60.91	1.52
24	0.77 (0.97)	51.78	1.02
25	1.17 (1.20)	41.12	3.55
26	0.89 (1.06)	47.72	2.03
27	0.48 (0.77)	65.99	0.51
28	0.94 (1.08)	46.70	1.52
29	0.47 (0.77)	72.08	2.03
30	0.76 (1.02)	53.81	2.54
31	1.32 (1.18)	32.49	3.05
32	1.27 (1.25)	36.55	6.60
33	0.89 (1.07)	49.24	2.54
34	0.61 (0.89)	59.90	1.52

Legend: SD = standard deviation; RCTQ = Racing and Crowded thoughts Questionnaire

Table

Table 2. Demographic and clinical characteristics of participants

Variable	Total sample (n = 197)
Mean age, years (SD)	26,0 (7,3)
Range	19 - 56
Sex, N (%)	
Female	128 (65,0%)
Male	69 (35,0%)
Occupation status, N (%)	
Student	146 (74,1%)
Employed	47 (23,9%)
Unemployed	4 (2,0%)
Mean years of study (SD)	16.3 (1,9)
Range	12 - 22
Mean ASRM (SD)	4,0 (3,5)
n above cut-off of 5	58 (29.4%)
Mean BDI (SD)	3,3 (3,4)
n above cut-off of 7	22 (11.8%)
Mean TEMPS-A cyclothymic (SD)	3,7 (2,7)
Mean TEMPS-A dysthymic (SD)	2,4 (2,2)
Mean TEMPS-A irritable (SD)	1,2 (1,5)
Mean TEMPS-A hyperthymic (SD)	4,3 (2,2)
Mean TEMPS-A anxious (SD)	1,3 (1,1)
Mean RRS (SD)	34,7 (11,1)
RRS brooding	8,3 (3,1)
RRS reflection	7,9 (3,3)
Mean RCTQ (SD)	33,5 (25,6)

Legend: SD= standard deviation; ASRM= Altman Self-Rating Mania Scale; BDI= Beck Depression Inventory; TEMPS-A= Temperament Evaluation of Memphis, Pisa, Paris and San Diego-autoquestionnaire; RRS= Rumination Response Scale; RCTQ= Crowded Racing Thoughts Questionnaire.

Table

Table 3. Principal component analysis with oblimin rotation

Item No	RCTQ Question	Factor 1	Factor 2	Factor 3
1	*I have too many thoughts at the same time.*	**.75**	.22	.14
2	My thoughts race at 200km/h	**.82**	.01	.02
3	*My thoughts get twisted and mixed up.*	.58	.46	.15
4	*Thoughts accumulate in my head.*	**.73**	.26	.09
5	*My thoughts keep changing topics.*	**.55**	.14	.21
6	When I speak, I feel less distressed by the stream of thoughts in my mind.	.34	.17	.11
7	*My thoughts take off on their own.*	**.57**	.22	.16
8	There is a succession of thoughts in my mind, racing from one to the other with incredible ease.	**.80**	.34	.25
9	*Many thoughts come up and cross my mind at the same time.*	**.79**	.03	.12
10	The intensity of my mental activity is unbearable.	.11	**.72**	.04
11	My mind 'jumps ' from one thought to another ceaselessly.	.39	.17	.39
12	Each object, each detail surrounding me gives rise to a new thought.	.03	.04	**.75**
13	My brain cannot manage all these thoughts that arise at the same time.	.05	**.68**	.15
14	I feel distressed in my everyday life by the great number of thoughts or by the velocity of the thoughts in my mind.	.03	**.87**	.01
15	I cannot seem to stop the mechanism that generates all of these thoughts in my head.	.06	**.59**	.08
16	At any given moment, a great number of thoughts come and go in my head.	.31	.11	.50
17	My thoughts race when my attention is not captured by an activity	.26	.03	**.53**
18	My thoughts overflow : it is like an overload.	.11	**.69**	.16
19	My brain moves faster than my body.	.19	.19	.45
20	At any given moment, new thoughts burst from nowhere in my mind.	.28	.11	**.54**
21	Everything I hear or see immediately gives rise to a new thought.	.14	.05	**.83**
22	There is not enough time to grasp the meaning of a thought, as new ones immediately arise.	.14	.18	**.51**
23	Keeping focused in the middle of this thought overload is a constant struggle.	.12	**.65**	.36
24	Thoughts pile up in my head.	.23	.46	.26
25	A thought immeadiately leads to another, which leads to another, then another…	.13	.03	**.68**
26	*My thoughts fly in all directions.*	.19	.28	.48
27	I find it difficult to express myself because of the amount or the speed of my thoughts.	.00	.32	.43
28	My thoughts race much too fast.	.46	.01	.40
29	My mental overactivity is exhausting.	.10	**.79**	.07
30	I cannot slow down or reduce the stream of thoughts in my head.	.06	**.62**	.11
31	*My thoughts often take me very far away from my initial idea.*	.12	.00	**.68**
32	When my thoughts race, I disconnect from everything around me.	.09	.30	**.57**
33	*My thoughts bump into each other in my head*	.39	.32	.27
34	There is a permanent parade of thoughts in my mind : one after the other, ceaselessly.	.15	.40	.40

Italics: items from the 9-item STOQ; colored items in bold refer to loadings >.50 on one component with a loading difference of at least .20 with other components

Table

Table 4. Correlations between RCTQ total score, RCTQ subscales, and other selected instruments.

Instrument	RCTQ thought overactivation		RCTQ burden of thought overactivation		RCTQ thought overexcitability	
	R	*p*	R	*p*	R	*p*
RCTQ thought overactivation						
RCTQ burden of thought overactivation	.67	**< .01***				
RCTQ thought overxcitability	.69	**< .01***	.70	**< .01***		
RRS brooding	.23	**< .01**	.37	**< .01***	.26	**< .01***
RRS reflection	.16	**< .05**	.24	**< .01**	.20	**<.01**
ASRM	.29	**< .01***	.17	**.02**	.30	**< .01***
BDI	.24	**< .05***	.43	**< .01***	.33	**< .01***
TEMPS-A cyclothymic	.44	**< .01***	.45	**< .01***	.48	**< .01***
TEMPS-A dysthymic	.22	**< .05**	.34	**< .01***	.26	**< .01***
TEMPS-A irritable	.19	**< .01**	.23	**< .01**	.27	**< .01***
TEMPS-A hyperthymic	.17	**.01**	.00	.95	.15	**.02**
TEMPS-A anxious	.22	**< .01**	.19	**< .01**	.21	**< .01**

Legend: RCTQ= Crowded Racing Thoughts Questionnaire; RRS= Rumination Response Scale; ASRM= Altman Self-Rating Mania Scale; BDI= Beck Depression Inventory; TEMPS-A= Temperament Evaluation of Memphis, Pisa, Paris and San Diego-autoquestionnaire. Significant results are presented in bold; $p < 0.05$. * Significant results following Bonferroni correction (0,05/30 tests); $p < 0.05$.

Table

Table 5. RCTQ subscale scores as a function of other instruments (multiple linear regression)

Instrument	RCTQ thought overactivation* (n = 194)			RCTQ burden of thought overactivation** (n = 194)			RCTQ thought overexcitability*** (n= 194)		
	β	t	*p*	β	t	*p*	β	t	*p*
TEMPS-A cyclothymic	0.79	3.74	**<0.01**	0.52	2.87	**<0.01**	0.78	3.93	**<0.01**
TEMPS-A dysthymic	0.15	0.62	0.53	0.20	0.93	0.35	0.10	0.30	0.76
TEMPS-A irritable	-0.09	-0.27	0.79	0.04	0.15	0.88	0.22	0.75	0.45
TEMPS-A hyperthymic	0.57	2.53	**0.01**	0.23	1.21	0.23	0.51	2.41	**0.02**
TEMPS-A anxious	0.47	1.08	0.28	0.28	0.76	0.45	0.23	0.57	0.57
ASRM	0.29	2.11	**0.04**	0.09	0.82	0.41	0.28	2.22	**0.03**
BDI	0.24	1.38	0.17	0.44	2.96	**<0.01**	0.40	2.47	**0.01**
RRS-brooding	0.03	0.18	0.86	0.20	1.19	0.24	-0.02	-0.13	0.90
RRS-reflection	-0.06	-0.36	0.72	-0.04	-0.30	0.76	-0.01	-0.09	0.93

Legend: RCTQ= Crowded Racing Thoughts Questionnaire; RRS= Rumination Response Scale; ASRM= Altman Self-Rating Mania Scale; BDI= Beck Depression Inventory; TEMPS-A= Temperament Evaluation of Memphis, Pisa, Paris and San Diego-autoquestionnaire. *R^2 = .27 adjusted R^2 = .24, F(9,184)=7.41, $p < .001$. **R^2 = .30, adjusted R^2 = .26, F(9,184)=8.67, p < .001. ** *R^2 = .32, adjusted R^2 = .28, F(9,184)=9.46, p < .001..Significant results are presented in bold (p < 0.05).

Article 2: Preliminary results obtained in patients with bipolar disorder

In the patient study, 341 subjects were included in four French-speaking sites (University Hospital of Strasbourg, EPSAN, Hospital of Colmar, and the Psychiatric Clinic of Henri-Chapelle in Belgium) and one Italian-speaking site (University Hospital of Parma). Since the last subject of our sample was included last month (October 2017), the analyses presented here are preliminary. Results from the confirmatory factor analysis will certainly allow to further improve the psychometric properties of the RCTQ. Moreover, in the final article detailed demographic information regarding our samples will be provided (such as medication status). Here we present, in a synthetic manner, our main results because they will allow us to address, in the discussion, some of the main questions surrounding the racing and crowded thoughts phenomena (e.g., its structure and morphology across mood states).

Put very shortly, in this study we split the whole sample (n = 341) in two, and performed an exploratory factor analysis in the first sample, which was indicative of a single-factor solution. However, the single-factor model yielded a poor fit (results from the Confirmatory Factor Analysis, CFA, performed in the second sample). We thus compared fit indices of the single-factor solution to those from two a priori models – the three-factor solution obtained in the healthy sample (article 1), and the two-factor solution based on our a priori model of racing vs. crowded thoughts. Compared to the single and bifactorial models, the three-factor model yielded the best fit. There is still room for improvement through the removal of redundant items within factors. Nevertheless, these preliminary results are supportive of the idea according to which racing and crowded thoughts are a multi-faceted construct in patients as well as in healthy individuals. Of note, internal consistency alpha values for the three factors were excellent, similar to results found in healthy individuals (cf. results below).

Importantly, when we compared the results on the RCTQ among the groups, as we had initially operationalized them (cf. materials and procedure), we found that RCTQ subscale scores were similar among acute groups, and higher than those of controls and euthymic patients (cf. results). However, when we split the depression group in two – the first with no manic symptoms (YMRS[24] score of 0), and the second with very few subthreshold manic symptoms (YMRS score of 1 or 2)[25] – we found that RCTQ total score was significantly higher in the mixed groups but also in the depression with few manic subthreshold manic symptoms group (YMRS score of 1 or 2) compared to the 'pure' depression group (YMRS=0). Regarding its subscales, 'thought overactivitation' and 'thought overexcitability' scores were higher in the pure manic, mixed manic, mixed depression (YMRS score ranging from 3 to 5), and depression with few subthreshold manic symptoms compared to the depression (YMRS=0) and euthymic groups. By contrast, 'burden of thought overactivation' scores were higher in mixed mania and mixed depression compared to depression; scores on this subscale did not differ between 'pure' depression and mania. Euthymic patients' scores differed from that of controls on the three subscales[26]. These results are further presented below in figures 1 until 8 and table 2.

Lastly, we investigated the relationship between different clinical dimensions – i.e., anxiety, rumination, worry, depression, and mania -- and the RCTQ subscale scores. Through multiple regression analyses conducted in the bipolar group from the French-speaking sites only (i.e., excluding the control group), we found that anxiety scores consistently predicted scores in the three RCTQ subscales – i.e., thought overactivation, burden of thought overactivation, and thought overexcitability. Manic scores were a significant predictor of scores in the 'thought

[24] Young Mania Rating Scale (YMRS; Young, Biggs, Ziegler, & Meyer, 1978).
[25] Based on Miller et al.'s (2016) criteria, in our study, episodes of depression (QIDS-C16 > 5) concurrent with a score ranging from 3 to 5 on the YMRS, which assesses current manic symptoms, were classified as 'mixed depression'.
[26] Results from planned comparisons.

overactivation' and 'thought overexcitability' subscales. Worry scores were significantly associated with scores on the 'thought overexcitability' subscale, but also on the 'burden of thought overactivition' subscale. Rumination scores also significantly predicted results on the 'burden of thought overactivation' subscale.

Preliminary versions of the method and results parts are presented below, and discussed in section 3.1 (Summary and general discussion).

2. Methods

2.1 Participants

Two hundred and twenty-one patients ages 18 – 64 (M = 44.69, SD = 0.83) with bipolar disorder and 120 healthy individuals ages 18 – 64 (M = 33.59, SD = 1.13) were recruited in France, Italy and Belgium from the inpatient and outpatient clinics of the Alsace region in France (University Hospital of Strasbourg, EPSAN, and Hospital of Colmar), the University Hospital of Parma, and the Psychiatric Clinic of Henri-Chapelle in Belgium. Patients fulfilled criteria for either BD or MDD according to the DSM-IV-TR (APA, 2003). They had no history of neurological disorder, ADHD, substance use disorder within the last 12 months or borderline personality disorder. Detailed demographic data from French-speaking (France and Belgium), and Italian-speaking subjects are presented on table 1.

Healthy volunteers were recruited by advertisement. They had no current or past personal history of psychiatric or neurological disorders nor did they have any first-degree relatives with psychosis or mood disorders. Prior to their inclusion, they filled out the Mood Disorders Questionnaire (MDQ; Hirschfeld et al., 2000) and the Quick Inventory of Depressive Symptomatology-self rated (QIDS-SR16; Rush et al., 2003) in order to rule out current depression or past manic episodes. Subjects provided written informed consent prior to inclusion in the study in accordance with the Declaration of Helsinki. This study was approved by the regional ethics committee of the East of France (CPP EST IV).

Table1: Demographic data from the French and Italian speaking samples

	French sites n = 180	Italian site n =161	p
Age	41.49 (12.91)	40.03 (14.02)	ns
Sex (% female)	65%	57%	ns
Years of education	14.35 (2.62)	/	
Illness duration (months)	157.73 (143.46)	185.64 (159.44)	ns
patients/controls	138/42	83/78	

2 Materials and procedure

Mania and depression symptoms were assessed with the Young Mania Rating Scale (YMRS; Young et al., 1978) and the Quick Inventory of Depressive Symptomatology–Clinician-Rated Version (QIDS-C16; Rush et al., 2003). A YMRS score > 5 was considered reflective of hypomania (Favre et al., 2003) and a QIDS-C16 score > 5 was reflective of depression (Rush et al., 2003). Subjects were considered to be in a mixed manic state, if manic AND depressive symptoms were above the respective cut-offs (Suppes et al., 2005). Mixed depression was operationalized as above threshold depressive symptoms (QIDS-C16 score > 5), co-occurring with mild hypomanic symptoms (YMRS score > 2 and < 6; Miller et al., 2016). Euthymia was defined as below the threshold scores in both the YMRS, and the QIDS-C16. Based on these criteria, 53 subjects were classified as having a manic episode, 24 were in a mixed manic episode, 29 were having a mixed depressive episode, 67 were depressed (non-mixed), and 46 were euthymic (cf. Table 2). Following the assessment of depressive and manic symptoms, in addition to the RCTQ, participants in French-speaking sites only were also administered self-rated questionnaires, assessing anxiety, worry, and rumination. Questionnaires were administered in a fixed order. All measures were completed in a quiet room as part of a wider testing session.

2.2.1 Racing and Crowded Thoughts Questionnaire (RCTQ)

The RCTQ is a 34-item self-report questionnaire that assesses thought overactivity during the past 24 hours. Nine items of the RCTQ belong to the STOQ (Keizer et al., 2014), of which 4 underwent very minor wording adaptations, whereas the remaining 25 items were developed by three experienced clinicians (GB, IK and LW) based on the six themes that emerged in the qualitative reports of patients with mood disorders in the study of Keizer et al. (2014). If some items were clearly related to the phenomenology of racing thoughts or crowded thoughts, others were more related to the consequences of thought overactivation and less exclusively linked to the racing versus crowded distinction (e.g., 'My mental overactivity is exhausting'). Initially 17 items were conceived to refer to racing thoughts; they convey the notion of an acceleration and an increased amount of thoughts that are linked to each other in a sequential manner (e.g., my thoughts race at 200 km/hour); clinically these thoughts are usually associated with positive emotions, and are not perceived as being emotionally overwhelming. In contrast, the remaining 17 items that refer to crowded thoughts are related to an increased amount of thoughts that are linked to each other in a simultaneous manner, as if thoughts were accumulating in one's mind (e.g., thoughts accumulate in my head); these thoughts are usually associated with an increased information processing load, and the feeling of being emotionally overwhelmed. Both racing and crowded thoughts items portray thoughts as arising in one's mind involuntarily (e.g., my thoughts take off on their own). Items are rated on a scale from 0 ("not at all") to 4 ("completely agree"). Since RCTQ items were conceived in French, they were translated to Italian and back-translated to French. The Italian version was elaborated following the backtranslation procedure. In healthy individuals, principal component analysis of RCTQ scores yielded a three-factor solution, which were labeled: (i) thought overactivation, (ii) burden of thought overactivation, and (iii) thought overexcitability. Internal consistency was excellent (Cronbach's alpha of 0.92, 0.91 and 0.92, for factors 1, 2 and 3), and the instrument had good convergent validity with measures of cyclothymic temperament (Weiner et al., submitted).

2.2.2 Other measures

The Ruminative Response Scale State version (RRS-S) (Nolen-Hoeksema & Morrow, 1991; Treynor et al., 2003) is a 22-item self-report questionnaire which evaluates two aspects of rumination during the past 7 days: 'Brooding' (5 items) taps passive rumination on negative mood and is considered to be maladaptive whereas 'reflection' (5 items) refers to active efforts to understand one's negative feelings, and is considered to be adaptive. Treynor et al. (Treynor et al., 2003) found that internal consistency was acceptable for both brooding and reflection subscales (Cronbach's alpha .72 and .77, respectively). Items are rated on a scale from 1 ("almost never") to 4 ("almost always").

The Penn State Worry Questionnaire-state version (PSWQ; Stöber & Bittencourt, 1998) is 15-item scale which measures the level of worry during the previous week. Items are rated on a 7-point scale from 0 (never) to 6 (almost always). Scores can range between 0 and 90. Stöber and Bittencourt (1998) reported good validity and reliability with a Cronbach's alpha of .91.

The Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988) is a 21-item self-report questionnaire that measures symptoms of anxiety during the past 7 days. The symptoms are rated on a four-point scale, ranging from "not at all" (0) to "severely" (3). The instrument has excellent internal consistency ($\alpha = .92$) and high test–retest reliability ($r = .75$; Beck & Steer, 1990).

2.3 Statistical analyses

In order to investigate the factor structure of the RCTQ, we used Confirmatory Factor Analysis (CFA). Like Exploratory Factor Analysis (EFA), CFA is a tool that may be utilized to reduce the overall number of observed variables into latent factors based on commonalities within the data. CFA differs from EFA in that it assists in the reduction of measurement error and allows the comparison of a priori models at the latent factor level (Atkinson et al., 2011). The use of CFA increases thus the level of statistical precision and can provide confirmation of possible sub-domains within the dataset. In the present study, there were two a priori models regarding the construct validity of the RCTQ: the bifactorial model, referring to racing vs. crowded thoughts items, and the 3-factor model, based on the results obtained in healthy individuals (Weiner et al., submitted). Several fit indices were selected in order to test which CFA model best represents RCTQ scores: root-mean-squared error of approximation (RMSEA), comparative fit index (CFI), and chi-square. RMSEA is a measure of the average of the residual variance and covariance; good models have RMSEA values that are at or less than 0.08. CFI is an index that fall between 0 and 1, with values greater than 0.90 considered to be indicators of good fitting models. When comparing models, a lower chi-square value indicates a better fit, given an equal number of degrees of freedom[27] (Schreiber, Nora, Stage, Barlow, & King, 2006).

Before testing these models, however, we performed EFA in half (n = 169) of the sample which had been randomly split in two, and assessed the resulting model, which yielded a single-factor structure, in the other half of the sample (n = 169). Although the fit indices obtained (i.e., RMSEA, CFI, and chi-square) with this single-factor model were poor, we decided to include it among the a priori models. Overall, three models were tested in our study: single-factor, bifactorial, and three-factor models. Internal consistency of each identified factor (i.e., to what extent items belonging to that factor are inter-correlated) was assessed with the Cronbach's alpha coefficient (Cronbach, 1951). A coefficient of at least 0.7 was expected.

[27] Other fit indices will be taken into account in the final version of the paper.

In order to investigate the validity of the instrument, we compared scores obtained via the RCTQ in patients and controls via one-way ANOVA with group as a between-group variable. If the instrument has good discriminant validity, it should distinguish patients from controls, but also patients in different mood states. Multiple regression analyses were performed in order to partial out the effects of the different clinical dimensions (YMRS, QIDS-C16, RRS, PSWQ and BAI) on the RCTQ scores in the subset of French-speaking subjects. Statistical significance was set at 0.05. Analyses were performed using the Stata 14.1 and Statistica softwares.

3. Results

3.1 Confirmatory factor analysis (CFA)

Using CFA we compared fit indices among the three models outlined below: (i) single-factor, (ii) bifactorial, and (iii) three-factor. For the single-factor model, the 34 items of the RCTQ were included in the analysis (model 1); for the bifactorial model (model 2), 17 items belonged to the 'racing' a priori factor: 2, 5, 7, 8, 11, 12, 14, 17, 20, 21, 22, 25, 28, 30, 31, 32 & 34, and 17 items belonged to the 'crowded' one: 1, 3, 4, 6, 9, 10, 13, 15, 16, 18, 19, 23, 24, 26, 27, 29, 33; for the three-factor model (model 3), factor 1 consisted of items 1, 2, 4, 5, 7, 8 & 9, factor 2 consisted of items 10, 13, 14, 15, 18, 23, 29 & 30, and factor 3 consisted of items 12, 17, 20, 21, 22, 25, 31 & 32 (Weiner et al., submitted). Through this method, we found that the three-factor model had the best fit, although it still can be improved, (such is the case especially for the RMSEA, as CFI and chi-square indices are acceptable; cf. table 2).

Table 2: Comparison of CFA fit indices in three models

	RMSEA	90% CI		CFI	χ2
Model 1 (one factor)	0.099	0.094	0.103	0.884	2259.883
Model 2 (two factors)	0.098	0.094	0.102	0.886	2229.397
Model 3 (three factors)	0.093	0.087	0.100	0.930	895.009

RMSEA = Root Mean Squared Error of Approximation; CI = confidence interval; CFI = Comparative Fit Index.

3.2 Reliability

Alpha coefficients were equally high for the three subscales of the RCTQ (0.95, 0.97 and 0.95, for factors 1, 2 and 3 respectively), suggesting excellent internal consistency.

3.4 Discriminant validity

3.4.1 Descriptive analyses

Mean scores and standard errors on the questionnaires administered to the whole sample, including the Italian site, are presented in table 3. Those include the RCTQ, the YMRS, and the QIDS-C16. Mean scores and standard errors on the questionnaires administered exclusively in the French-speaking sites are presented in table 4.

3.4.2 Initial results: comparing 5 groups of patients and controls

RCTQ scores were significantly higher in patients compared to controls for the whole scale, $F(1,133) = 60.66$, $p < .001$, as well as for its three subscale scores: thought overactivation, $F(1,133) = 45.21$, $p < .001$, burden of thought overactivation, $F(1, 133) = 59.86$, $p < .001$, and thought overexcitability, $F(1, 133) = 54.25$, $p < .001$.

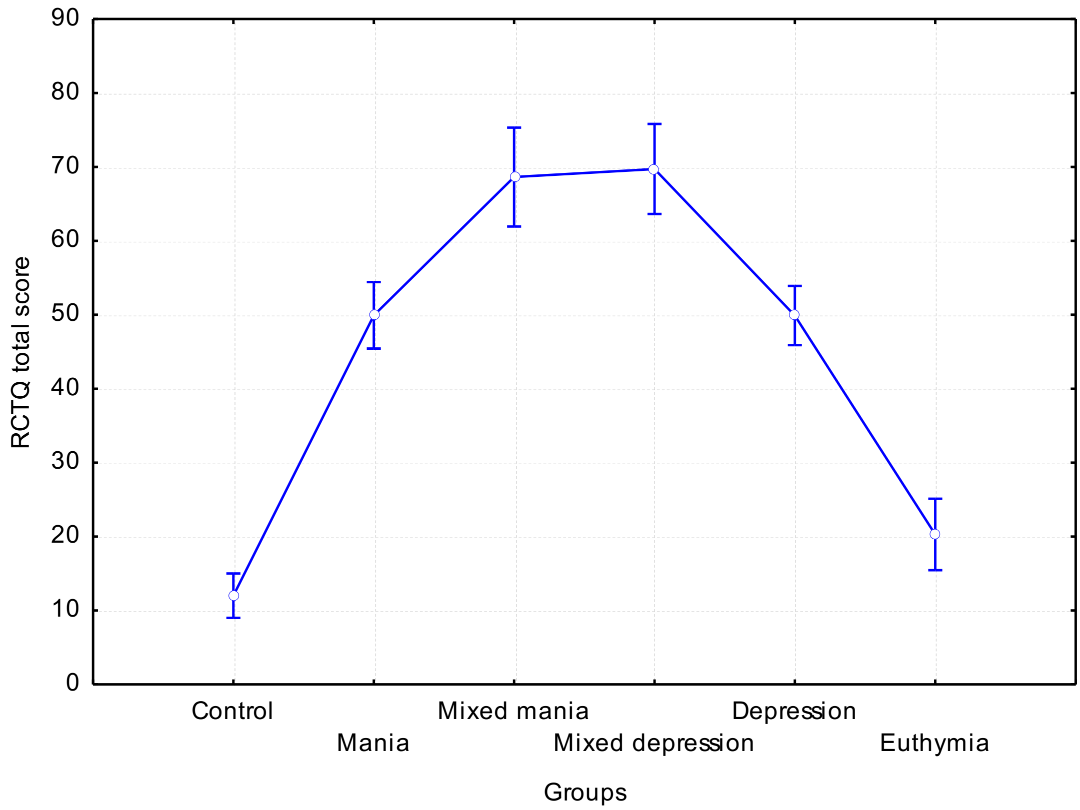


Figure 1: RCTQ total scores in 6 groups (5 patient groups)

When comparing patients in different mood states – mania, mixed mania, mixed depression, depression, euthymia – and controls, we found that RCTQ total score differed between groups ($F(5, 332) = 30.13$, $p < .001$; Figure 1). Regarding the RCTQ subscales, scores differed significantly between groups for the 'thought overactivation' subscale ($F(5,332) = 23.51$, $p < .001$), the 'burden of thought overactivation' subscale ($F(5,332) = 29.01$, $p < .001$), and the 'thought overexcitability' subscale ($F(5,332) = 26.14$, $p < .001$). Post hoc Tukey analyses results are presented in table 3.

Table 3: Means and standard erros of questionnaires administered to subjects in France, Belgium and Italy

	Mania n= 53	Mixed Mania n = 24	Mixed Depression n = 29	Depression n = 67	Euthymia n = 46	Controls n = 119	F	p	Post hoc tukey test
YMRS	14.61 (0.48)	13.46 (.0.71)	3.83 (0.64)	0.75 (0.42)	0.86 (0.52)	0.75 (0.32)	F(5,328) = 175.04	*<.001*	
QIDS-C16	2.36 (0.44)	9.5 (0.76)	13.12 (0.54)	12.34 (0.4)	1.45 (0.59)	0.88 (0.41)	F(5,328) = 147.10	*<.001*	
RCTQ total	49.92 (4.50)	68.62 (6.69)	69.72 (6.08)	49.89 (4.0)	20.28 (4.83)	12 (3)	F(5,332) = 30.13	*<.001*	control = euthymia > acute groups
RCTQ overactivation	12.11 (1.04)	14.62 (1.54)	15.28 (1.41)	10.96 (0.92)	4.61 (1.12)	3.73 (0.69)	F(5,332) = 23.51	*<.001*	control = euthymia > acute groups
RCTQ burden	9.21 (1.15)	16.04 (1.71)	16.76 (1.55)	11.94 (1.02)	4.83 (1.23)	1.61 (0.77)	F(5,332) = 29	*<.001*	mania = dep = euth < mixed; clinical groups > controls
RCTQ overexcitability	11.09 (0.93)	13.33 (1.38)	13.10 (1.26)	9.79 (0.83)	4.09 (1)	2.71 (0.62)	F(5,332) = 26.14	*<.001*	control = euthymia > acute groups

Legend: YMRS = Young Mania Rating Scale; QIDS-C16 = Quick Inventory of Depressive Symptomatology RCTQ = Racing and Crowded Thoughts Questionnaire; RRS = Rumination Response Scale; significant results are presented in italics.

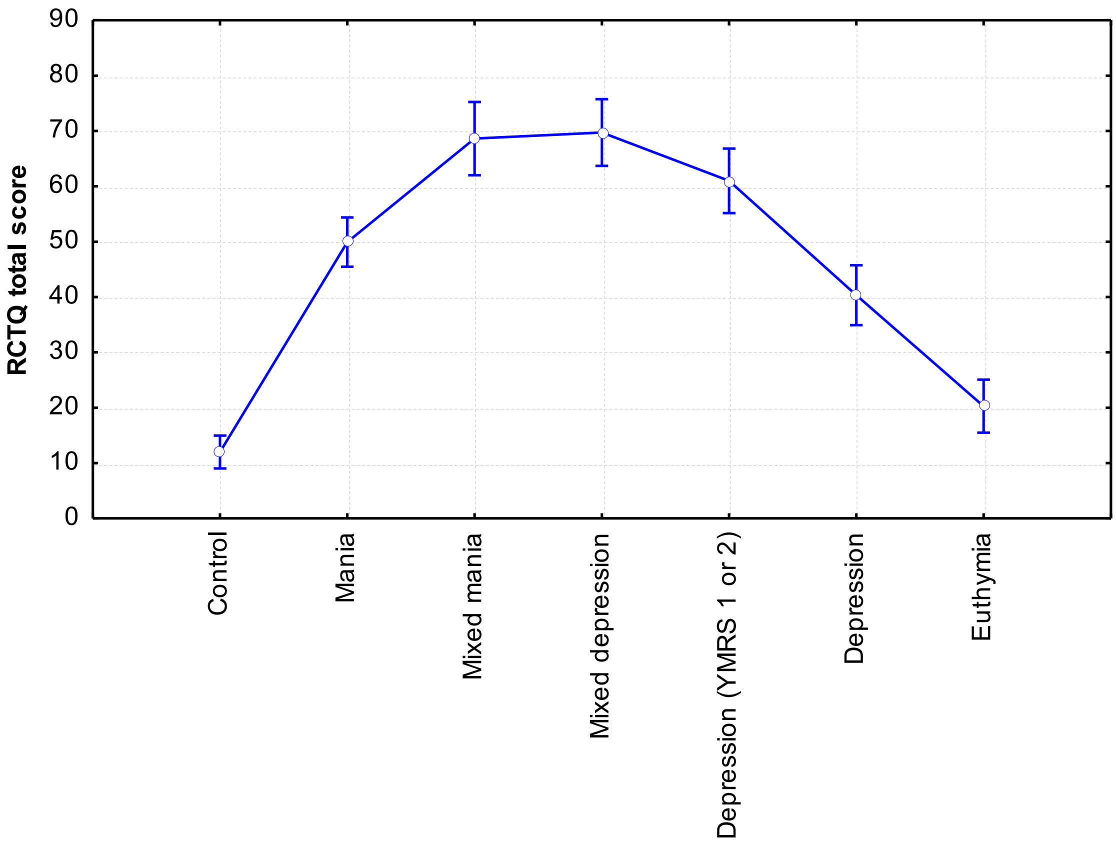
Table 4: Means and standard erros of in questionnaires administered in France and Belgium (n = 180)

	Mania	**Mixed Mania**	**Mixed Depression**	**Depression**	**Euthymia**	**Controls**	**F**	**p**
	n= 36	**n = 12**	**n = 24**	**n = 43**	**n = 20**	**n = 42**		
BAI	14.36 (1.41)	22 (2.55)	26.96 (1.73)	17.12 (1.29)	3.95 (1.89)	2.22 (1.32)	F(5,169) = 35.6	*<.001*
RRS brooding	9.48 (0.56)	14.64 (0.99)	15.25 (0.67)	11.86 (0.51)	8.2 (0.74)	6.90 (0.51)	F(5,169) = 27.28	*<.001*
RRS reflection	9.57 (0.53)	14.27 (0.94)	13.33 (0.64)	11.69 (0.48)	7.9 (0.7)	6.69 (0.48)	F(5,168) = 23.34	*<.001*
PSWQ	40.88 (2.49)	61.67 (4.19)	67.29 (2.96)	53.19 (2.24)	26.25 (3.25)	29.63 (2.27)	F(5,167) = 33.48	*<.001*

Legend: BAI = Beck Anxiety Inventory; RRS = Rumination Response Scale; PSWQ = Penn-State Worry Questionnaire; significant results are presented in italics.

3.4.3 Additional results: splitting the depression group in two, and comparing 6 groups of patients and controls

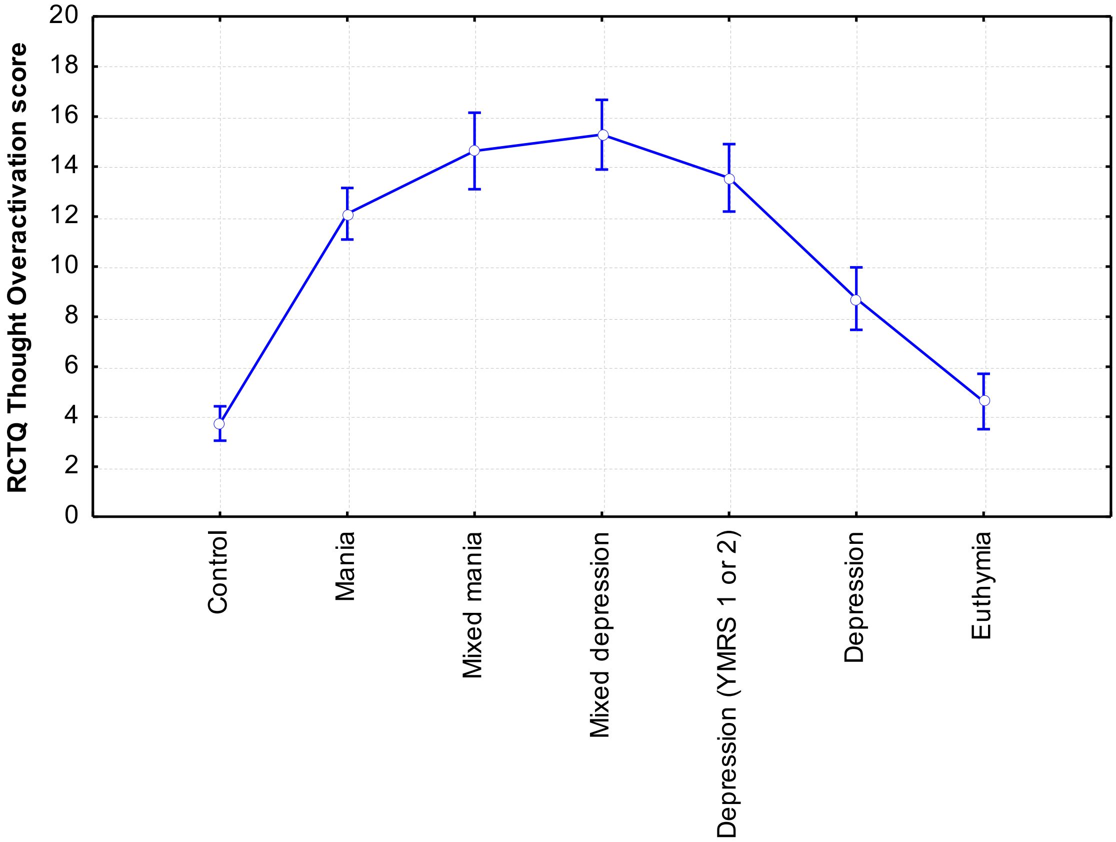
Since the RCTQ scores did not differ between depression and manic groups, we hypothetized that the RCTQ could be excessively sensitive to slight manic symptoms. We thus checked this hypothesis with additional analyses. For these analyses, we split the depression group in two – i.e., 'pure' depression (YMRS score = 0; n = 36), and depression with very few manic subthreshold symptoms (YMRS scores of 1 or 2; n = 30). We then found that RCTQ total score differed between groups ($F(6, 331) = 26.66$, $p < .001$; Figure 2). Of particular interest, post hoc Tukey analysis revealed that the RCTQ total score was higher in the depression with few subthreshold manic symptoms (YMRS score of 1 or 2) compared to pure depression group (YMRS = 0) ($p < .05$), and did not differ from scores obtained in the two mixed groups (mixed mania and mixed depression). RCTQ total score was significantly higher in the two mixed groups compared to pure depression. No significant differences were found between depression and mania groups.



Fi

gure 2: RCTQ total score in the 7 groups

Regarding the RCTQ subscales, scores differed significantly between groups for the ‘thought overactivation’ subscale (F (6,331) = 21.01, p < .001; Figure 3), the ‘burden of thought overactivation’ subscale (F(6,331) = 25.46, p < .001; Figure 4), and the ‘thought overexcitability’ subscale (F(6,331) = 22.96, p < .001, Figure 5). Broadly speaking, we found that scores were higher on the ‘thought overactivation’ and ‘thought overexcitability’ subscales in the pure manic, mixed manic, mixed depression (YMRS score ranging from 3 to 5), and depression with few subthreshold manic symptoms compared to the depression (YMRS=0) and euthymic groups. By contrast, ‘burden of thought overactivation’ scores were higher in mixed mania and mixed depression compared to depression; scores on this subscale did not differ between 'pure' depression and mania. Euthymic patients' scores differed from that of controls on the three subscales[28].



Fi

gure 3: RCTQ thought overactivation subscale score across 7 groups

[28] Results from planned comparisons.

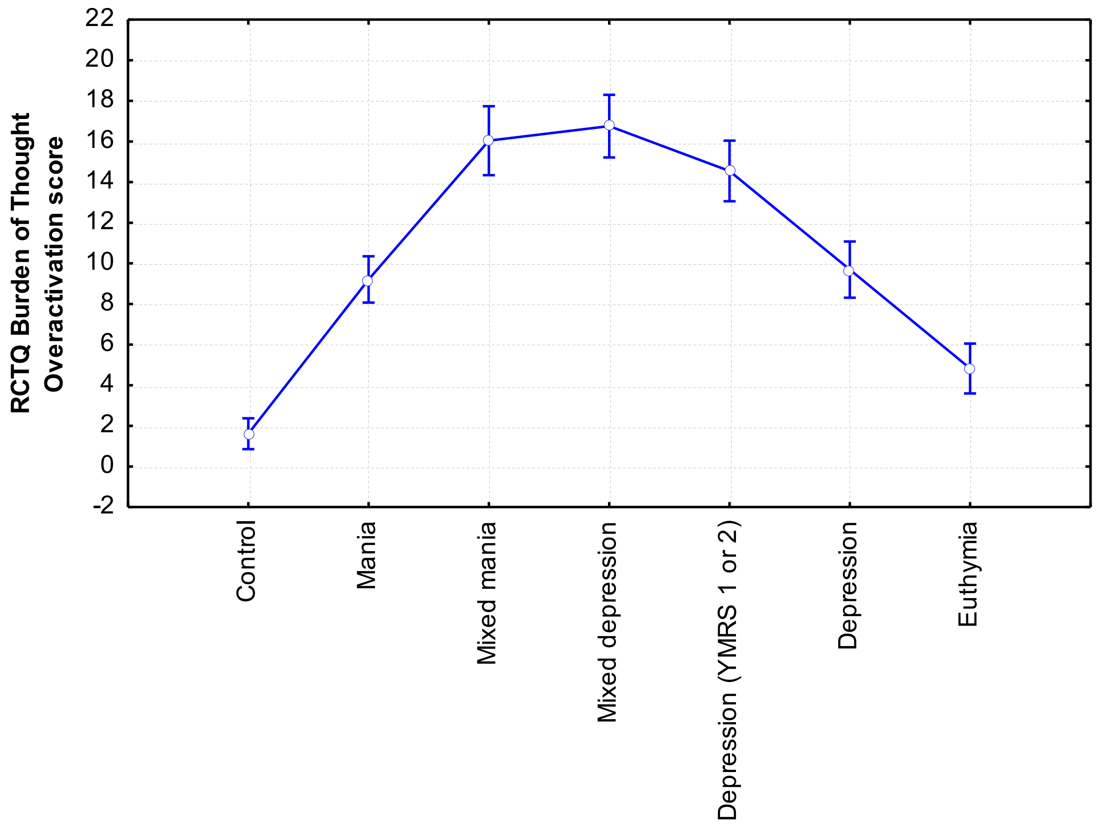


Figure 4: RCTQ burden of thought overactivation subscale score across 7 groups

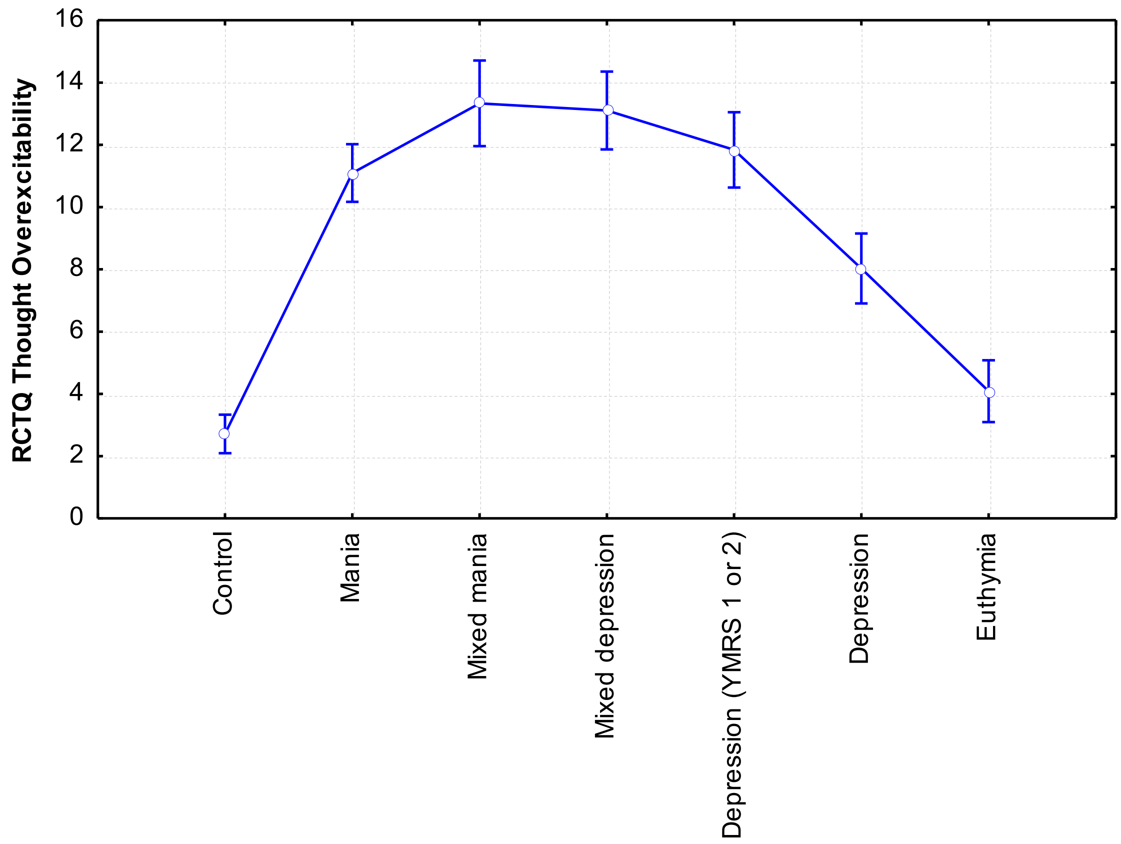


Figure 5: RCTQ thought overexcitability subscale score across 7 groups

3.5 Multiple regression analyses

To investigate the relationship between clinical dimensions and RCTQ subscale scores, we conducted multiple regression analyses. Regarding factor 1 ('thought overactivation'), predictors accounted for 43% of the variance, with significant contributions from (i) YMRS score ($\beta = .33$, $p < .01$), and (ii) BAI score ($\beta = .33$, $p < .01$). For factor 2 ('burden of thought overactivation'), the predictors accounted for 50% of the variance, with significant effects of (i) BAI score ($\beta = .41$, $p < .01$), (ii) PSWQ score ($\beta = .20$, $p = .03$), and (iii) RRS brooding score ($\beta = .23$, $p = .03$). Regarding factor 3 ('thought overexcitability'), the predictors accounted for 43% of the variance, with significant contributions from (i) YMRS score ($\beta = .33$, $p < .01$), (ii) BAI score ($\beta = .30$, $p < .01$), and (iii) PSWQ score ($\beta = .22$, $p = .02$). Results from these analyses are presented in table 5.

4. Discussion

These results will be discussed in section 3.1, along with the results from article 1.

Table 5. RCTQ subscale scores as a function of other instruments (multiple linear regression) in patients (n = 138)

Instrument	RCTQ thought overactivation*			RCTQ burden of thought overactivation**			RCTQ thought overexcitability***		
	β	t	*p*	β	t	*p*	β	t	*p*
YMRS	0.33	4.10	**<0.01**	0.11	1.38	.17	0.33	4.12	**<0.01**
QIDS-C16	0.03	0.25	0.80	-0.01	-.05	.95	-0.01	-0.01	0.99
BAI	0.33	3.68	**<.001**	0.41	4.84	**<0.01**	0.30	3.32	**<0.01**
PSWQ	0.17	1.79	0.07	0.20	2.24	**0.03**	0.22	2.30	**0.02**
RRS-brooding	0.09	0.84	0.40	0.23	2.20	**0.03**	0.18	1.63	0.11
RRS-reflection	0.09	1.01	0.31	-0.01	-0.13	0.90	-0.01	-0.11	0.92

Legend: RCTQ= Crowded Racing Thoughts Questionnaire; RRS= Rumination Response Scale; ASRM= YMRS= Young Mania Rating Scale ; QIDS-C16= Quick Inventory of Depressive Symptomatology; BAI= Beck Anxiety Inventory; PSWQ= Penn State Worry Questionnaire. *R^2 = .46 adjusted R^2 = .43, $F(6,122)=17.36$, $p < .001$. **R^2 = .52, adjusted R^2 = .50 $F(6,122)=22.23$, $p < .001$. ** *R^2 = .46, adjusted R^2 = .43, $F(6,122)=17.24$, $p < .001$..Significant results are presented in bold ($p < 0.05$).

References

A.P.A. (2000). Diagnostic and Statistical Manual of Mental Disorders, 4th Edition, Text Revision (4th edition). Washington, DC: American Psychiatric Association.

Atkinson, T. M., Rosenfeld, B. D., Sit, L., Mendoza, T. R., Fruscione, M., Lavene, D., … Basch, E. (2011). Using Confirmatory Factor Analysis to Evaluate Construct Validity of the Brief Pain Inventory (BPI). Journal of Pain and Symptom Management, 41(3), 558–565. https://doi.org/10.1016/j.jpainsymman.2010.05.008

Beck, A. T., Epstein, N., Brown, G., & Steer, R. A. (1988). An inventory for measuring clinical anxiety: psychometric properties. Journal of Consulting and Clinical Psychology, 56(6), 893–897.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometrika, 16(3), 297–334. https://doi.org/10.1007/BF02310555

Favre, S., Aubry, J.-M., Gex-Fabry, M., Ragama-Pardos, E., McQuillan, A., & Bertschy, G. (2003). [Translation and validation of a French version of the Young Mania Rating Scale (YMRS)]. L'Encephale, 29(6), 499–505.

Hirschfeld, R. M. a, Williams, J. B. w, Spitzer, R. L., Calabrese, J. R., Flynn, L., Keck, P. E., … Zajecka, J. (2000). Development and Validation of a Screening Instrument for Bipolar Spectrum Disorder: The Mood Disorder Questionnaire. The American Journal of Psychiatry, 157(11), 1873–1875.

Keizer, I., Piguet, C., Favre, S., Aubry, J.-M., Dayer, A., Gervasoni, N., … Bertschy, G. (2014). Subjective experience of thought overactivation in mood disorders: beyond racing and crowded thoughts. Psychopathology, 47(3), 174–184. https://doi.org/10.1159/000354781

Miller, S., Suppes, T., Mintz, J., Hellemann, G., Frye, M. A., McElroy, S. L., … Post, R. M. (2016). Mixed Depression in Bipolar Disorder: Prevalence Rate and Clinical Correlates During Naturalistic Follow-Up in the Stanley Bipolar Network. American Journal of Psychiatry, 173(10), 1015–1023. https://doi.org/10.1176/appi.ajp.2016.15091119

Nolen-Hoeksema, S., & Morrow, J. (1991). A prospective study of depression and posttraumatic stress symptoms after a natural disaster: The 1989 Loma Prieta earthquake.

Journal of Personality and Social Psychology, 61(1), 115–121. https://doi.org/10.1037/0022-3514.61.1.115

Rush, A. J., Trivedi, M. H., Ibrahim, H. M., Carmody, T. J., Arnow, B., Klein, D. N., … Keller, M. B. (2003). The 16-Item Quick Inventory of Depressive Symptomatology (QIDS), clinician rating (QIDS-C), and self-report (QIDS-SR): a psychometric evaluation in patients with chronic major depression. Biological Psychiatry, 54(5), 573–583.

Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, J. (2006). Reporting Structural Equation Modeling and Confirmatory Factor Analysis Results: A Review. The Journal of Educational Research, 99(6), 323–338. https://doi.org/10.3200/JOER.99.6.323-338

Stöber, J., & Bittencourt, J. (1998). Weekly assessment of worry: an adaptation of the Penn State Worry Questionnaire for monitoring changes during treatment. Behaviour Research and Therapy, 36(6), 645–656.

Suppes, T., Mintz, J., McElroy, S. L., Altshuler, L. L., Kupka, R. W., Frye, M. A., … Post, R. M. (2005). Mixed hypomania in 908 patients with bipolar disorder evaluated prospectively in the Stanley Foundation Bipolar Treatment Network: a sex-specific phenomenon. Archives of General Psychiatry, 62(10), 1089–1096. https://doi.org/10.1001/archpsyc.62.10.1089

Treynor, W., Gonzalez, R., & Nolen-Hoeksema, S. (2003). Rumination Reconsidered: A Psychometric Analysis. Cognitive Therapy and Research, 27(3), 247–259. https://doi.org/10.1023/A:1023910315561

Young, R. C., Biggs, J. T., Ziegler, V. E., & Meyer, D. A. (1978). A rating scale for mania: reliability, validity and sensitivity. The British Journal of Psychiatry: The Journal of Mental Science, 133, 429–435.

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Dispositional Mindfulness and Subjective Time in Healthy Individuals

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How a human observer perceives duration depends on the amount of events taking place during the timed interval, but also on psychological dimensions, such as emotional-wellbeing, mindfulness, impulsivity, and rumination. Here we aimed at exploring these influences on duration estimation and passage of time judgments. One hundred and seventeen healthy individuals filled out mindfulness (FFMQ), impulsivity (BIS-11), rumination (RRS), and depression (BDI-sf) questionnaires. Participants also conducted verbal estimation and production tasks in the multiple seconds range. During these timing tasks, subjects were asked to read digits aloud that were presented on a computer screen. Each condition of the timing tasks differed in terms of the interval between the presentation of the digits, i.e., either short (4-s) or long (16-s). Our findings suggest that long empty intervals (16-s) are associated with a relative underestimation of duration, and to a feeling that the time passes slowly, a seemingly paradoxical result. Also, regarding more mindful individuals, such a dissociation between duration estimation and passage of time judgments was found, but only when empty intervals were short (4-s). Relatively speaking, more mindful subjects showed an increased overestimation of durations, but felt that time passed more quickly. These results provide further evidence for the dissociation between duration estimation and the feeling of the passage of time. We discuss these results in terms of an alerting effect when empty intervals are short and events are more numerous, which could mediate the effect of dispositional mindfulness.

Keywords: time perception, dispositional mindfulness, duration estimation, passage of time, duration production

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INTRODUCTION

The subjective experience of duration is modulated by a number of contextual and individual factors independent of actual physical time. That is, the same time interval is experienced differently across individuals. Thus, time perception is involved in how one may feel according to the event taking place, and may play a crucial role in how one makes decisions in everyday life. For instance, if an individual overestimates the duration of a specific situation encountered in the past, during which time seemed to 'drag,' he might feel inclined to avoid it. Subjective time thereby involves at least two aspects – the judgment of the passage of time (i.e., how fast the time seems to pass) and the estimation of duration (i.e., how long an event seemed to have lasted), experiences which can vary independently of each other (Wearden et al., 2014). Personality traits, the nature of an event (as more or less attention capturing), and momentary physiological and psychological states are all involved in duration judgments. Here we designed a study in order to evaluate the relationship between dispositional mindfulness in a healthy population and different aspects of the experience of time in the multiple seconds range, such as the amount of events presented during the interval, and the kind of duration judgment required in the task – regarding the judgment of the passage of time and the estimation of duration.

Several factors should be controlled for when assessing empirically the experience of time. Findings suggest that the amount and the kind of events presented during an interval affect how alerting the event is judged to be, and thus how fast the passage of time and duration are estimated (Droit-Volet and Meck, 2007; Zakay, 2014). Essentially, the instructions given to participants before the actual task influence the judgment of time. When subjects are unaware that they are going to be asked questions about time (i.e., retrospective timing after the event or an interval has elapsed), they have to rely on memory retrieval. The more events and contextual changes are encoded and stored in memory the longer the duration is judged to be (Zakay and Block, 2004; Zakay, 2014). In contrast, when subjects are informed that the task they are going to perform is related to time (i.e., prospective timing), duration is estimated based on the attentional resources allocated to the task, i.e., duration estimation (rather than to the events). The more resources are allocated for timing, the longer the prospective duration judgment (Brown, 1997; Zakay and Block, 2004).

Multiple studies have found results consistent with this model (e.g., Block and Zakay, 1997; Wittmann and Paulus, 2008). Yet discordant results have also been reported in the literature, which seem to be related to the type, duration and complexity of information processed during the timed intervals (Wearden et al., 2014). Wearden (2008) included passage of time judgments in his study and found that, in a retrospective timing task, high information processing load (i.e., semantic vs. visual processing of words) was associated with a slowing of the passage of time when durations were relatively short (i.e., 18 s), and a speeding of the passage of time when durations were long (i.e., 72 s). However, there was no effect of the experimental manipulations on duration estimation. This dissociation between passage of time and duration judgments (see also Watt, 1991) suggests that passage of time judgments are particularly sensitive to the content of the events timed and how one subjectively reacts to this content (Wearden et al., 2014). All in all, these results first of all imply that the amount and the kind of events should be controlled for, and second, that the way subjects react to the amount of information during an interval has to be considered: the information may draw their attention or bore them depending on their disposition. Therefore, the experience of duration might be affected by subjective dimensions, such as mindfulness as a trait, and personality traits like impulsivity, or the tendency to ruminate.

Mindfulness affects the way individuals attend to the environment, regardless of the kind of events taking place. Mindfulness has been defined as intentionally focusing one's attention on experiences occurring in the present moment in a non-judgmental way, i.e., attending to and accepting events as they occur (Kabat-Zinn, 1990). It is a multi-faceted concept that can be either conceptualized as a personality trait, or as a skill that can be trained. People who are more mindful are more able to allocate attention to each present moment, regardless of the information processing load. This would extend even to periods without specific events, during which more mindful subjects tend to attend to each moment in an accepting way. Besides effects on attention, mindfulness may also affect time perception (Wittmann and Schmidt, 2014). One of the main aspects that link mindfulness to time perception is its focus on moment-to-moment awareness. Several studies suggest that there is a relationship between mindfulness training and the experience of duration (Berkovich-Ohana et al., 2012; Kramer et al., 2013; Sucala and David, 2013; Droit-Volet et al., 2015; Wittmann et al., 2015) but there is only few data regarding the impact of mindfulness as a personality trait. In one study, Wittmann et al. (2014) examined the relationship between dispositional mindfulness, evaluated via two self-report questionnaires (FMI, Walach et al., 2006; CHIME, Bergomi et al., 2013) and the performance on prospective timing tasks. The authors found a relationship between elevated levels of self-rated mindfulness, particularly the 'acceptance' subscale of the FMI, and increased time discrimination accuracy in the milliseconds and seconds range. However, this study did not assess the judgment of the passage of time, and the impact of the nature of the task (e.g., with more or less events) on the experience of duration.

There are also other personality traits that might affect duration judgments. Conceptually, impulsivity is on the other end of a spectrum with trait mindfulness and self-control, and several studies (e.g., Peters et al., 2011; Wittmann et al., 2014, 2015) found an inverse relationship between dispositional mindfulness and impulsivity. Furthermore, like mindfulness, time perception seems to be related to impulsive behavior. For example, when making choices between smaller immediate versus larger delayed outcomes, impulsive individuals tend to prefer the smaller immediate outcome more often as compared to more self-controlled participants, who choose more often the larger delayed outcomes (e.g., Baumann and Odum, 2012). This choice bias in impulsive individuals has been found to be related to an overestimation of long durations (Wittmann and Paulus, 2008; Baumann and Odum, 2012). Moreover, in patients with psychiatric conditions characterized by an increased impulsivity, such as borderline personality disorder, substance-use disorder, and ADHD, an overestimation and under-production of intervals ranging from seconds to minutes has been found consistently (e.g., Barkley et al., 2001; Smith et al., 2002; Berlin and Rolls, 2004; Berlin et al., 2004; Wittmann et al., 2007). However, to our knowledge, these studies did not partial out the effect of facets of impulsivity on time perception. Several factor analytic studies suggest indeed that, like mindfulness, impulsivity is a multi-faceted concept (e.g., Stanford et al., 2009), including a (i) cognitive subtrait, involved in making cognitive decisions, a (ii) motor subtrait, involved in acting without thinking, and a (iii) non-planning subtrait, characterized as a present-orientation or a lack of "futuring" (Patton et al., 1995; Stanford et al., 2009). The non-planning subtrait seems to be particularly related to duration judgments, and can be expected to predict performance in timing tasks. On the other hand, the motor subtrait might be selectively involved in duration production. In addition, none of the previous studies with highly impulsive individuals included judgments of the passage of time nor did they partial out the specific contribution of different personality traits (mindfulness, impulsivity or rumination) on estimation of duration.

Here we aimed at taking into account the two personality traits of mindfulness and impulsivity which have been associated with the experience of time. In addition, we evaluated the contribution of the tendency to ruminate as well as current depressive symptoms, because they might represent confounding factors (Thönes and Oberfeld, 2015). Rumination has been defined as a repetitive and analytical pattern of thinking found to be a vulnerability trait for the development of depression (Aldao et al., 2010). According to the Response Styles Theory (RST; Nolen-Hoeksema, 1987), rumination includes both self-reflection, considered to be an adaptive form of rumination, and brooding, i.e., a repetitive focus on one's negative emotions, considered to be maladaptive (Treynor et al., 2003). Maladaptive rumination is often accompanied by low mood, and a feeling that time is slowed down (e.g., Bschor et al., 2004; Boschloo et al., 2013; Marchetti et al., 2014). Conceptually, maladaptive rumination has been positively associated with impulsivity on the one hand, and negatively associated with mindfulness on the other hand (e.g., Paul et al., 2013; Marchetti et al., 2014; Selby et al., 2014; Crawley, 2015). Unlike brooding, self-reflection might be associated with mind-wandering and positive mood (Marchetti et al., 2014). Both aspects of rumination may thus have a distinct impact on time perception. This suggests that both facets associated with rumination tendency and current depressive mood should be taken into account when evaluating the specific contribution of mindfulness-proneness to duration judgments.

In our study, all subjects were tested in several experimental conditions, aimed at manipulating the amount of secondary-task events during duration judgments. The amount of events can have two opposite effects, as described above: it can divert attention from encoding duration, or it can lead subjects to feel less bored and be more attentive. To contrast these two possibilities, we manipulated the duration of empty intervals (4 vs. 16 s) between secondary-task events in a series of prospective tasks of duration estimation (32-s and 128-s duration) and duration production (30-s and 60-s duration). In addition to the duration judgments, we asked subjects to evaluate the subjective speed of the passage of time after the verbal estimation task. If subjects allocate more attention to time when empty intervals are long, then we should find a relative overestimation of durations for 16-s empty intervals. If the feeling of the passage of time is directly derived from duration estimation, an overestimation of duration should be associated with the feeling that time passes slowly. The feeling of the passage of time might be dissociated from duration estimation, however, (Wearden et al., 2014; Wearden, 2015). For example, long empty intervals may not affect attention allocation, but may be essentially boring. Reversely, short empty intervals may have an alerting effect. In that case, long empty intervals might lead subjects to evaluate the passage of time as being slower compared to shorter ones. Self-report questionnaires were used in order to evaluate the relationship between performance in these different conditions and personality traits. Our study design should be able to partial out the specific impact of mindfulness-proneness on duration evaluation and/or on the feeling of the passage of time, and to check whether such effects are independent or not from impulsivity, rumination tendency, and current mood.

MATERIALS AND METHODS

Participants

For this cross-sectional study design, 117 healthy individuals aged 17–56 years ($M = 26$, $SD = 7.7$) were recruited among the staff and students at the University Hospital of Strasbourg. Women constituted 59% of the sample. Out of the 117 participants, 78 were university students, mostly in psychology and medical schools. It is to be noted that the results reported below were similar when only the university students were included in the analyses. Participants provided informed consent prior to inclusion in the study in accordance with the Declaration of Helsinki.

Materials and Procedures

Timing Tasks

Equipment and stimuli

Time estimation and production tasks were generated via the Microsoft PowerPoint software (Wittmann et al., 2015). The presentation was displayed on a 17′ LCD color monitor. Participants viewed the display from a distance of 60 cm. During the timing tasks, digits were displayed, white on a black background, and were well-contrasted. Digits were 2.4° of visual angle high (1 cm corresponds to 1° of visual angle at a distance of 57 cm). Digits were presented on the center of the screen inside a red-lined square that measured 4.8° of visual angle and they were displayed for the duration of 1 s. The keyboard was used when motor responses were required. Four verbal estimation tasks, followed by a subjective judgment of the passage of time, were administered. Following the estimation tasks, four production tasks were administered.

Procedure for the verbal estimation and judgment of the passage of time tasks

Participants were asked to read aloud the numbers that were presented on the center of the computer screen, and estimate the duration of the task when it was over. The secondary number reading task was meant to prevent counting, and we additionally asked subjects to avoid counting while performing the task. Following the verbal estimation of the duration, subjects were asked to complete a visual analog scale (VAS), ranging from 1 (time passed very fast) to 10 (time passed very slowly), in order to evaluate their subjective perception of the passage of time during the estimation task. The conditions of the verbal estimation task differed in terms of their total duration (32 s vs. 128 s), as well as the stimulus onset asynchrony (SOA) between the digits that were presented and read aloud (mean = 4 s vs. mean = 16 s). The four conditions were presented in random order. In the 4-s SOA conditions, SOA actually ranged from 3 s to 5 s (mean = 4 s), and interval durations were presented in a random manner, in order to avoid anticipation. Likewise, in the 16-sec SOA conditions, SOA actually ranged from 13 to 19 s (mean = 16 s), and interval durations were presented in a random manner.

Procedure for the production tasks

Participants were asked to read aloud the numbers that were presented on the center of the screen, and press the "escape" button on the computer keyboard when 30 s (4 s vs. 16 s SOA between numbers) or 60 s (4 s vs. 16 s SOA between numbers) had passed. Like the estimation tasks, the secondary number reading task was meant to prevent counting, and we additionally asked subjects to avoid counting while performing the task. The actual time lapse produced by the participants was recorded via a timer. Like the estimation tasks, production tasks differed in terms of the duration expected (30 vs. 60 s), and the SOA between the digits that were presented (mean = 4 s vs. mean = 16 s). The four conditions were presented in a random order.

Self-Report Questionnaires

Participants filled-out four self-report questionnaires in-between verbal estimation and production task conditions. Questionnaires were administered in a fixed order.

Mindfulness

The Five Facets Mindfulness Questionnaire (FFMQ; Baer et al., 2008) is a 39-item self-report questionnaire which contains items rated on a five-point scale ranging from 1 (never or rarely true) to 5 (very often or always true). Mindfulness is measured on the basis of a five-dimensional structure with the factor 'observing' referring to the awareness of internal and external experiences; the factor 'describing' consisting of items related to 'labeling internal experiences with words'; the 'acting with awareness' factor referring to the attention one pays to present activities; the 'non-judgment of inner experiences' factor relating to 'the tendency to take a non-evaluative stance toward thoughts and feelings'; and the 'non-reactivity to inner experience' factor referring to the tendency to allow 'thoughts and feelings to come and go.' This questionnaire has good psychometric properties, and was constructed based on the items of five other mindfulness questionnaires. Indeed, Cronbach's alpha for all of the five factors of the FFMQ are higher than 0.75, suggesting good internal consistency (Heeren et al., 2011). Because of its multifaceted nature, the FFMQ is supposed to reliably measure the complex construct of mindfulness (Sauer and Baer, 2010). The version of the scale we used has been validated in French (Heeren et al., 2011).

Impulsivity

The Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995) is a 30-item self-report questionnaire with items rated on a 4-point scale ranging from 1 (rarely) to 4 (almost always). Items are grouped into three subscales corresponding to non-planning impulsivity ("I plan tasks carefully"), motor impulsivity ("I do things without thinking"), and cognitive impulsivity ("I concentrate easily"). Patton et al. (1995) reported an Alpha coefficient for the BIS total score of 0.82, suggesting an overall good internal consistency. The French version of the scale has been validated (Baylé et al., 2000).

Rumination

The Ruminative Response Scale (RRS; Nolen-Hoeksema and Morrow, 1991; Treynor et al., 2003) is a 22-item self-report questionnaire which evaluates two aspects of trait-rumination: 'Brooding' (five items) taps passive rumination on negative mood and is considered to be maladaptive whereas 'reflection' (five items) refers to active efforts to understand one's negative feelings, and is considered to be adaptive. A total score is obtained *via* the sum of the 22 items. Items are rated on a scale of 1 ("almost never") to 4 ("almost always"). In their psychometric analysis of the reflection and brooding subscales of the RRS, Treynor et al. (2003) found an Alpha coefficient of 0.72 and 0.77, respectively. The French version of the scale has been validated (Jermann et al., 2010).

Mood

The Beck Depression Inventory short-form (BDI-sf; Beck and Beamesderfer, 1974) is a 13-item self-report scale that measures the severity of depressive symptoms. Items are rated on a scale ranging from 0 (the symptom is absent) to 3 (maximum severity). This scale has been validated in French (Bourque and Beaudette, 1982).

RESULTS

Analyses were undertaken using the Statistica® software. For each one of the three timing tasks – verbal estimation, judgment of the passage of time, and production –, we conducted a repeated measures ANOVA with two within-subject factors, task duration (32 vs. 128 s) and SOA between successive numbers (4 s vs. 16 s).

Verbal Estimation, Judgment of the Passage of Time, and Temporal Production

Overall, participants on average overestimated durations in both the 32-s and the 128-s duration conditions (mean = 39.41 s SD = 24.01 and mean = 144.23 s, SD = 78.08, respectively). In the verbal estimation tasks, there was no significant main effect of the SOA, $F(1,116) = 3.06$, $p = 0.08$, $\eta^2 = 0.026$, but duration had a significant effect, $F(1,116) = 333.48$, $p < 0.001$, $\eta^2 = 0.742$ (cf. Supplementary Material for means and standard errors across conditions in this task). As expected, estimations were longer when the actual durations were longer (128 s) as compared to when they were shorter (32 s). In the judgment of the flow of time, there was a significant main effect of both the SOA and duration, $F(1,116) = 66.76$, $p < 0.001$, $\eta^2 = 0.366$, and $F(1,116) = 161.33$, $p < 0.001$, $\eta^2 = 0.582$, respectively. Regardless of the duration condition, subjects judged the time to pass faster when the SOA was short (4 s), compared to when it was long (16 s; cf. **Figure 1** and Supplementary Material for means and standard

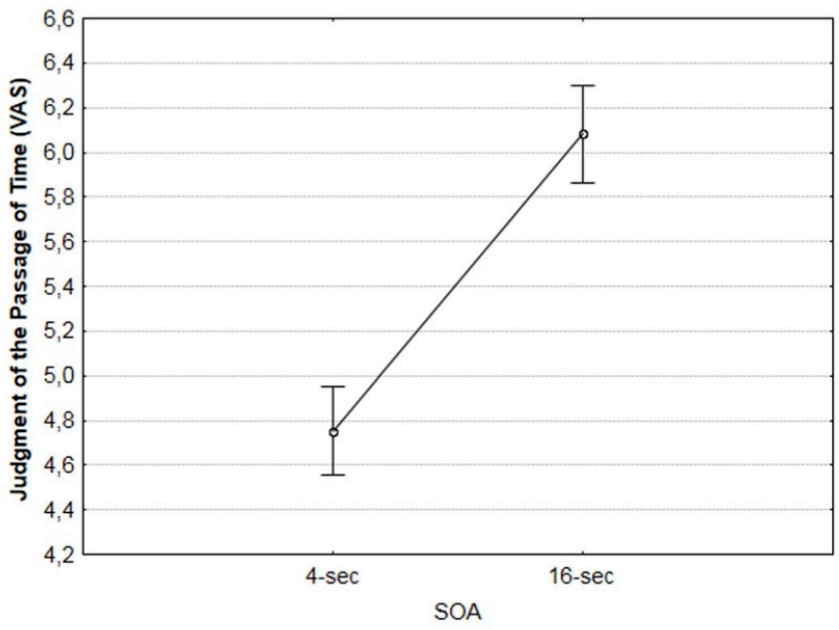

FIGURE 1 | Effect of the SOA between numbers on the judgment of the passage of time (VAS).

errors across conditions in this task). Also, as expected, subjects judged the time to pass faster when the actual duration was short (32 sec), compared to when it was long (128 s).

In the production tasks, on average, subjects overproduced durations in both the 30-s and the 60-s duration conditions (mean = 35.20, *SD* = 13.64, and mean = 67.85 and *SD* = 26.07, respectively). Moreover, there were significant main effects of both the SOA and the duration on the production performance, $F(1,116) = 9.11$, $p < 0.001$, $\eta^2 = 0.072$, and $F(1,116) = 466.35$, $p < 0.001, \eta^2 = 0.800$, respectively. As expected, subjects produced longer intervals when the duration was long (60 s), compared to when it was short (30 s). More interestingly, subjects overproduced more when the SOA was long (16 s) compared to when it was short (4 s), regardless of the task duration. There was a significant duration X SOA interaction, $F(1,116) = 6.24$, $p = 0.01$, $\eta^2 = 0.052$. *Post hoc* Tukey test analyses revealed that only in the 60-s duration condition SOA had a significant effect on performance, with subjects overproducing more when the SOA was long (16 s) compared to when it was short (4 s; cf. **Figure 2** and Supplementary Material for means and standard errors across conditions in this task).

Correlation Analyses between Psychological Dimensions

Regarding the correlation results reported below, in addition to presenting significance levels of $p < 0.05$ and $p < 0.01$, we applied a rigorous method of alpha level adjustment for multiple comparisons, the false discovery rate (FDR) method. FDR is a multiple comparisons correction, developed by Benjamini and Hochberg (1995), where we set the initial *p*-value to 0.05.

We conducted a first order correlation analyses in order to assess the relationship between the psychological dimensions evaluated via the questionnaires, namely trait-mindfulness, current mood, trait-impulsivity, and trait-rumination. Our aim was to check whether we could replicate the typically found relationships between mindfulness, impulsivity, rumination, and mood. Hence, we report here the correlations between different facets of mindfulness and different facets of these psychological dimensions. Overall, our results suggest that subjects who are more mindful, are also less impulsive (**Table 1**), ruminate less (**Table 2**), and report less depressive mood (**Table 3**). There is only one correlation going against those associations, i.e., a positive relationship between one subscale of the FFMQ, 'observing' and the subscales as well as the total score on the RRS. These correlations suggest that subjects, who observe more their inner experiences, are also more prone to rumination.

Regression Analyses

The regressions between the psychological dimensions suggest that several aspects of personality and mood are related to dispositional mindfulness. Any correlation between performance and the FFMQ may thus be partly due to another trait of personality. Thus, we conducted a multiple regression analysis

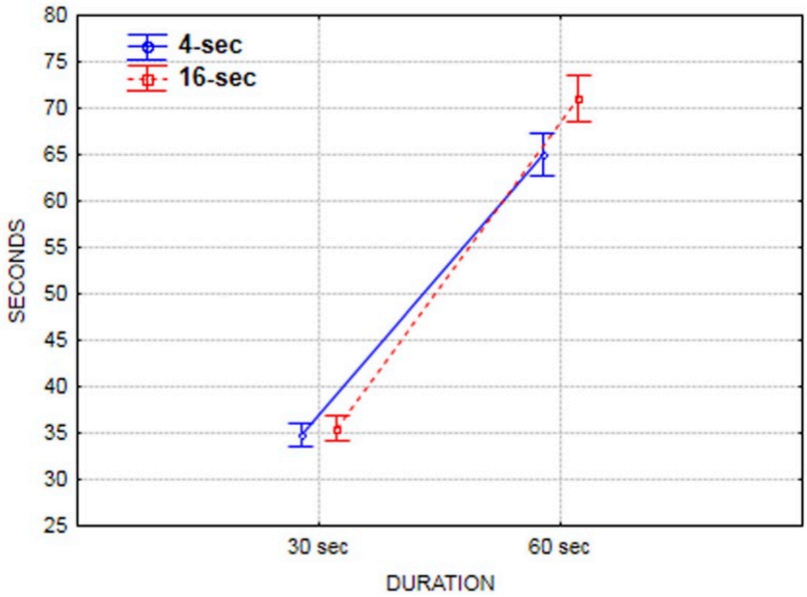

FIGURE 2 | Performance in the production task as function of the duration and the SOA.

TABLE 1 | Relationship between mindfulness and impulsivity.

	FFMQ Observing	FFMQ Describing	FFMQ Acting with awareness	FFMQ Non-reactivity	FFMQ Non-judgment	FFMQ Total
BIS non-planning	−0.01	−0.19*	−0.27***	−0.16	−0.12	−0.28***
BIS Motor	0.04	0.16	−0.23***	0.03	0.06	0.01
BIS Cognitive	0.08	−0.23***	−0.51***	0.02	−0.41***	−0.42***
BIS Total	0.05	−0.12	−0.45***	−0.07	−0.19*	−0.31***

*$p < 0.05$; ***FDR corrected FFMQ, Five Facets Mindfulness Questionnaire; BIS, Barratt Impulsiveness Scale.*

TABLE 2 | Relationship between mindfulness and rumination.

	FFMQ Observing	FFMQ Describing	FFMQ Acting with awareness	FFMQ Non-reactivity	FFMQ Non-judgment	FFMQ Total
RRS brooding	0.21***	−0.05	−0.25***	−0.36***	−0.41***	−0.30***
RRS reflection	0.37***	0.14	−0.20***	−0.09	−0.21***	0.03
RRS total	0.34***	−0.01	−0.40***	−0.19*	−0.38***	−0.21***

*$p < 0.05$; ***FDR corrected; RRS, Ruminative Responses Scale; FFMQ, Five Facets Mindfulness Questionnaire.*

TABLE 3 | Relationship between mindfulness and mood.

	FFMQ Observing	FFMQ Describing	FFMQ Acting with awareness	FFMQ Non-reactivity	FFMQ Non-judgment	FFMQ Total
BDI-sf	0.07	−0.21*	−0.29***	−0.14	−0.52***	−0.40***

*$p < 0.05$; ***FDR corrected; FFMQ, Five Facets Mindfulness Questionnaire; BDI, Beck Depression Inventory – short form.*

to distinguish between the contribution of all evaluated aspects of personality and mood on timing performance. In the introduction, we suggested that specific facets of the personality dimensions assessed could be more specifically related to time perception than others. Because of this, all the personality subscales were entered into the model. Eleven predictors – all the subscales from four questionnaires, the FFMQ, the RRS, the BDI, and the BIS –, were simultaneously entered into the model: (i) 5

FFMQ subscores, (ii) 2 RRS subscores, (iii) BDI total score, and (iv) 3 BIS subscores.

Verbal Estimation

In the 4-s SOA conditions of the verbal estimation tasks, only the FFMQ subscales 'acting with awareness' and 'observing' were significant predictors of performance respectively in the 32-s (β = 0.25, $p = 0.031$) and 128-s (β = 0.25, $p = 0.018$) duration conditions (cf. **Table 4**; see the Supplementary Material for all data). Regardless of the duration condition, only when the SOA is relatively short (4-s) elevated levels of specific facets of mindfulness were associated with an overestimation of durations. In the 16-s SOA conditions of the verbal estimation tasks, there were no significant predictors of performance.

Judgment of the Passage of Time

Significant predictors of performance in the judgment of the passage of time were only found in the 4-s SOA conditions. The 'reflection' subscale of the RRS was a significant predictor of performance in the 32-s condition (β = 0.24, $p = 0.049$). (cf. **Table 5**). An increased tendency to display an adaptive form of rumination was associated with the feeling that time passed slowly during the 32-s duration condition. On the other hand, the 'acting with awareness' subscale of the FFMQ was a significant predictor of performance in the 128-s duration conditions of this task (β = −0.25, $p = 0.046$) (cf. **Table 5**). Elevated levels of a specific facet of mindfulness (i.e., 'acting with awareness') were associated with an increased feeling that the time passed fast during the 128-s duration condition. In contrast, in the 16-s SOA conditions there were no significant predictors of performance.

Production Tasks

In the 4-s SOA conditions of this task, only the FFMQ 'describing' subscale was a significant predictor of performance when subjects had to produce an interval of 30 s (β = −0.28, $p = 0.011$; cf. **Table 6**). Therefore, elevated levels of this specific facet of mindfulness were associated with a relative underproduction (i.e., overestimation) of duration. In the 16-s SOA conditions, only the RRS 'reflection subscale' was a significant predictor of performance in the 30-s condition of this task (β = 0.23, $p = 0.048$; cf. **Table 7**). An increased tendency to display this adaptive form of rumination was associated with a relative overproduction (i.e., underestimation) of duration.

DISCUSSION

The study results suggest that duration perception and the feeling of the passage of time are influenced both by external events and by personality traits. Overall, there was no effect of the length of the empty interval (4-s *vs.* 16-s) on verbal

TABLE 4 | Multiple linear regression analysis between verbal estimation (4-s SOA conditions) and significant psychological dimensions.

	Estimation 32-s (4-s SOA)*				Estimation 128-s (4-s SOA)**			
	B	β	*t*	*p*	*B*	β	*t*	*P*
FFMQ Observing	0.07	0.02	1.83	0.07	**3.24**	**0.25**	**2.40**	**0.02**
FFMQ acting with awareness	**1.00**	**0.25**	**2.19**	**0.03**	1.60	0.10	0.86	0.39

B, regression coefficient; β, standardized regression coefficient; FFMQ, Five Facets Mindfulness Questionnaire. * $\Delta R^2 = 0.172$, *adjusted* $R^2 = 0.085$, $F(11,105) = 1.981$, $p = 0.037$. ** $\Delta R^2 = 0.142$, *adjusted* $R^2 = 0.052$, $F(11,105) = 1.583$, $p = 0.114$. *Significant values in bold.*

TABLE 5 | Multiple linear regression analysis between judgment of the passage of time (4-s SOA conditions) and significant psychological dimensions.

	Judgment of the passage of time 32-s (4-s SOA)*				Judgment of the passage of time 128-s (4-s SOA)**			
	B	β	*t*	*p*	*B*	β	*t*	*P*
FFMQ acting with awareness	−0.05	−0.17	−1.44	0.15	**−0.08**	**−0.247**	**−2.02**	**0.046**
RRS Reflection	**0.11**	**0.24**	**1.98**	**0.049**	0.03	0.06	0.51	0.61

B, regression coefficient; β, standardized regression coefficient; FFMQ = Five Facets Mindfulness Questionnaire; RRS = Ruminative Responses Scale. * $\Delta R^2 = 0.088$, *adjusted* $R^2 = –$, $F(11,105) = 0.917$, $p = 0.527$. ** $\Delta R^2 = 0.051$, *adjusted* $R^2 = –$, $F(11,105) = 0.514$, $p = 0.890$. *Significant values in bold.*

TABLE 6 | Multiple linear regression analysis between production tasks (4-s SOA conditions) and significant psychological dimensions.

	Production 30-s (4-s SOA)*				Production 60-s (4-s SOA)**			
	B	β	*t*	*p*	*B*	β	*t*	*P*
FFMQ Describing	**−0.68**	**−0.28**	**−2.58**	**0.01**	−0.45	−0.10	−0.87	0.38

B, regression coefficient; β, standardized regression coefficient; FFMQ, Five Facets Mindfulness Questionnaire. * $\Delta R^2 = 0.156$, *adjusted* $R^2 = 0.067$, $F(11,105) = 1.765$, $p = 0.0695$. ** $\Delta R^2 = 0.059$, *adjusted* $R^2 = –$, $F(11,105) = 0.599$, $p = 0.826$. *Significant values in bold.*

TABLE 7 | Multiple linear regression analysis between production tasks (16-s SOA conditions) and significant psychological dimensions.

	Production 30-s (16-s SOA)*				Production 60-s (16-s SOA)**			
	B	**β**	***t***	***P***	***B***	**β**	***t***	***P***
RRS Reflection	**0.88**	**0.23**	**2.00**	**0.048**	−0.001	−0.00	−0.00	0.99

B, regression coefficient; β, standardized regression coefficient; RRS, Ruminative Responses Scale. * $\Delta R^2 = 0.140$, *adjusted* $R^2 = 0.050$, $F(11,105) = 1.554$, $p = 0.123$. ** $\Delta R^2 = 0.107$, *adjusted* $R^2 = 0.013$, $F(11,105) = 1.143$, $p = 0.336$. *Significant values in bold.*

estimates of duration, but long empty intervals (16-s) led to a relative overproduction (i.e., underestimation) of durations. In addition, compared to short empty intervals (4-s), long empty intervals (16-s) were associated with a slowing of the feeling of the passage of time. Thus, we found a dissociation between passage of time and duration judgments: the feeling that time passes slowly is associated with estimations that durations are shorter than they are. Regarding personality dimensions, a dissociation between passage of time and duration judgments was also found: when empty intervals were short (4-s) increased levels of self-reported mindfulness were associated with both an overestimation of durations, and with a feeling that the time passes fast.

The results concerning the effects of different SOAs in the time perception tasks suggest that judgments of the passage of time were based on the feeling of boredom rather than on duration estimates *per se*. This assumption is crucial to interpret the whole pattern of results, and we will develop it first. Subjects knew in advance that they would have to estimate durations (prospective judgments), and we thus expected that more attention to duration itself would lead to lengthened duration estimates, i.e., overestimation and underproduction (Zakay and Block, 2004). Had this been the case, a high number of events, i.e., with 4-s SOAs, should have distracted subjects from time. In contrast, when empty intervals were long, attention should have been more easily diverted from the secondary ongoing task (reading numbers aloud) and be more focused on time itself, which should have led to an even stronger overestimation of durations. Hence durations should have been judged as being longer for long empty intervals (16-s SOAs) than for short empty intervals (4-s SOAs). This was not the case, however. Regarding duration estimation, there was no main effect of the SOA. Moreover, in the production tasks, long empty intervals led to an amplified overproduction, i.e., underestimation of durations. Hence, longer empty intervals of 16-s do not lead subjects to attend more to time, and, as a consequence, to lengthened duration estimates. In addition, the passage of time did not systematically co-vary with duration perception. There was only one case in which it did: Long duration conditions (128-s) were associated with a relative slowing of the passage of time compared to short ones (32-s). This suggests that subjects feel that time passes more slowly when actual durations are indeed longer. This could have been interpreted as a conflation of passage of time judgments with duration judgments. However, within the same duration conditions, subjects felt that the time passed faster when empty intervals were short (4-s) compared to when they were long (16-s), although duration estimates did not differ between the two conditions. If passage of time judgments had reflected duration perception *per se*, then a shortening of duration estimates should have been associated with a feeling that time passes fast (and conversely). Long empty intervals led to an overproduction, which, according to the standard cognitive pacemaker-accumulator model, corresponds to a shortening of duration estimates (Zakay and Block, 2004; Droit-Volet and Meck, 2007; Wearden et al., 2014). This relative shortening of duration should thus have been associated with a feeling that time passes faster. However, the results showed the reverse. Long empty intervals led to an overproduction (underestimation) of durations, but also to a feeling that time passes slowly. Similar dissociations between the subjective passage of time and duration estimation judgments were observed when considering psychological dimensions. Compared to other psychological dimensions, mindfulness was the main predictor of performance on duration estimation and the passage of time judgments for short (4-s SOA) empty intervals. However, high levels of mindfulness were associated with both a greater overestimation of duration, and with a faster passage of time. That is, we show a dissociation between duration estimation and the judgment of passage of time, as more mindful individuals in one condition relatively overestimated duration but also felt that the time passed faster. Again, if the evaluation of the passage of time had been directly related to duration estimation, overestimation of durations should have led to the feeling that time passed slowly, whereas we observed the reverse relation. This means that the judgment of the subjective passage of time reflects something different than duration estimation. Our results do not seem to be easily explained by boredom either.

Past studies have reported a relationship between boredom and a slowing of the passage of time (Watt, 1991; Wittmann and Paulus, 2008; Wearden et al., 2014). As suggested by Zakay (2014), boredom may not only induce the feeling that time passes slowly, but may also increase the attentional resources allocated to time. Indeed, in a boring situation, subjects would look forward to the end of the boring period, and thus would attend more to time, leading to a lengthening of duration estimation. If the 16-s empty interval is experienced as unusually long, it should lead subjects to both an underproduction, i.e., a lengthening of duration perception, and the feeling that time passes more slowly. As underlined above, this was not observed. Even if long (16-s) intervals were associated with a slowing of the passage of time, they did not lead subjects to attend more to time and, as a consequence, to an overestimation of durations. Wearden (2015) suggested recently that the feeling of the passage of time and duration estimation are two independent dimensions, and our results are consistent with this proposal. The duration of the tasks as a whole was rather short (i.e., up to 128-s for verbal estimation and 60-s for production tasks), and subjects may not have felt bored enough to attend more to time when empty intervals were long (16-s) compared to when they were short (4-s). However, the structure of our experiment may suggest yet another possibility. According to the model of Zakay and Block (2004), attention is allocated to either time or the task at hand, but not to both. This is particularly well adapted to everyday life, when a stimulating task possibly captures all one's attention, leading subjects to 'lose track of time.' However, in the case of empty intervals, it is extremely difficult to control the kind of internal information processing that subjects might engage themselves in Zakay (1993). In non-stimulating situations, they could either attend to time (e.g., because they are bored), or mind-wander. It is perfectly possible that the regular interruption of empty intervals by the presentation of numbers prevented subjects from mind-wandering. This would not have been the case for 16-s intervals though, because they were exceptionally long. Hence, if mind-wandering was more frequent during long empty intervals, it might have paradoxically distracted subjects from attending to time, contrary to our initial predictions. If, at all, 4-s intervals may have produced a non-specific alerting effect, which might have helped subjects to be more attentive both to temporal and non-temporal events, thus leading to less overproduction when empty intervals were short (4-sec SOAs). An explanation in terms of alertness is consistent with results reported by Treisman (1963) and Wearden (2008), and recent studies by Wearden et al. (2014) and Droit-Volet and Wearden (2015). These authors suggest that increased arousal, which might also be translated as increased alertness, may be associated to both a lengthening of durations, and to a faster passage of time, as observed in the present study. Such a non-specific attentional effect might also explain the results regarding dispositional mindfulness.

To our knowledge, this is the first study to partial out the specific contributions of dispositional mindfulness on judgments of multiple-seconds intervals. Before developing this point, it is important to note that our evaluation of personality traits is consistent with the literature. We found a significant negative relationship between (i) dispositional mindfulness and impulsivity (e.g., Wittmann et al., 2014), (ii) mindfulness and rumination (e.g., Paul et al., 2013; Marchetti et al., 2014; Crawley, 2015), and (iii) mindfulness and current depressive symptoms (e.g., Shorey et al., 2014). The replication of results found in earlier studies suggests that self-report measures are reliable, and that these psychological dimensions are strongly related to each other. However, when all of them were taken into account, only dispositional mindfulness and reflection-rumination significantly predicted performance on both duration estimation and passage of time judgments. Indeed, in our study, mindfulness was associated with a greater overestimation of duration and a faster passage of time, and the opposite was found for reflection-rumination. Regarding passage of time judgments, as mentioned before, long empty intervals led to a feeling that time passed more slowly, whereas there was no effect of the length of the empty interval on verbal estimates of duration. When personality dimensions were taken into account, only when empty intervals were short (4-s SOA) did mindfulness and trait reflection-rumination predict performance on the feeling of the passage of time. This suggests that, regardless of personality traits, when empty intervals are long (16-s SOA), subjects as a whole feel that time passes more slowly. This might be akin to a ceiling effect, where 16-s intervals are too long to distinguish more mindful from less mindful individuals. In contrast, when empty intervals are short, personality traits such as mindfulness and trait reflection-rumination predict, in a distinctive manner, the way subjects feel that the time has passed – either fast or slow, respectively.

Since high levels of mindfulness were related to a relative speeding of the passage of time, this suggests that highly mindful subjects were rather less bored and more attentive to the secondary ongoing task, whereas the opposite would hold true for individuals with higher values in trait reflection-rumination, who were probably more bored and reported a slowing of the passage of time. The fact that more mindful subjects are more attentive to the ongoing task is consistent with previous studies showing improved performance on attention tasks in these subjects (e.g., Ainsworth et al., 2013). Also, consistent with this interpretation, it is interesting to note that 'acting with awareness' was the only mindfulness subscale which predicted performance on passage of time judgments in our study. This indicates that those individuals, who are more able to allocate attention to present non-temporal events, are those who feel that the time passes faster. In addition, being more mindful during the time perception task itself leads to longer duration estimates, as found in our study. As suggested above, this might be explained by a non-specific effect of attention. If mindful subjects are particularly attentive to present events, and if these events have a non-specific arousal effect, then these attention mechanisms would explain why highly mindful subjects overestimate durations, on the one hand, and feel that time passes faster, on the other hand. These results nevertheless should be interpreted with caution, since a high number of psychological dimensions were entered in our regression model, and only a few facets of mindfulness and rumination seemed to be related to time perception. Although we checked for multiple comparisons, it is difficult to exclude the possibility of false positives, and it is also possible that some relationships were overlooked due to the alpha adjustment for multiple testing.

There are a few limitations to this study. First of all, the majority of our sample comprised young students, which raises the question of the generalizability of our findings. Future studies should include more individuals in other age groups, since time perception abilities may change during the life-span (Ulbrich et al., 2007; Wearden, 2015). Second, the concept of mindfulness is derived from eastern Buddhist tradition, and whether self-report questionnaires are able to evaluate the psychological mechanisms involved in this concept is still a matter of debate (Grossman, 2011). Third, the design of our study makes it difficult to determine how individuals responded to empty intervals, and whether they felt bored during the task. Thus, boredom – as a personality trait and as a state related to the task – should be assessed directly in future studies. In addition, the mechanisms involved in passage of time judgments are still hypothetical, and deserve to be explored in a more thorough manner. Finally, the relationship between time perception and other psychological dimensions, such as the tendency to self-reflect or mind-wander, should be addressed in a more in-depth manner in future studies.

All in all, our results are nonetheless in line with findings reported by Wittmann et al. (2014) who suggested that, as a personality trait, mindfulness is associated with duration estimation. They are also consistent with results in experienced mindfulness meditators, since several studies have shown that meditators relatively overestimate durations in the milliseconds to seconds and also minutes range (Kramer et al., 2013; Sucala and David, 2013; Droit-Volet et al., 2015). Moreover, our findings add to those showing dissociation between duration judgments and the feeling of the passage of time (Wearden et al., 2014; Wearden, 2015).

AUTHOR CONTRIBUTIONS

AG and MW devised the study, with the help of LW. LW recruited and tested the subjects, and analyzed the results with the help of AG and MW. All authors (LW, MW, GB, and AG) interpreted the data. LW wrote the first draft of the manuscript. All authors (LW, MW, GB, and AG) reviewed and approved the manuscript.

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SUPPLEMENTARY MATERIAL

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REFERENCES

Ainsworth, B., Eddershaw, R., Meron, D., Baldwin, D. S., and Garner, M. (2013). The effect of focused attention and open monitoring meditation on attention network function in healthy volunteers. *Psychiatry Res.* 210, 1226–1231. doi: 10.1016/j.psychres.2013.09.002

Aldao, A., Nolen-Hoeksema, S., and Schweizer, S. (2010). Emotion regulation strategies across psychopathology: a meta-analytic review. *Clin. Psychol. Rev.* 30, 217–237. doi: 10.1016/j.cpr.2009.11.004

Baer, R. A., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., et al. (2008). Construct validity of the five facet mindfulness questionnaire in meditating and nonmeditating samples. *Assessment* 15, 329–342. doi: 10.1177/1073191107313003

Barkley, R. A., Edwards, G., Laneri, M., Fletcher, K., and Metevia, L. (2001). Executive functioning, temporal discounting, and sense of time in adolescents with attention deficit hyperactivity disorder (ADHD) and oppositional defiant disorder (ODD). *J. Abnorm. Child Psychol.* 29, 541–556. doi: 10.1023/A:1012233310098

Baumann, A. A., and Odum, A. L. (2012). Impulsivity, risk taking, and timing. *Behav. Process.* 90, 408–414. doi: 10.1016/j.beproc.2012.04.005

Baylé, F. J., Bourdel, M. C., Caci, H., Gorwood, P., Chignon, J. M., Adés, J., et al. (2000). Factor analysis of french translation of the Barratt impulsivity scale (BIS-10). *Can. J. Psychiatry* 45, 156–165.

Beck, A. T., and Beamesderfer, A. (1974). Assessment of depression: the depression inventory. *Mod. Probl. Pharmacopsychiatry* 7, 151–169. doi: 10.1159/000395074

Benjamini, Y., and Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to powerful testing. *J. R. Statist. Soc. B* 57, 289–300.

Bergomi, C., Tschacher, W., and Kupper, Z. (2013). Measuring mindfulness: first steps towards the development of a comprehensive mindfulness scale. *Mindfulness* 4, 18–32. doi: 10.1007/s12671-012-0102-9

Berkovich-Ohana, A., Glicksohn, J., and Goldstein, A. (2012). Mindfulness-induced changes in gamma band activity–implications for the default mode network, self-reference and attention. *Clin. Neurophysiol.* 123, 700–710. doi: 10.1016/j.clinph.2011.07.048

Berlin, H. A., and Rolls, E. T. (2004). Time perception, impulsivity, emotionality, and personality in self-harming borderline personality disorder patients. *J. Pers. Disord.* 18, 358–378. doi: 10.1521/pedi.2004.18.4.358

Berlin, H. A., Rolls, E. T., and Kischka, U. (2004). Impulsivity, time perception, emotion and reinforcement sensitivity in patients with orbifrontal cortex lesions. *Brain* 127, 1108–1126. doi: 10.1093/brain/awh135

Block, R. A., and Zakay, D. (1997). Prospective and retrospective duration judgments: a meta-analytic review. *Psychon. Bull. Rev.* 4, 184–197. doi: 10.3758/BF03209393

Boschloo, L., Vogelzangs, N., van den Brink, W., Smit, J. H., Beekman, A. T., and Penninx, B. W. (2013). The role of negative emotionality and impulsivity in depressive/anxiety disorders and alcohol dependence. *Psychol. Med.* 43, 1241–1253. doi: 10.1017/S0033291712002152

Bourque, P., and Beaudette, D. (1982). Psychometric study of the Beck Depression Inventory on a sample of French-speaking university students. *Can. J. Behav. Sci.* 14, 211–218. doi: 10.1037/h0081254

Brown, S. W. (1997). Attentional resources in timing: interference effects in concurrent temporal and nontemporal working memory tasks. *Percept. Psychophys.* 59, 1118–1114. doi: 10.3758/BF03205526

Bschor, T., Ising, M., Bauer, M., Lewitzka, U., Skerstupeit, M., Müller-Oerlinghausen, B., et al. (2004). Time experience and time judgment in major depression, mania and healthy subjects. A controlled study of 93 subjects. *Acta Psychiatr. Scand.* 109, 222–229. doi: 10.1046/j.0001-690X.2003.00244.x

Crawley, R. (2015). Trait mindfulness and autobiographical memory specificity. *Cogn. Process.* 16, 79–86. doi: 10.1007/s10339-014-0631-3

Droit-Volet, S., Fanget, M., and Dambrun, M. (2015). Mindfulness meditation and relaxation training increases time sensitivity. *Conscious. Cogn.* 31, 86–97. doi: 10.1016/j.concog.2014.10.007

Droit-Volet, S., and Meck, W. H. (2007). How emotions colour our perception of time. *Trends Cogn. Sci.* 11, 504–513. doi: 10.1016/j.tics.2007.09.008

Droit-Volet, S., and Wearden, J. H. (2015). Experience sampling methodology reveals similarities in the experience of time in young and elderly adults. *Acta Psychol.* 156, 77–82. doi: 10.1016/j.actpsy.2015.01.006

Grossman, P. (2011). Defining mindfulness by how poorly I think I pay attention during everyday awareness and other intractable problems for psychology's (re)invention of mindfulness: comment on Brown et al. (2011). *Psychol. Assess.* 23, 1034–1040. doi: 10.1037/a0022713

Heeren, A., Douilliez, C., Peschard, V., Debrauwere, L., and Philippot, P. (2011). Cross-cultural consistency of the Five Facets Mindfulness Questionnaire: adaptation and validation in a French sample. *Eur. Rev. Appl. Psychol.* 61, 147–151. doi: 10.1016/j.erap.2011.02.001

Jermann, F., Billieux, J., Bizzini, L., Van der Linden, M., and Bondolfi, G. (2010). "Rumination-Reflection Questionnaire (RRQ): Psychometric properties of the French translation and exploration of the relationships between the RRQ and depressive symptoms and mindfulness," in *Proceeding of the VI World Congress of Behavioural and Cognitive Therapies (WCBCT)*, 4th June 2010, Boston.

Kabat-Zinn, J. (1990). *Full-Catastrophe Living: Using the Wisdom in Your Body and Mind to Face Stress, Pain, and Illness*. New York, NY: Division of Bantam Doubleday Dell Publisher Group.

Kramer, R. S. S., Weger, U. W., and Sharma, D. (2013). The effect of mindfulness meditation on time perception. *Conscious. Cogn.* 22, 846–852. doi: 10.1016/j.concog.2013.05.008

Marchetti, I., Van de Putte, E., and Koster, E. H. W. (2014). Self-generated thoughts and depression: from daydreaming to depressive symptoms. *Front. Hum. Neurosci.* 8:131. doi: 10.3389/fnhum.2014.00131

Nolen-Hoeksema, S. (1987). Sex differences in unipolar depression: evidence and theory. *Psychol. Bull.* 101, 259–282. doi: 10.1037/0033-2909.101.2.259

Nolen-Hoeksema, S., and Morrow, J. (1991). A prospective study of depression and posttraumatic stress symptoms after a natural disaster: the 1989 Loma Prieta Earthquake. *J. Pers. Soc. Psychol.* 61, 115–121. doi: 10.1037/0022-3514.61.1.115

Patton, J. H., Stanford, M. S., and Barratt, E. S. (1995). Factor structure of the Barratt impulsiveness scale. *J. Clin. Psychol.* 51, 768–774. doi: 10.1002/1097-4679(199511)51:6<768::AID-JCLP2270510607>3.0.CO;2-1

Paul, N. A., Stanton, S. J., Greeson, J. M., Smoski, M. J., and Wang, L. (2013). Psychological and neural mechanisms of trait mindfulness in reducing depression vulnerability. *Soc. Cogn. Affect. Neurosci.* 8, 56–64. doi: 10.1093/scan/nss070

Peters, J. R., Erisman, S. M., Upton, B. T., Baer, R. A., and Roemer, L. (2011). A preliminary investigation of the relationships between dispositional mindfulness and impulsivity. *Mindfulness* 2, 228–235. doi: 10.1007/s12671-011-0065-2

Sauer, S., and Baer, R. A. (2010). "Mindfulness and decentering as mechanisms of change in mindfulness- and acceptance-based interventions," in *Assessing Mindfulness & Acceptance Processes in Clients*, ed. R. A. Baer (California, CA: New Harbinger Publications), 25–45.

Selby, E. A., Kranzler, A., Panza, E., and Fehling, K. B. (2014). Bidirectional-compounding effects of rumination and negative emotion in predicting impulsive behavior: implications for emotional cascades. *J. Pers.* 84, 139–153. doi: 10.1111/jopy.12147

Shorey, R. C., Brasfield, H., Anderson, S., and Stuart, G. L. (2014). Differences in trait mindfulness across mental health symptoms among adults in substance use treatment. *Subst. Use Misuse.* 49, 595–600. doi: 10.3109/10826084.2014.850310

Smith, A., Taylor, E., Rogers, J. W., Newman, S., and Rubia, K. (2002). Evidence for a pure time perception deficit in children with ADHD. *J. Child Psychol. Psychiatry* 43, 529–542.

Stanford, M. S., Mathias, C. W., Dougherty, D. M., Lake, S. L., Anderson, N. E., and Patton, J. H. (2009). Fifty years of the Barratt impulsiveness scale: an update and review. *Pers. Individ. Differ.* 47, 385–395. doi: 10.1016/j.paid.2009.04.008

Sucala, M., and David, D. (2013). Mindful about time in a fast forward world. the effects of mindfulness exercise on time perception. *Transl. J. Psychol.* 14, 243–253.

Thönes, S., and Oberfeld, D. (2015). Time perception in depression: a meta-analysis. *J. Affect. Disord.* 175, 359–372. doi: 10.1016/j.jad.2014.12.057

Treisman, M. (1963). Temporal discrimination and the indifference interval: Implications for a model of the "internal clock". *Psychol. Monogr.* 77, 1–13. doi: 10.1037/h0093864

Treynor, W., Gonzalez, R., and Nolen-Hoeksema, S. (2003). Rumination reconsidered: a psychometric analysis. *Cogn. Ther. Res.* 27, 247–259. doi: 10.1023/A:1023910315561

Ulbrich, P., Churan, J., Fink, M., and Wittmann, M. (2007). Temporal reproduction: further evidence for two processes. *Acta Psychol.* 125, 51–65. doi: 10.1016/j.actpsy.2006.06.004

Walach, H., Buchheld, N., Buttenmüller, V., Kleinknecht, N., and Schmidt, S. (2006). Measuring mindfulness—the Freiburg Mindfulness Inventory (FMI). *Pers. Individ. Dif.* 40, 1543–1555. doi: 10.1016/j.paid.2005.11.025

Watt, J. D. (1991). Effects of boredom proneness on time perception. *Psychol. Rep.* 69, 323–327. doi: 10.2466/PR0.69.5.323-327

Wearden, J., O'Donoghue, A., Ogden, R., and Montgomery, C. (2014). "Subjective duration in the laboratory and the world outside", in *Subjective Time, the Philosophy, Psychology, and Neuroscience of Temporality*, eds V. Arstilla and D. Lloyd (London: MIT Press), 287–306.

Wearden, J. H. (2008). The perception of time: basic research and some potential links to the study of language. *Lang. Learn.* 58(Suppl. 1), 149–171. doi: 10.1111/j.1467-9922.2008.00468.x

Wearden, J. H. (2015). Passage of time judgments. *Conscious. Cogn.* 38, 165–171. doi: 10.1016/j.concog.2015.06.005

Wittmann, M., Leland, D., Churan, J., and Paulus, M. P. (2007). Impaired time perception and motor timing in stimulant-dependent subjects. *Drug Alcohol. Depend.* 90, 183–192. doi: 10.1016/j.drugalcdep.2007.03.005

Wittmann, M., Otten, S., Schötz, E., Sarikaya, A., Lehnen, H., Jo, H.-G., et al. (2015). Subjective expansion of expanded time-spans in experienced meditators. *Front. Psychol.* 5:1586. doi: 10.3389/fpsyg.2014.01586

Wittmann, M., and Paulus, M. P. (2008). Decision making, impulsivity and time perception. *Trends Cogn. Sci.* 12, 7–12. doi: 10.1016/j.tics.2007.10.004

Wittmann, M., Peter, J., Gutina, O., Otten, S., Kohls, N., and Meissner, K. (2014). Individual differences in self-attributed mindfulness levels are related to the experience of time and cognitive self-control. *Pers. Individ. Differ.* 64, 41–45. doi: 10.1016/j.paid.2014.02.011

Wittmann, M., and Schmidt, S. (2014). "Mindfulness meditation and the experience of time", Meditation – Neuroscientific approaches and philosophical implications. Studies," in *Neuroscience, Consciousness and Spirituality*, eds S. Schmidt and H. Walach (Switzerland: Springer-Verlag), 199–210.

Zakay, D. (1993). Time estimation methods–do they influence prospective duration estimates? *Perception* 22, 91–101. doi: 10.1068/p220091

Zakay, D. (2014). Psychological time as information: the case of boredom. *Front. Psychol.* 5:197. doi: 10.3389/fpsyg.2014.00917

Zakay, D., and Block, R. A. (2004). Prospective and retrospective duration judgments: an executive-control perspective. *Acta Neurobiol. Exp.* 614, 319–328.

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Article 3 Appendix: Results with the RCTQ

We analyzed the relationship between the temporal measures presented in article 3, and the RCTQ total score in the same sample of healthy individuals (n = 117). Since the RCTQ had not been validated when we first started to analyze the results, they were not further explored at the time. Moreover, we did not find any correlations between the duration estimates, passage of time judgments and the RCTQ total score.

In the present additional analysis, we split our healthy sample in three groups, based on the distribution of results on the RCTQ (through visual inspection of the histogram): (i) low RCTQ total score < 20; (ii) moderate RCTQ total score ranging from 20 until 40; and (iii) high RCTQ total score > 40. We compared the results between the two extreme groups (low RCTQ and high RCTQ, n = 32 and n = 47, respectively)[29], and found that the effect of the interaction SOA x Interval x Group on passage of time judgments tended to be significant (F (1,83) = 3.79, p = .055; figure 2). For verbal estimation tasks, we only found a significant effect of interval length on duration estimates; and no group or interaction effects (F < 1, ns; figure 1). In the production tasks, the effect of the interaction SOA x Interval x Group tended to be significant (F (1,83) = 3.15, p = .08; figure 3).

These results are discussed in 3.1 (Summary and general discussion), in light of the findings reported in article 4 for another sample of healthy individuals (control group).

[29] For each condition of the temporal tasks – i.e., verbal estimation, passage of time judgment and temporal production -- we conducted a mixed-design ANOVA with two within-subject factors (i.e., SOA and interval length), and one between-subject factor (i.e., group).

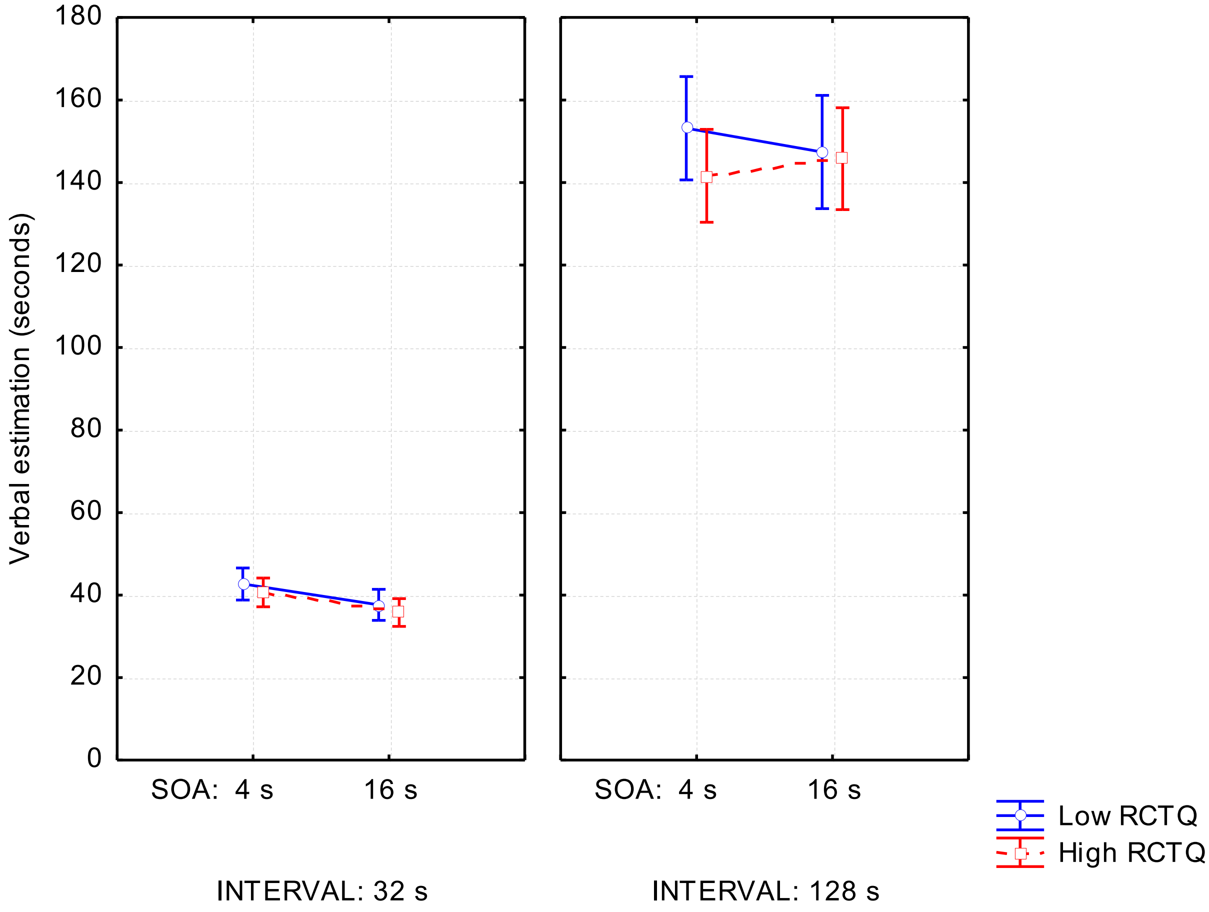

Figure 1: Performance in the verbal estimation task according to group, SOA, and interval length

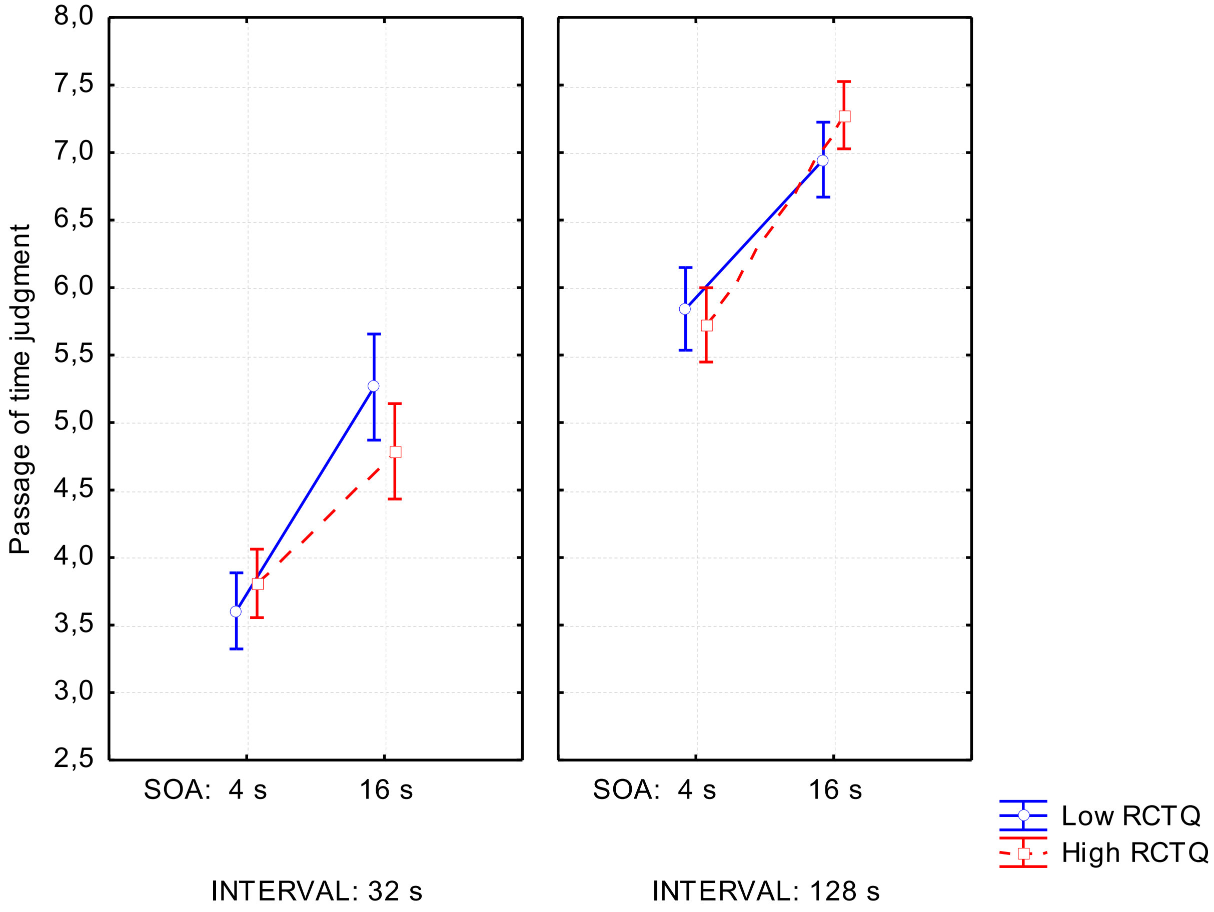

Figure 2: Passage of time judgments according to group, SOA, and interval length

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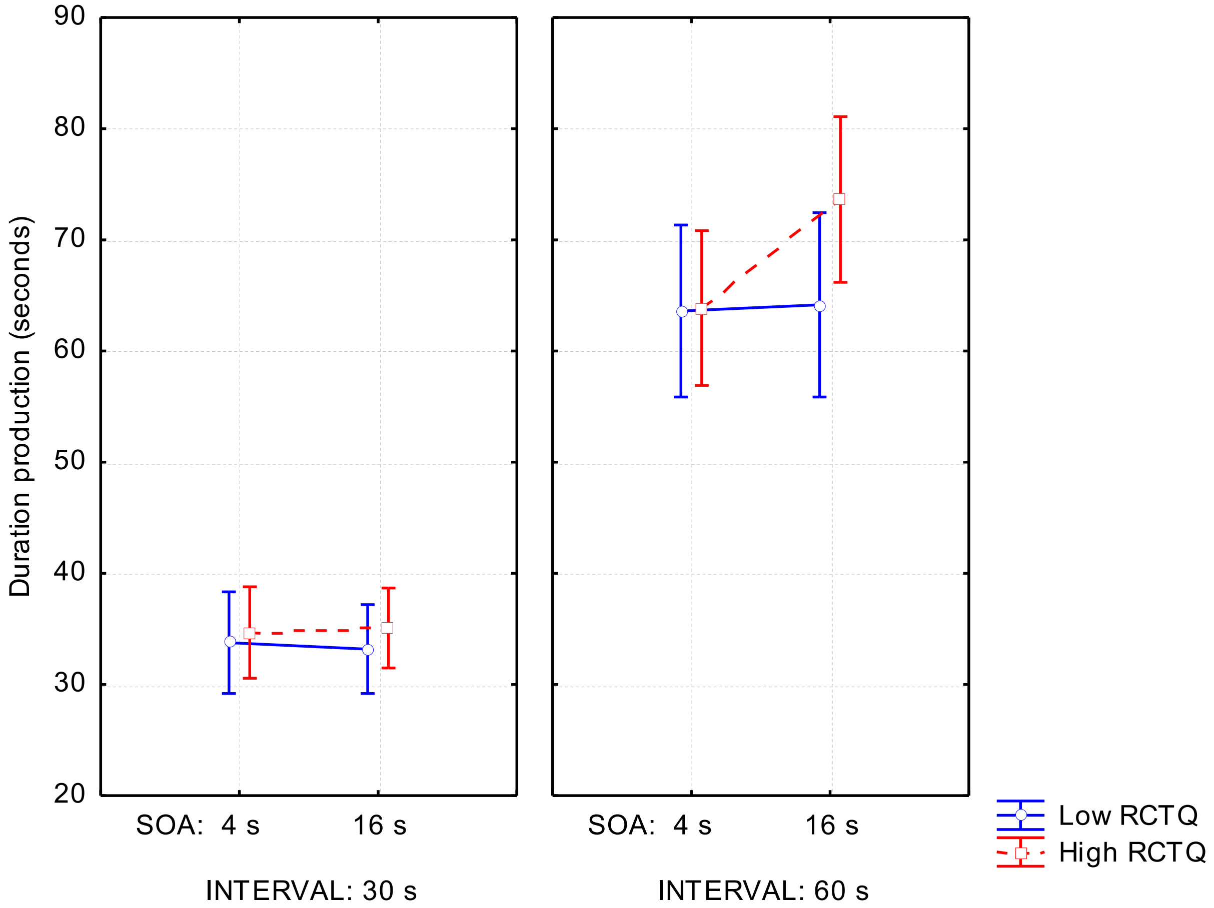

Figure 3: Performance in the production task according to group, SOA, and interval length

Article 4: Time perception in bipolar disorder

How subjective time relates to clinical and cognitive anomalies in mood episodes of bipolar disorder

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ABSTRACT

Background

Time perception abnormalities have been described in Bipolar Disorder (BD), possibly related to attention dysfunction and clinical symptoms, such as rumination and racing thoughts. In depressive episodes, patients usually feel that time slows down, whereas the opposite has been reported in mania. Here we aimed at investigating time perception in different episodes of bipolar disorder, and their relationship to clinical symptoms, medication and attention.

Method

76 patients with BD – i.e., 24 manic, 19 in mixed depression, 14 depressed, and 19 euthymic -- and 26 controls completed racing thoughts and rumination questionnaires, and were administered three temporal tasks in the multiple seconds range – verbal estimation, temporal production, and passage of time judgment – as well as attention and working memory tasks.

Results

Depressed and euthymic subjects underestimated durations compared to controls and manic patients. However, underestimation in euthymia was due to benzodiazepine intake, whereas, in depression, it was related to decreased working memory performance. Duration estimates in mania and mixed depression did not differ from controls. A relative acceleration of the passage of time was associated with manic symptoms in patients, and with racing thoughts in controls.

Limitations

The number of trials in time perception tasks was limited.

Conclusion

Results are partially consistent with phenomenal and experimental accounts of time perception in BD, as we found that manic symptoms were associated with an acceleration of the passage of time in patients. Underestimation of durations in depression is in line with previous studies, and is related to working memory.

Keywords: time perception, passage of time judgments, working memory, bipolar disorder, mixed depression

1 Introduction

Mania and depression are characterized by opposite symptoms in affective, cognitive, psychomotor and interpersonal domains, which might co-occur in mixed states. Phenomenologists have long suggested that time perception relates to the psychopathology of bipolar disorder (BD) (e.g., Northoff et al., 2017). The perceived duration of events is affected by attention, arousal and how boring the concurrent non-temporal activity is (Droit-Volet and Wearden, 2016). Increased arousal in particular is thought to affect the speed of the internal clock leading to an overestimation of durations, whereas decreased attention to time has been associated with opposite results, i.e., underestimation of durations (Droit-Volet, 2013; Droit-Volet and Wearden, 2016). Because elated mood is arousing, mania should lead to overestimating durations (Bschor et al., 2004). However, manic and mixed episodes are also characterized by increased distractibility (Benazzi, 2009). During temporal tasks, this means that attention can be more easily captured by something other than time; subjects might miss temporal information and underestimate the target duration (Terhune et al., 2017). The subjective feeling of the passage of time, assessed via passage of time judgments, is typically slowed down rather than accelerated in depression, i.e., time 'drags' or 'stands still' (Droit-Volet, 2013) whereas the opposite has been reported in mania (Bschor et al., 2004). Passage of time judgements can be independent from duration estimation (Droit-Volet and Wearden, 2016). Surprisingly, few empirical studies have investigated duration experience in BD, with divergent findings reported in hypomanic and depressive states (Thönes and Oberfeld, 2015, for a recent meta-analysis in unipolar depression). For instance, Tysk (1984) found that depressed patients underestimated durations whereas hypomanic patients overestimated durations compared to controls, as expected from the hypotheses developed above. However, Bschor et al. (2004) showed that manic and depressed individuals overestimated long durations in the seconds range in a production task, where subjects have to produce a given interval by signaling when the duration has been reached. In contrast, depressed subjects underestimated durations in a verbal estimation task compared to manic ones, where duration is quantified after the display of a given interval. The speed of the passage of time was also assessed via a visual analog scale. Slowing of the passage of time was observed in depression, whereas an acceleration was found in mania. Bschor et al. (2004) speculated that overestimation of long durations found in both groups was due to opposing clinical symptoms: racing thoughts in mania and rumination and boredom in depression. Because racing and ruminative thoughts are intrinsically related to thinking speed in BD (Piguet et al., 2010), it is likely that they are involved in time perception. Moreover, racing and ruminative thoughts are associated with disturbance in emotion and attention mechanisms (e.g., Piguet et al., 2010) which play a role in time perception (e.g., Droit-Volet, 2013). Here we aimed at assessing duration estimation and the feeling of the passage of time in different mood episodes of BD, and their relationship to clinical symptoms and attention.

2 Methods

2.1 Participants

Seventy-six patients, 31 female, aged 18 – 64 (M = 42.47, SD = 13.23) with bipolar type 1 and type 2 disorder and 26 healthy individuals, 19 female, aged 18 – 64 (M = 38.77, SD = 10.78) were recruited. Patients fulfilled criteria for BD according to the DSM-IV-TR (APA, 2003), and were recruited from inpatient and outpatient clinics at the University Hospital of Strasbourg. They had no history of neurological disorder, ADHD, borderline personality disorder or substance use disorder within the last 12 months. Two patients were not taking any psychotropic medication at the time of the assessment. Of the remaining 74 patients, 50% were taking lithium, 48.64% were prescribed antiepileptic drugs, 41.89% were taking antipsychotics, 35.14% were on antidepressants, and 21.62 % were taking benzodiazepines.

Healthy volunteers had no current or past personal history of psychiatric or neurological disorders nor did they have any first-degree relatives with psychosis or mood disorders. Subjects provided written informed consent prior to inclusion in the study in accordance with the Declaration of Helsinki. This study was approved by the Eastern France regional ethics committee (CPP IV).

2.2 Materials and Procedures

2.2.1 Mood evaluation

Mania and depression symptoms were assessed with the Young Mania Rating Scale (YMRS; Young et al., 1978) and the Quick Inventory of Depressive Symptomatology–Clinician-Rated Version (QIDS-C16; Rush et al., 2003). Based on the criteria put forward by Miller et al., (2016), mixed depression was operationalized as YMRS score > 2 and < 6, concurrent with above threshold depression scores on the QIDS-C16 (>5). Twenty-four subjects were in a manic/hypomanic episode, 19 in mixed depression, 14 in depression, and 19 were euthymic. Following the assessment of depression and manic symptoms, participants filled out self-report questionnaires, and were administered the timing and neuropsychological tasks.

2.2.2 Timing Tasks

Time estimation and production tasks were generated via the Microsoft PowerPoint software. The presentation was displayed on a 17′ LCD color monitor. During the timing tasks, digits were displayed for 1s, white on a black background. Digits were 2.4° of visual angle high, and were presented on the center of the screen inside a red-lined square that measured 4.8° of visual angle. The keyboard was used when motor responses were required. Participants were asked to read aloud the numbers that appeared on the center of the computer screen. The secondary number reading task was meant to prevent counting; we also explicitly asked subjects to avoid counting while performing the task. The total duration of the task was 32s, and the stimulus onset asynchrony (SOA) between the digits was 4s on average (3, 4 or 5s). Subjects were instructed to estimate the total duration of the task when it was over. Following the verbal estimation, subjects were asked to evaluate the passage of time during the estimation task by completing a visual analog scale (VAS), ranging from 1 (time passed very fast) to 10 (time passed very slowly). In the production task that followed, participants were asked to read aloud the numbers that appeared on the center of the screen (SOA mean = 4s), and press the "escape" button on the keyboard when 30s had passed. The actual time lapse produced by the participants was recorded via a timer.

2.2.3 Neuropsychological tasks

Attention and working memory were evaluated by means of the Trail Making Test A & B (TMT; Tombaugh, 2004) and the digit-span task (Wechsler, 1997), respectively.

2.2.4 Self-report questionnaires

The *Racing and Crowded Thoughts Questionnaire* (RCTQ; Weiner et al., submitted) is a 34-item self-report questionnaire that assesses racing thoughts during the past 24 hours. A total score was obtained via the sum of the 34 items. Items are rated on a scale of 0 ("not at all") to 4 ("completely agree").

The *Ruminative Response Scale* State version (RRS-S; Treynor et al., 2003) is a 22-item self-report questionnaire which evaluates two aspects of rumination during the past 7 days: 'Brooding' (5 items) is considered to be maladaptive whereas 'reflection' (5 items) refers to efforts to understand one's negative feelings, and is viewed as adaptive. Items are rated on a scale from 1 ("almost never") to 4 ("almost always").

2.2.5 Statistical analyses

Analyses were undertaken using the Statistica® software. For each condition of the timing (i.e., estimation, judgment of the passage of time, and production) and neuropsychological tasks, one-way ANOVA with group as a between-group variable were conducted. Correlation analyses, using Pearson's coefficient, were performed between the timing measures, the neuropsychological and clinical measures in the patient and control groups.

3 Results

3.1 Descriptive statistics

There were no significant differences among groups in terms of age, $F<1$, or years of study, $F<1$. Patients did not differ from controls in terms of sex, $\chi2$ (1, n = 102) =1.59, p = .21. Scores on the digit-span task did not differ among groups, $F(4,97)=1,33$, $p=.26$. On the TMT-A and B, scores differed significantly among groups, $F(4,97)=2.51$, $p<.05$, and $F(4,97)=2.55$, $p<.05$, respectively. Post-hoc Tukey analyses revealed that manic patients were significantly slower on the TMT-B compared to controls ($p<.05$).

3.2 Timing tasks

Groups differed significantly in the verbal estimation task $F(4,97)=2.86$, $p<.05$ (Figure 1). Post-hoc Tukey analyses revealed that the depressed group significantly underestimated durations compared to the manic and control groups.

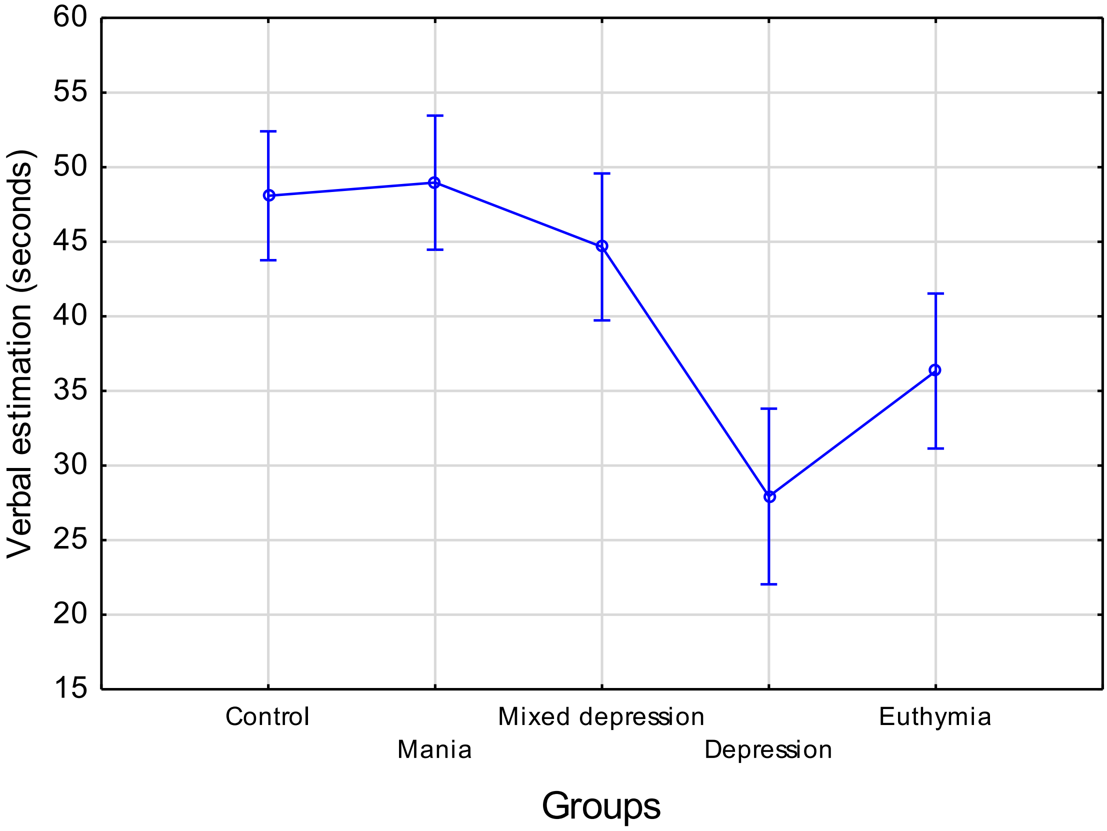

Figure 1: Duration estimation in seconds in each group (from left to right: controls, manic, mixed depression, depression, euthymic).

In the production task, results differed significantly between groups, $F(4,97)=3.52$, $p=.01$ (Figure 2). Post-hoc Tukey analyses revealed that euthymic patients significantly overproduced (underestimated) durations compared to manic and control subjects.

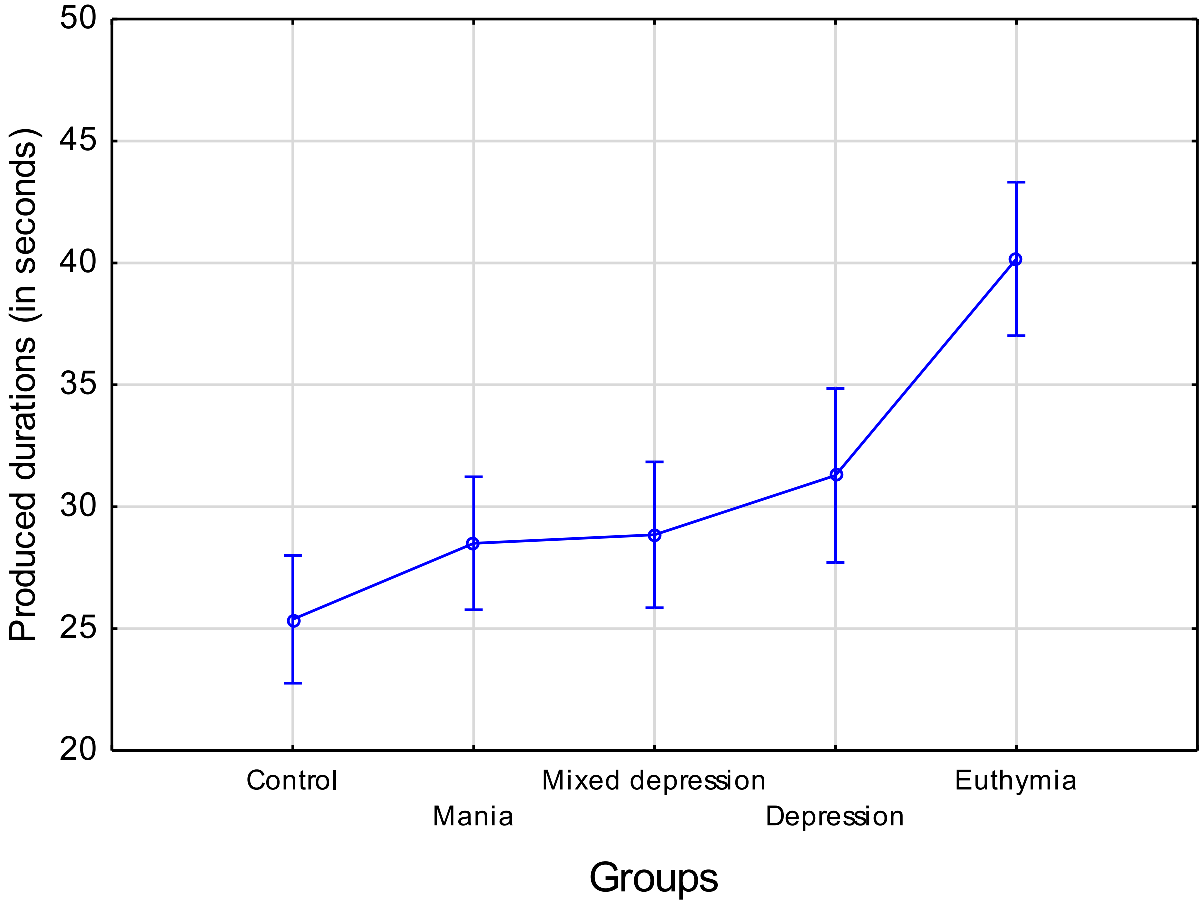

Figure 2: Produced durations in seconds in the Production task, in each group (from left to right: controls, maniac, mixed depression, depression, euthymic).

The subjective judgment of the feeling of the passage of time did not differ among groups, $F<1$.

3.3 Correlation analyses

In the depressed group, shorter verbal estimates of durations were correlated to decreased working memory performance ($r = .73$, $p < .01$). In the mixed depression group, decreased attention switching performance on the TMT-B was associated with a relative acceleration of the passage of time ($r = -.66$, $p < .01$). In manic patients, elevated manic symptoms were associated with an acceleration of the passage of time ($r=-.46$, $p<.05$), whereas in euthymic patients, both elevated manic and depressive symptoms were associated with a feeling that time passed faster ($r=-.53$, $p<.05$ and $r = -.49$, $p < .05$ respectively). In euthymic patients, elevated subthreshold depressive symptoms were related to underestimation of durations in the production task ($r= .51$, $p <.05$). Among controls, elevated rates of racing thoughts measured via the RCTQ were associated with the feeling that time passed fast ($r = -.42$, $p < .05$). Racing thoughts and time perception tasks were not correlated in patients.

Medication effects

We took the intake vs absence of intake of each treatment class as a between-group factor in the analyses described above to check to which extent the results depended on the class of treatment intake. Controls were excluded from this analysis. Only the intake of benzodiazepines (with vs. without) had an effect and interacted significantly with the effect of group in the production task ($F(3, 66)=6.7$, $p<.001$). A group effect was still found in case of benzodiazepine intake ($F(3, 8)=5.7$, $p<.05$), but disappeared in the absence of benzodiazepine intake ($F(3, 58)=1.5$, ns, Figure 3). There was no other treatment-related effect.

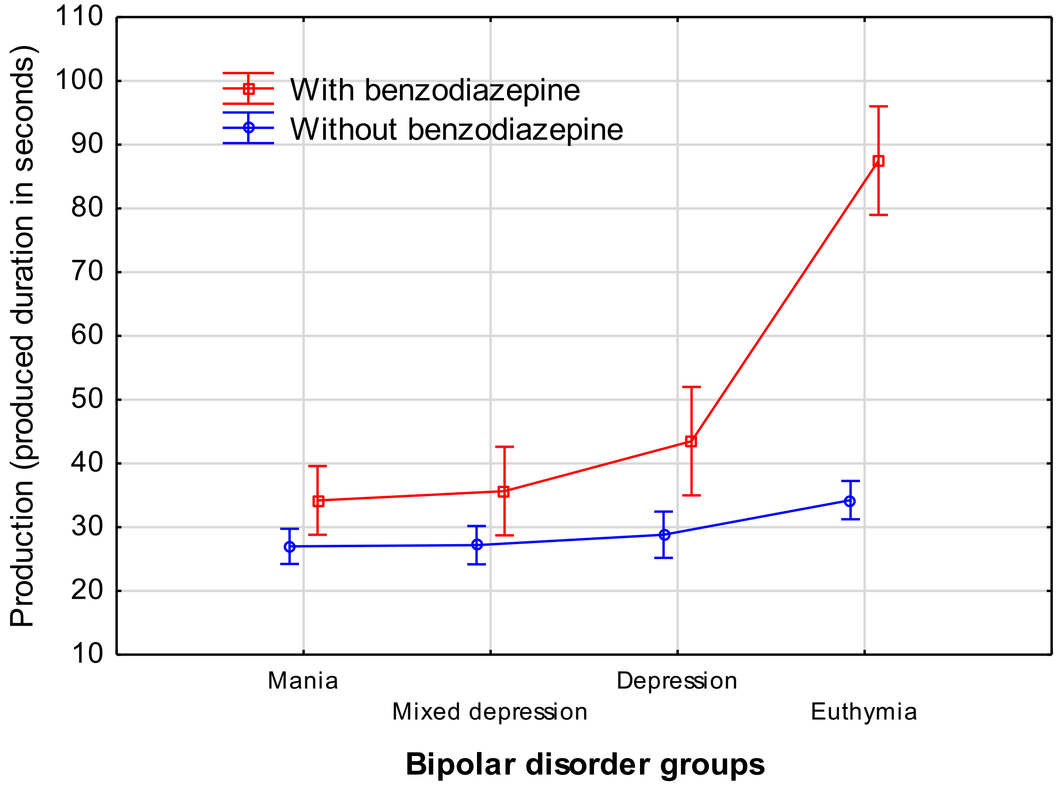

Figure 3: Results in the production task in the 4 patient groups (from left to right: mania, mixed depression, depression, euthymia), as a function of the intake of benzodiazepines (in red) or not (in blue).

4 Discussion

Consistent with previous empirical data (e.g., Tysk, 1984; Mezey and Knight, 1965; Bschor et al., 2004), our results suggest that depressed patients with BD underestimate durations compared to manic and control subjects. Underestimation of durations in the production task in euthymic patients could have suggested a trait abnormality. However, in euthymic patients, underestimation of durations can be attributed to the intake of benzodiazepines. Underestimation of durations in bipolar depression seems to be related to decreased working memory abilities, which are necessary to maintain and update duration information (Üstün et al., 2017). Interestingly, underestimation of durations was not found in patients with mixed depression, suggesting that subthreshold manic symptoms in depression may influence the experience of time, and should be taken into account.

Consistent with previous findings (e.g., Bschor et al., 2014), underestimation of durations was only found in the more passive condition of the task, i.e., the estimation task, rather than when depressed subjects had to actively produce durations. Since the latter condition is more attention-demanding, these results suggest that enhanced attention may compensate for temporal underestimation in depressed patients, possibly by enhancing working memory. In mixed depression and in manic episodes, duration estimates did not differ from that of controls, but, at least for manic patients, they were significantly lengthened compared to that of depressed patients. This might be explained by various reasons, one of them being that the effects of distractibility, characteristic of racing thoughts in mixed and hypomanic episodes (Benazzi, 2007; Benazzi, 2009), on the one hand, and arousal associated with elated mood (MacKinnon, 2008), on the other, might cancel each other.

Judgment of the passage of time did not differ between groups, but was correlated with clinical dimensions. A relative acceleration of the passage of time was associated with elevated manic symptoms in the euthymic and manic groups, which is consistent with previous studies (e.g., Bschor et al., 2004). These results are also in line with a recent study by Wearden & Droit-Volet (2016), who reported that happy mood and increased arousal influenced how fast time seemed to pass in healthy individuals. Self-reported racing thoughts were correlated with the acceleration of passage of time judgement only in healthy volunteers, supporting the idea that racing thoughts of mild intensity can affect passage of time judgment (Mezey and Knight, 1965; Bschor et al., 2004).

Taken together, our findings partially support phenomenal accounts of time in BD, as passage of time judgments were influenced by elated mood, but mostly not by low mood. Temporal distortions were found in depression and euthymia only, and seem related to working memory impairment and medication effects, respectively.

References

Benazzi, F., 2009. What is hypomania? Tetrachoric factor analysis and kernel estimation of DSM-IV hypomanic symptoms. J. Clin. Psychiatry 70, 1514–1521. doi:10.4088/JCP.09m05090

Benazzi, F., 2007. Challenging the unipolar-bipolar division: does mixed depression bridge the gap? Prog. Neuropsychopharmacol. Biol. Psychiatry 31, 97–103. doi:10.1016/j.pnpbp.2006.08.003

Bschor, T., Ising, M., Bauer, M., Lewitzka, U., Skerstupeit, M., Müller-Oerlinghausen, B., Baethge, C., 2004. Time experience and time judgment in major depression, mania and healthy subjects. A controlled study of 93 subjects. Acta Psychiatr. Scand. 109, 222–229. doi:10.1046/j.0001-690X.2003.00244.x

Droit-Volet, S., 2013. Time perception, emotions and mood disorders. J. Physiol. Paris 107, 255–264. doi:10.1016/j.jphysparis.2013.03.005

Droit-Volet, S., Wearden, J., 2016. Passage of Time Judgments Are Not Duration Judgments: Evidence from a Study Using Experience Sampling Methodology. Front. Psychol. 7, 176. doi:10.3389/fpsyg.2016.00176

MacKinnon, D.F., 2008. Bipolar disorder as maladaptive arousal: a behavioral model and evidence. Ann. N. Y. Acad. Sci. 1129, 185–189. doi:10.1196/annals.1417.000

Mezey, A.G., Knight, E.J., 1965. Time Sense in Hypomanic Illness. Arch. Gen. Psychiatry 12, 184–186. doi:10.1001/archpsyc.1965.01720320072008

Miller, S., Suppes, T., Mintz, J., Hellemann, G., Frye, M.A., McElroy, S.L., Nolen, W.A., Kupka, R., Leverich, G.S., Grunze, H., Altshuler, L.L., Keck, P.E., Post, R.M., 2016. Mixed Depression in Bipolar Disorder: Prevalence Rate and Clinical Correlates During Naturalistic Follow-Up in the Stanley Bipolar Network. Am. J. Psychiatry 173, 1015–1023. doi:10.1176/appi.ajp.2016.15091119

Northoff, G., Magioncalda, P., Martino, M., Lee, H.-C., Tseng, Y.-C., Lane, T., 2017. Too Fast or Too Slow? Time and Neuronal Variability in Bipolar Disorder-A Combined Theoretical and Empirical Investigation. Schizophr. Bull. doi:10.1093/schbul/sbx050

Piguet, C., Dayer, A., Kosel, M., Desseilles, M., Vuilleumier, P., Bertschy, G., 2010. Phenomenology of racing and crowded thoughts in mood disorders: a theoretical reappraisal. J. Affect. Disord. 121, 189–198. doi:10.1016/j.jad.2009.05.006

Rush, A.J., Trivedi, M.H., Ibrahim, H.M., Carmody, T.J., Arnow, B., Klein, D.N., Markowitz, J.C., Ninan, P.T., Kornstein, S., Manber, R., Thase, M.E., Kocsis, J.H., Keller, M.B., 2003. The 16-Item Quick Inventory of Depressive Symptomatology (QIDS), clinician rating (QIDS-C), and self-report (QIDS-SR): a psychometric evaluation in patients with chronic major depression. Biol. Psychiatry 54, 573–583.

Terhune, D.B., Croucher, M., Marcusson-Clavertz, D., Macdonald, J.S.P., 2017. Time contracts and temporal precision declines when the mind wanders. J. Exp. Psychol. Hum. Percept. Perform. 43, 1864–1871. doi:10.1037/xhp0000461

Thönes, S., Oberfeld, D., 2015. Time perception in depression: a meta-analysis. J. Affect. Disord. 175, 359–372. doi:10.1016/j.jad.2014.12.057

Tombaugh, T.N., 2004. Trail Making Test A and B: Normative data stratified by age and education. Arch. Clin. Neuropsychol. 19, 203–214. doi:10.1016/S0887-6177(03)00039-8

Treynor, W., Gonzalez, R., Nolen-Hoeksema, S., 2003. Rumination Reconsidered: A Psychometric Analysis. Cogn. Ther. Res. 27, 247–259. doi:10.1023/A:1023910315561

Tysk, L., 1984. Time perception and affective disorders. Percept. Mot. Skills 58, 455–464. doi:10.2466/pms.1984.58.2.455

Üstün, S., Kale, E.H., Çiçek, M., 2017. Neural Networks for Time Perception and Working Memory. Front. Hum. Neurosci. 11. doi:10.3389/fnhum.2017.00083

Wechsler, D. (1997). Wechsler Memory Scale–Third Edition. San Antonio, TX: The Psychological Corporation.

Weiner, L., Weibel, S., de Sousa Gurgel, W., Keizer, I., Gex-Fabry, M., Giersch, A., Bertschy, G. submitted. Measuring racing thoughts in healthy individuals: The Racing and Crowded Thoughts Questionnaire

Young, R.C., Biggs, J.T., Ziegler, V.E., Meyer, D.A., 1978. A rating scale for mania: reliability, validity and sensitivity. Br. J. Psychiatry J. Ment. Sci. 133, 429–435.

Article 5: Verbal fluency in bipolar disorder

What can verbal fluency tasks teach us about language and thought disturbance in bipolar disorder?

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ABSTRACT

Background:

Bipolar disorder (BD) is characterized by speech abnormalities, reflected by symptoms such as pressure of speech in mania and poverty of speech in depression. However, speech abnormalities have been understudied in BD from a neuropsychological standpoint. Here we aimed at investigating speech abnormalities in different episodes of BD via process-oriented qualitative measures of verbal fluency performance, and assessing their relationships to clinical symptoms.

Method:

93 patients with BD – i.e., 25 manic, 12 mixed manic, 19 in mixed depression, 17 depressed, and 20 euthymic -- and 31 controls completed racing thoughts and rumination questionnaires, and were administered three verbal fluency tasks – letter, semantic and free -- and a comprehensive neuropsychological assessment. Verbal fluency measures consisted of word count, semantic and phonological clusters and number of switches between clusters or words.

Results:

Word count and switches in the semantic task were reduced in depressed and euthymic patients compared to controls. Manic patients showed larger phonological cluster size in the semantic task, and increased switches in the free task, compared to control and euthymic groups. Switches were increased in mixed depression compared to depression in the free task.

Limitations:

The size of our mixed manic group was reduced.

Conclusion:

Switching and clustering abnormalities reflect enhanced flexibility at the expense of defective inhibition in mania, and are related to racing thoughts and manic symptoms. Switching distinguished depression from mixed depression.

Keywords: flight of ideas, verbal fluency, clustering, switching, racing thoughts, distractibility

1 Introduction

Bipolar disorder (BD) is characterized by acute episodes of mania and depression, mixed episodes whereby depressive and manic symptoms may co-occur, and periods of partial or full remission. Language disturbances such as flight of ideas and poverty of speech are among the main symptoms of acute episodes in BD (Goodwin & Jamison, 2007), and may prevail during periods of remission (Harrow, Grossman, Silverstein, Meltzer, & Kettering, 1986). Here we aimed at investigating these language disturbances by means of verbal fluency tasks across different mood episodes in BD, and assessing the relationship between verbal fluency performance and clinical symptoms such as racing thoughts and rumination.

Different kinds of language disturbances have been described during mood episodes of bipolar disorder. Pressure of speech, with increased rapidity of speech and racing thoughts, is a common symptom of mania, second only to elevated mood (Cutting, 1997; Sass and Pienkos, 2015). Manic speech has also been characterized as extremely combinatory, shifting quickly from one discourse structure to another, which authors have linked to distractibility and overactivation (Hoffman et al. 1986). Other linguistic features frequently reported during manic episodes include increased verbosity (Binswanger, 1933; Goodwin and Jamison, 2007), tangentiality (Mota et al., 2014), and clang associations, i.e., associations based on sound rather than on the meaning of words (Esmaeelpour and Sasani, 2016; Jamison, 2017). In contrast, poverty of speech and increased pause times are common in depression, and have been hypothesized to be associated with psychomotor retardation and rumination (Henry and Crawford, 2005; Fossati et al., 2003; Sass and Pienkos, 2015). In mixed episodes, linguistic features have been understudied, but phenomenological and linguistic accounts suggest that patients may experience ‘disorganized flight of ideas’ (Binswanger, 1933), distractibility and ‘crowded thoughts’ (Benazzi, 2007; Piguet et al., 2010) accompanied by both pressure and poverty of speech (Esmaeelpour & Sasani, 2016). Compared to these rich phenomenological descriptions, few empirical investigations have been tailored to specifically address them.

In the neuropsychological literature, verbal fluency tasks (Cardebat et al. 1990; Lezak, 2004) are among the most widely used methods for studying language disorders in patients with psychiatric and neurological disorders. In these tasks, subjects are instructed to generate words as quickly as possible according to specified rules based on phonemic or semantic criteria (‘letter’ and ‘semantic’ fluency, respectively), or in the absence of a specified criterion (free word generation). These tasks tackle both the generation pattern and the rapidity of word associations, found to be disturbed in BD. Although traditionally only the total number of words produced within the allotted time period is taken into account, studies in subjects with brain damage have suggested that verbal fluency tasks are in fact multi-faceted (Troyer et al., 1997; Henry and Crawford, 2004). That is, the amount of words produced requires the integrity of at least two cognitive domains: the storage and organization of concepts in lexico-semantic memory, and the ability to retrieve words from memory storage, thought to rely on executive functioning (Henry and Crawford, 2005; Raucher-Chéné et al., 2017). These processes are thought to underlie two aspects of word output that are responsible for optimal performance: the ability to produce words within semantic or phonemic clusters, and the ability to shift to a new category, i.e., clustering and switching respectively (Troyer et al., 1997; Helms & Hall, 2016).

Based on this conceptual framework, several process-oriented scoring procedures of verbal fluency performance have evolved (Raskin et al., 1992; Troyer et al., 1997; Abwender et al., 2001). Among them, the most widely studied in patient and healthy populations is the one developed by Troyer et al. (1997), which provides reliable criteria for measuring clustering, and switching in verbal fluency tasks (Ross et al., 2007). According to Troyer et al. (1997), clustering is defined by the production of words within semantic subcategories in the semantic fluency task (e.g., bird subcategory if the category is "animals"), and phonemic subcategories in the letter fluency task (e.g., words that rhyme). The clustering measure of interest is the cluster size, which is determined by the number of words produced in each cluster beginning with the second word (n-1). Troyer et al. (1997) only acknowledged the possibility of task-consistent clustering, i.e., semantic relatedness in semantic fluency and phonemic relatedness in letter fluency. Task-discrepant clustering consists of phonemic relatedness in semantic fluency or semantic relatedness in letter fluency, but was assumed to be rare (Troyer et al., 1997). Switching is operationalized as the ability to shift from a subcategory to another. Troyer et al. (1997) suggested that temporal-lobe mediated processes such as lexico-semantic retrieval are represented in mean cluster size scores, whereas frontal-lobe-mediated processes such as cognitive flexibility and inhibition are reflected in switch scores. There is some support for this position, as patients with Alzheimer's disease demonstrate poor clustering performance relative to switching, whereas the reverse pattern has been observed in patients with Parkinson's disease and Huntington's disease (e.g., Tröster et al., 1998; Ho et al., 2002). More recently, studies suggested improvements to the qualitative scoring procedure provided by Troyer et al. (1997) through the addition of task-discrepant clustering, and a measure of cluster ratio (e.g., Ledoux et al., 2014; Helmes and Hall, 2016). First, task-discrepant clustering has been shown to be more frequent than initially thought (Ledoux et al., 2014). Second, mean cluster size is determined both by the total number of words and the organization of the verbal output. This means that averaging a list (e.g., 12 items) that includes one multiple-word cluster (e.g., 9 words) and three single words (cluster size 0), would produce the same mean cluster size (2) and number of switches (3), as a list that is composed of four three-word clusters (Abwender et al., 2001). To disentangle the total word production from word organization, the combined use of the mean cluster size and the cluster ratio (i.e., the number of clusters/number of words) may be considered a better index of clustering, as it is able to address respectively the integrity of the semantic store as well as its organization throughout the task (Raskin et al., 1992; Koren et al., 2005; Helmes & Hall, 2016). Combined measures, including task-discrepant clustering and cluster ratio, have proven to be valid and particularly sensitive to the peculiar verbal output found in patients with psychiatric disorders other than BD (Ledoux et al., 2014; Helmes & Hall, 2016). It is noteworthy that, in unipolar depression, Fossati et al. (2003) found a decreased number of words in the semantic task, and fewer switches in patients relative to healthy controls, whereas no difference was found in terms of cluster sizes. This led the authors to suggest that executive dysfunction subtended impaired verbal fluency performance in depression, and was potentially involved in clinical symptoms such as rumination.

In BD, to our knowledge, although verbal fluency tasks have been used in numerous studies, only the total word account was calculated, and processes-oriented approaches have not been investigated. Yet process-oriented approaches might be particularly useful in identifying the cognitive correlates of the linguistic abnormalities that are characteristic of BD, such as clang associations and abnormal combinatory patterns supposedly involved in racing thoughts and flight of ideas (Hoffman et al., 1986; Piguet et al., 2010). In a recent meta-analysis of verbal fluency tasks in BD, Raucher-Chéné et al. (2017) found that performance in letter and semantic fluency was equally reduced in patients with BD, with medium effect sizes. Most studies were conducted during euthymia (in their meta-analysis, 30 out of 39 studies), and only one study (i.e., Basso et al., 2002) included a group of patients in a mixed episode. Despite the small amount of data available for patients with acute episodes, Raucher-Chéné et al. (2017) found greater impairment in the semantic fluency task in euthymic compared to manic patients. Given that this was observed in the semantic fluency task and not in the letter condition, the authors argued that semantic memory dysfunction – i.e., storage and/or functional organization – could explain these results. Moreover, akin to formal thought disorder in schizophrenia (e.g., Kerns et al., 1999) they speculated that the relative "manic advantage" in the semantic fluency task was related to an over-activation of the semantic network, which supposedly underlies thought and language disturbances in mania (Raucher-Chéné et al., 2017). That is, compared to periods of remission, during manic episodes, the oral production of a given word might lead to faster spreading of activation, hence facilitating the retrieval of more remotely associated words. If such is the case, using the aforementioned combined scoring procedure, cluster ratio should be reduced in mania compared to controls and the other clinical groups. This means that we expect the abnormalities in verbal fluency tasks to be related to patients' mood state. None of the aforementioned studies examined the relationship between clinical symptoms and verbal fluency performance, and the exploration of relevant process-oriented procedures in symptomatic patients with BD are still lacking.

In the present study, we aimed at assessing verbal fluency performance through a comprehensive process-oriented method in patients with BD in different mood episodes. To do so, total word count, but also measures of clustering and switching were calculated in three conditions of VFT – i.e., letter, semantic, and free condition. Given the peculiarities of manic speech, namely pressure of speech, increased discourse switches, and clang associations (Esmaeelpour and Sasani, 2016), we expected to find a decrease in cluster ratio and an increase in the number of words, switches, and phonemic clustering compared to controls, euthymic and depressed patients. In contrast, the opposite pattern of results should be observed in depressed patients. Additionally, given that distractibility is a distinctive feature of mixed states, compared to pure depression, the mixed depression group should present an increased number of switches. To investigate the relationship between verbal fluency performance and clinical symptoms, we measured racing and crowded thoughts, i.e., the subjective equivalent of flight of ideas, and rumination. A link between racing thoughts or rumination and verbal fluency performance will indicate to which extent specific processes, i.e., switching or clustering, are involved in these symptoms.

2 - METHODS

2.1 - PARTICIPANTS

Thirty-one healthy individuals ages 18 – 64 (M = 38.13, SD = 11.43) and 93 patients ages 18 – 64 (M= 42.70, SD = 12.83) with BD were recruited. Patients fulfilled criteria for BD according to the DSM-IV-TR (APA, 2000). 50.5 % patients had BD type 1, and 49.5 % BD type 2. They were recruited from inpatient and outpatient clinics at the University Hospital of Strasbourg by senior psychiatrists. Patients with BD had no history of neurological disorder, ADHD, borderline personality disorder or substance use disorder within the last 12 months. Two patients were not taking any psychotropic medication at the time of the assessment. Of the remaining 91 patients, 45.2% were taking lithium, 44.1 % were prescribed antiepileptic drugs, 40.9% were taking antipsychotics, 32.3% were on antidepressants, and 20.4% were taking benzodiazepines. Detailed demographic data is presented on table 1. Results were similar with and without benzodiazepines and lithium, hence for the sake of simplicity we present the results averaged over all subjects.

Healthy volunteers were recruited from the region by advertisement, and were matched to patients on the basis of age, sex, and number of years of education. Healthy individuals had no current or past personal history of psychiatric or neurological disorders nor did they have any first-degree relatives with psychosis or mood disorders. Prior to their inclusion, they filled out the Mood Disorders Questionnaire (MDQ; Hirschfeld et al., 2000) and the Quick Inventory of Depressive Symptomatology-self rated (QIDS-SR16; Rush et al., 2003) in order to rule out current depression or past manic episodes. Subjects provided written informed consent prior to inclusion in the study in accordance with the Declaration of Helsinki. This study was approved by the regional ethics committee of the East of France (CPP EST IV).

Table1: Means and standard deviations of demographic data of patients and controls

	Mania n= 25	Mixed Mania n = 12	Mixed Depression n = 20	Depression n = 17	Euthymia n = 20	Controls n = 31	F/χ2	p
Age	39.52 (14.9)	42.67 (9.23)	42.9 (11.89)	45.29 (12.84)	43.7 (13.88)	38.12 (11.52)	F(5,119)=1.05	.39
Sex (F/M)	14/9	7/5	17/3	10/7	10/10	23/8	χ2 (5, n = 124) = 7.38	.19
Years of education	14.2 (2.04)	12.75 (2.6)	14.35 (1.95)	14.95(2.67)	15.05 (2.33)	14.1 (2.37)	F(5,119)=1.77	.12
Illness duration (months)	152.52 (125.16)	131 (104.77)	196.72 (153.10)	209.5 (203.47)	193.54 (145.92)	/	F(4,77) < 1	.64
YMRS	12.56 (3.59)	8.67 (2.31)	4 (1)	0.65 (0.86)	1.15 (1.63)	0.61 (0.88)	F(5,118) = 138.9	*<.001*
QIDS-C16	2.4 (1.55)	9.58 (2.78)	12.79 (3.07)	11.88 (3.22)	1.45 (1.57)	0.87 (1.20)	F(5,118) = 130.17	*<.001*

Legend: YMRS= Young Mania Rating Scale; QIDS-C16 = Quick Inventory of Depressive Symptomatology-Clinician version; significant results are presented in italics

2.2 – MATERIALS AND PROCEDURES

Prior to the neuropsychological assessment, mania and depression symptoms were assessed with the Young Mania Rating Scale (YMRS; Young et al., 1978) and the Quick Inventory of Depressive Symptomatology–Clinician-Rated Version (QIDS-C16; Rush et al., 2003). A YMRS score > 5 was considered reflective of hypomania (Favre et al., 2003) and a QIDS-C16 score > 5 was reflective of depression (Rush et al., 2003). Subjects were considered to be in a mixed manic state, if manic and depressive symptoms were above the cut-off (Suppes et al., 2005). Mixed depression was operationalized as above the threshold depressive symptoms (QIDS-C16 score > 5), co-occurring with mild hypomanic symptoms (YMRS score > 2 and < 6; Miller et al., 2016). Euthymia was defined as below the threshold scores in both the YMRS and the QIDS-C16. Based on these criteria, 25 subjects were classified as having a manic episode, 12 were in a mixed manic episode, 19 were having a mixed depressive episode, 17 were depressed, and 20 were euthymic.

Following the assessment of depression and manic symptoms, participants were administered self-rated questionnaires, assessing racing thoughts and rumination, and a battery of neuropsychological tests, including verbal fluency tasks.

2.2.1 Self-report questionnaires

The Racing and Crowded Thoughts Questionnaire (RCTQ; Weiner et al., submitted) is a 34-item self-report questionnaire that assesses three facets of racing thoughts during the past 24 hours, i.e., “thought overactivation” (7 items), which is related to the increased amount and velocity of racing thoughts, “burden of thought overactivation” (8 items), and “thought overexcitability” (8 items), which refer to the dysphoric feeling of having too many thoughts occurring at the same time, and distractibility, respectively. A total score is also obtained via the sum of the 34 items. Items are rated on a scale of 0 (“not at all”) to 4 (“completely agree”).

The Ruminative Response Scale State version (RRS-S; Nolen-Hoeksema and Morrow, 1991; Treynor et al., 2003) is a 22-item self-report questionnaire which evaluates two aspects of rumination during the past 7 days, including the past 24 hours: ‘Brooding’ (5 items) taps passive rumination on negative mood and is considered to be maladaptive whereas ‘reflection’ (5 items) refers to active efforts to understand one’s negative feelings, and is considered to be adaptive. Items are rated on a scale from 1 (“almost never”) to 4 (“almost always”).

2.2.2. Neuropsychological assessment

Executive functioning was evaluated by means of the Trail Making Test (TMT; Tombaugh, 2004), and the Hayling test (Burgess & Shallice, 1997), which assess switching and inhibition respectively. Working memory and processing speed were assessed by the means of the digit-span task, and the digit-symbol subtest of the Wechsler Adult Intelligence Scale—Third Edition (WAIS-III: Wechsler, 1997). In addition, the Vocabulary Subtest of the WAIS-III (Wechsler, 1997) was used to assess the lexico-semantic abilities of each group of participants. A large body of research has documented that the Vocabulary Subtest is a valid estimate of verbal intelligence and of vocabulary size (see Strauss et al., 2006).The French

National Adult Reading Test (NART; Mackinnon and Mulligan, 2005) was used as an additional estimate of their premorbid level of intellectual functioning, vocabulary size and education level (Ross et al., 2007).

2.2.3 Verbal fluency

Fluency was measured via three different verbal fluency trials, which are described hereafter.

2.2.3.1 Free fluency condition

In the free fluency trial, participants were asked to produce as many words as possible, with their eyes closed, during 150 s. This task is part of a communication assessment battery, the *Montréal Evaluation de la Communication* (MEC; Joanette, 2004) that has been validated in French.

2.2.3.2 Letter fluency condition

Subjects were asked to produce as many words as possible starting with the letter ‘p’, with the exception of proper nouns, during 120s. This task followed the same procedure as Cardebat et al. (1990).

2.2.3.3 Semantic fluency condition

Participants were asked to produce as many words as possible belonging to a specific category, i.e., ‘animals’, only one noun per species, during 120s, following the same procedure described by Cardebat et al. (1990).

2.2.3.4 Procedure

The three conditions of the verbal fluency task were administered in a fixed order, starting with the most unrestrictive condition, then following Cardebat et al.’s (1990) procedure: first the free condition, followed by the letter condition, and the category condition. Participants’ oral production was recorded using the Audacity© software. Verbatim verbal output was transcribed by French-speaking psychology undergraduates who were blind to the diagnostic status of the participants.

2.2.3.5 Scoring procedure

In addition to total word count, semantic and phonemic clustering and switching were calculated for the three fluency tasks according to procedures described by Raskin et al. (1992), Troyer et al., (1997), Abwender et al. (2001), and Ledoux et al. (2014). Using this combined method, semantic clusters were defined as a group of at least two serially produced words related categorically (e.g., fruits; the words were also considered as related if one of them was a superordinate), or contextually (e.g., animals that live in the forest). Synonyms but also antonyms were considered as being related. Phonemic clusters were defined as groupings of at least two serially produced words sharing the first two phonemes (e.g., plot and plight), sharing a syllable (e.g., propensity and pen), rhyming (e.g., daughter and water), differing only by a vowel sound (e.g., pin, pen), as well as homonyms (e.g., sum and some). Semantic and phonemic relatedness were assessed in the three conditions of the task; this combined procedure allows for the identification of both task-consistent and task-discrepant clustering. Additionally, it allows for the calculation of cluster ratios, i.e., the number of clusters/number of words (Raskin et al., 1992), and mean cluster size, i.e., total number of words in clusters beginning with the second word divided by the number of clusters produced (Troyer et al., 1997). Cluster sizes of zero were not considered in the analysis (Ledoux et al., 2014). Switches were defined by shifts from a cluster to another cluster, but also from a cluster to a word, or from a word to another word (Ledoux et al., 2014); the raw number of switches was our variable of interest (Troyer et al., 1997; Abwender et al., 2001; Ledoux et al., 2014). Two independent raters (graduate-level psychologists) blind to the diagnostic status of the participants scored the verbal fluency protocols following the combined procedure outlined above. Intra-class correlations between scoring of the two raters revealed excellent interrater reliability for both semantic and phonemic clustering in the letter ($r = .86$, $r = .95$, respectively), semantic ($r = .88$, $r = .93$, respectively) and free ($r = .93$, r =. 95, respectively) conditions.

3 - Results

Analyses were undertaken using the Statistica® software. For each scoring criterion and condition of the task, we conducted a one-way ANOVA with group as a between-group variable. In the patient groups, correlation analyses, using Pearson's coefficient, were performed between the verbal fluency measures, neuropsychological measures, current clinical symptoms, and thought patterns. Results on neuropsychological tasks and questionnaires are presented in table 2.

Table 2: Means and standard erros of neuropsychological tasks and self-rated questionnaires in patients and controls

	Mania n= 25	Mixed Mania n = 12	Mixed Depression n = 20	Depression n = 17	Euthymia n = 20	Controls n = 31	F	p	post-hoc Tukey test
TMT A (seconds)	37.04 (3.06)	41.67 (4.24)	32.61 (3.37)	39.82 (3.56)	37.65 (3.28)	26.71 (2.63)	F(5,116) = 3.16	*.02*	controls > mixed mania and depression
TMT B (seconds)	100.04 (9.29)	95.58 (12.86)	80.11 (10.22)	100.65 (10.80)	80.8 (9.96)	59.03 (8.0)	F(5,116) = 3.19	*<.01*	controls > mania and depression
Digit-span (WAIS-III)	14.36 (0.69)	13.08 (0.99)	14.47 (0.79)	14.76 (0.84)	14.65 (0.77)	16.16 (0.62)	F(5,118) = 1.68	.14	/
Hayling test inhibition (seconds)	3.53 (0.40)	3.17 (0.57)	3.48(0.45)	4.84 (0.48)	3.22 (0.44)	3.12 (0.35)	F(5,118) = 1.93	.09	/
Hayling test inhibition errors	7.52 (0.69)	5.75 (0.99)	5.26 (0.79)	6.23 (0.83)	5.30 (0.77)	3.59 (0.62)	F(5,118) = 3.89	*<.01*	controls > mania
Digit-symbol (WAIS-III)	63.88 (3.45)	57.83 (4.98)	70.67 (3.96)	58.47 (4.18)	69.9 (3.86)	84.39 (3.1)	F(5,118) = 7.65	*<.01*	controls > clinical groups except mixed depression
Vocabulary (WAIS-III)	36.04 (2.02)	30.50 (2.92)	39.47 (2.32)	37.53 (2.46)	44.8 (2.27	36.77 (1.82)	F(5,118) = 3.47	*<.01*	euthymia > mixed mania
NART (IQ)	109.68 (1.31)	105.83 (1.90)	109.95 (1.51)	108.35 (1.6)	110.35 (1.47)	113.1 (1.18)	F(5,118) = 2.56	*.03*	controls > mixed mania
RCTQ total	58.64 (6.04)	99.08 (8.72)	75.42 (6.93)	44.47 (7.33)	11.15(6.75)	7.29 (5.42)	F(5,118) = 27.10	*<.001*	
RCTQ overactivation	15.24 (1.4)	22 (2.02)	16.42 (1.6)	8.94 (1.69)	2.85 (1.56)	2.87 (1.25)	F(5,118) = 23.8	*<.001*	
RCTQ burden	9.36 (1.35)	19.83 (1.95)	15.63 (1.55)	7.58 (1.64)	1.65 (1.51)	0.13(1.22)	F(5,118) = 24.16	*<.001*	
RCTQ overexcitability	13.88 (1.48)	22.83 (2.13)	16.68 (1.69)	12.59 (1.79)	3.05 (1.65)	2.16 (1.33)	F(5,118) = 22.64	*<.001*	
RRS brooding	9.48 (0.63)	14.64 (0.94)	15.26 (0.72)	11.13 (0.81)	8.2 (0.7)	6.77 (0.56)	F(5,118) = 23.9	*<.001*	

Legend: TMT = Trail Making Test; NART = National Adult Reading Test; RCTQ = Racing and Crowded Thoughts Questionnaire; RRS = Rumination Response Scale; significant results are presented in italics.

3.1 Number of words

In the free condition and the letter condition, no significant difference was found in the number of words produced among groups, F (5, 118) = 1.03, p = .40 and F (5, 117) = 1.88, p = .10, and respectively.

In the semantic condition, a significant difference was found in the number of words produced among groups, F (5,114) = 2.32, p <.05 (cf. Figure 1). Planned comparisons revealed that the control group produced significantly more animal words than the depressed groups, F (1, 115) = 5.57, p <.001, and tended to be higher compared to the euthymic group, F (1,115) = 2.78, p = .09.

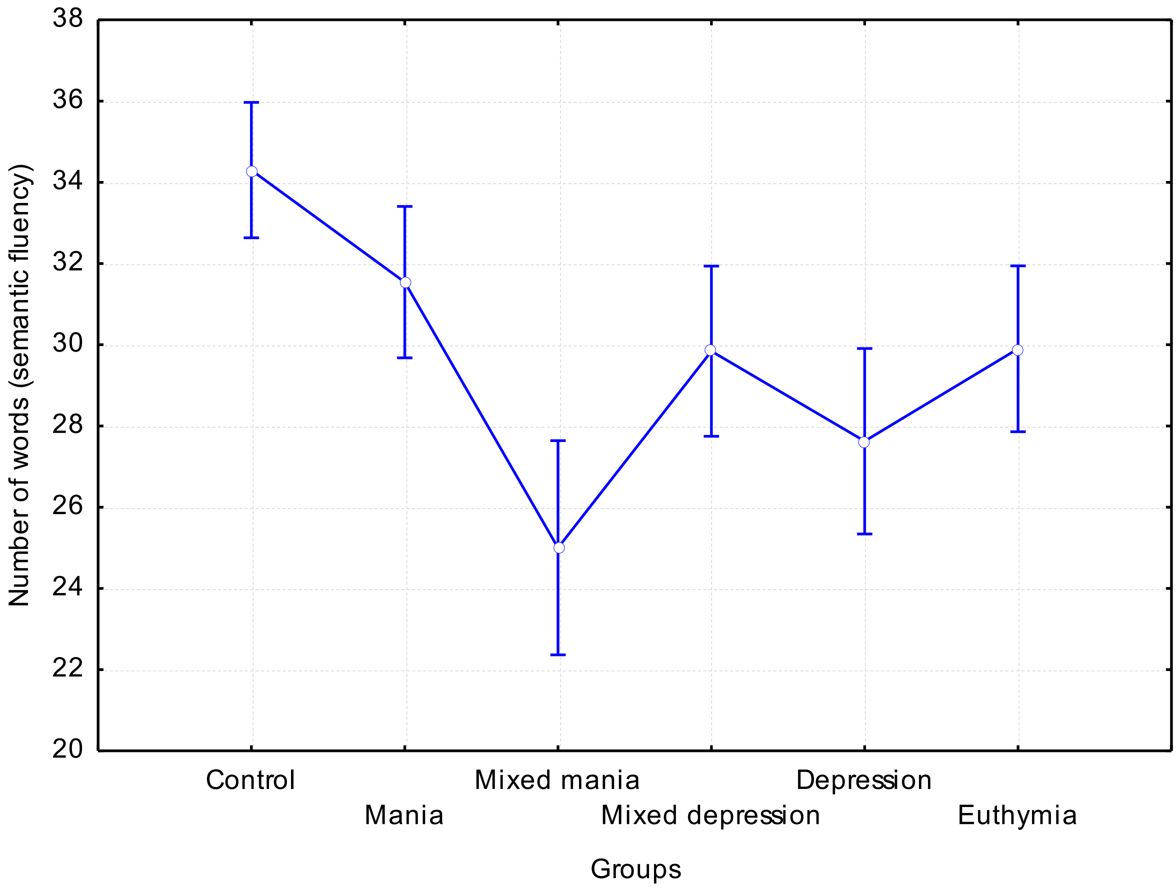

Figure 1: Number of words in the semantic fluency across groups

3.2 Cluster analyses

3.2.1 Semantic cluster size

Average semantic cluster size did not differ among groups in the free condition, $F (5, 118) = 1.10$, $p = .36$, the letter condition, $F (5, 117) = 1.62$, $p = .16$, and the semantic condition, $F <1$, ns.

3.2.2 Ratio of semantic clusters

The number of semantic clusters/total number of words differed significantly among groups in the free condition $F (5, 118) = 2.46$, $p < .05$ (cf. Figure 2). Planned comparisons showed that cluster ratio was significantly smaller in mania compared to controls, $F (1, 118) = 8.33$, $p < .01$. Cluster ratio did not differ in the manic compared to the depression group, $F < 1$, p = ns, and the euthymic group, $F < 1$, p = ns.

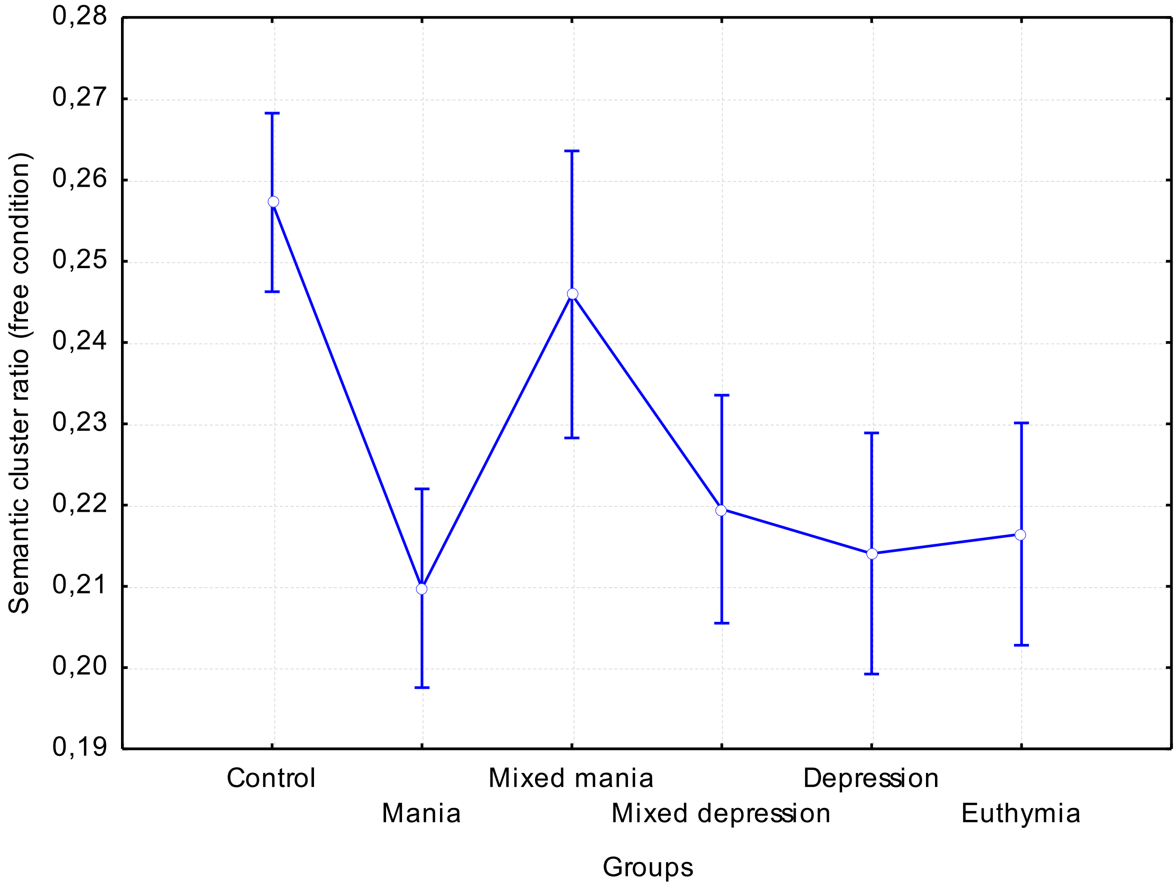

Figure 2: Ratio of semantic clusters in the free fluency across groups

In contrast, in the semantic and letter conditions, the ratio of semantic clusters did not differ among groups F (5, 114) = 1.04, p = .40, and F (5, 116) = 1.57, p =. 17, respectively. On average, semantic clusters were more common in the semantic condition (range = .26 -- .23), compared to the letter condition (range = .14 -- .08).

3.2.3 Phonological cluster size

Average phonological cluster size did not differ among groups in the free condition, F (5, 118) = 1.35, p = .25. Planned comparisons did not reveal any significant difference in phonological cluster size between groups. In the letter condition, phonological cluster size did not differ among groups, F < 1, ns. In the semantic condition, phonological cluster size tended to differ among groups, F (5, 115) = 2.07, p = .07 (Figure 3). Planned comparisons revealed that average phonological cluster size was significantly increased in the manic compared to the control, F (1,115) = 8.38, p < .001, and euthymic groups, F(1,116) = 4.63, p = .03. Moreover, phonological cluster size tended to be greater in manic compared to depressed patients, F (1,116) = 3.82, p =.05.

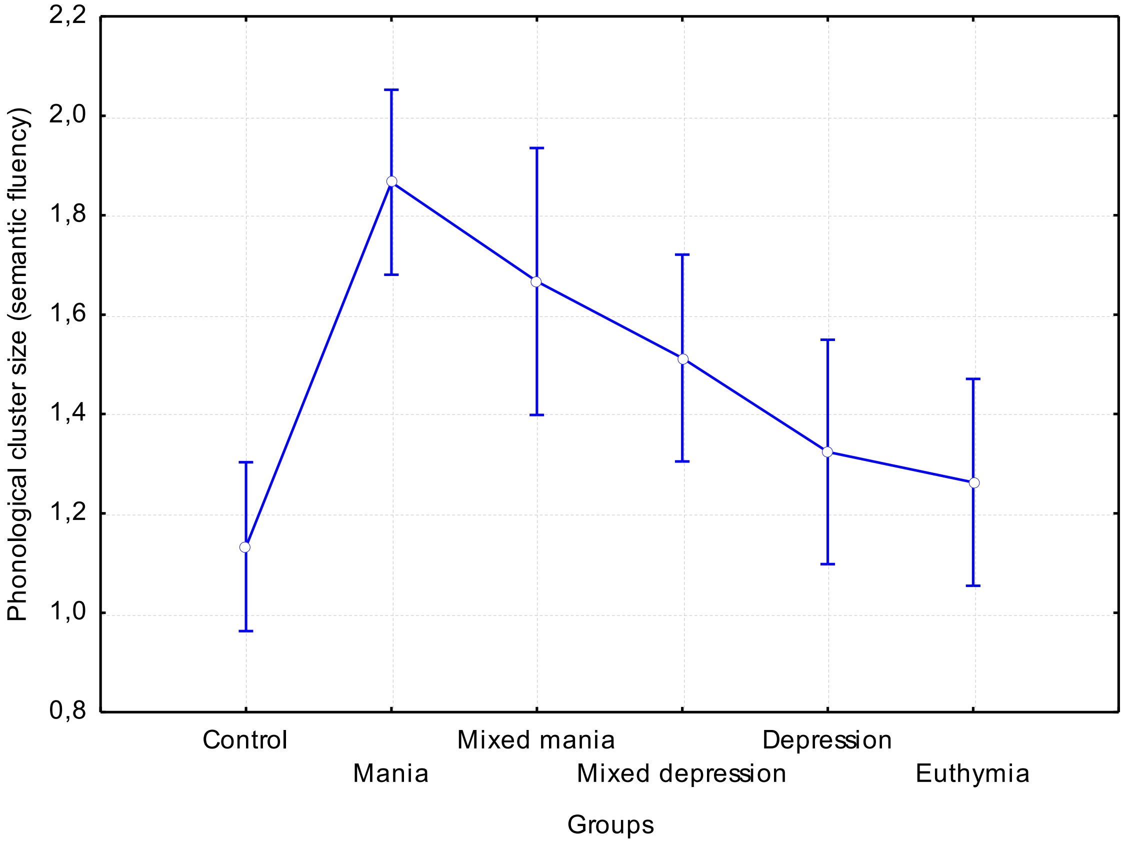

Figure 3: Phonological cluster size in the semantic fluency task across groups

3.2.4 Ratio of phonological clusters

The number of phonological clusters/total number of words did not differ among groups in the free condition, F (5, 118) = 1.70, p = .14, the letter condition, F (5,117) = 1.86, p =.11, and the semantic condition, F<1, ns. In the free condition, planned comparisons revealed that ratio of phonological clusters tended to be increased in manic compared to control subjects, F(1,118) = 2.87, p = .09, but not compared to depressed patients, F < 1, p = ns. On average, phonological clusters were more common in the letter condition (range = .19 -- .11), compared to the semantic condition (range = .05 -- .03).

3.3 Switches

In the free condition, the number of switches differed significantly among groups, $F(5, 118) = 2.66$, $p < .05$ (Figure 4). Planned comparisons showed that the number of switches was significantly increased in the manic group compared to the control group, $F(1,118) = 8.82$, $p < .01$, the euthymic group, $F(1,118) = 5.86$, $p < .05$, and the depressed group, $F(1,118) = 4.56$, $p = .03$. Compared to the depression group, switches were significantly increased in mixed depression group, $F(1,118) = 3.92$, $p < .05$.

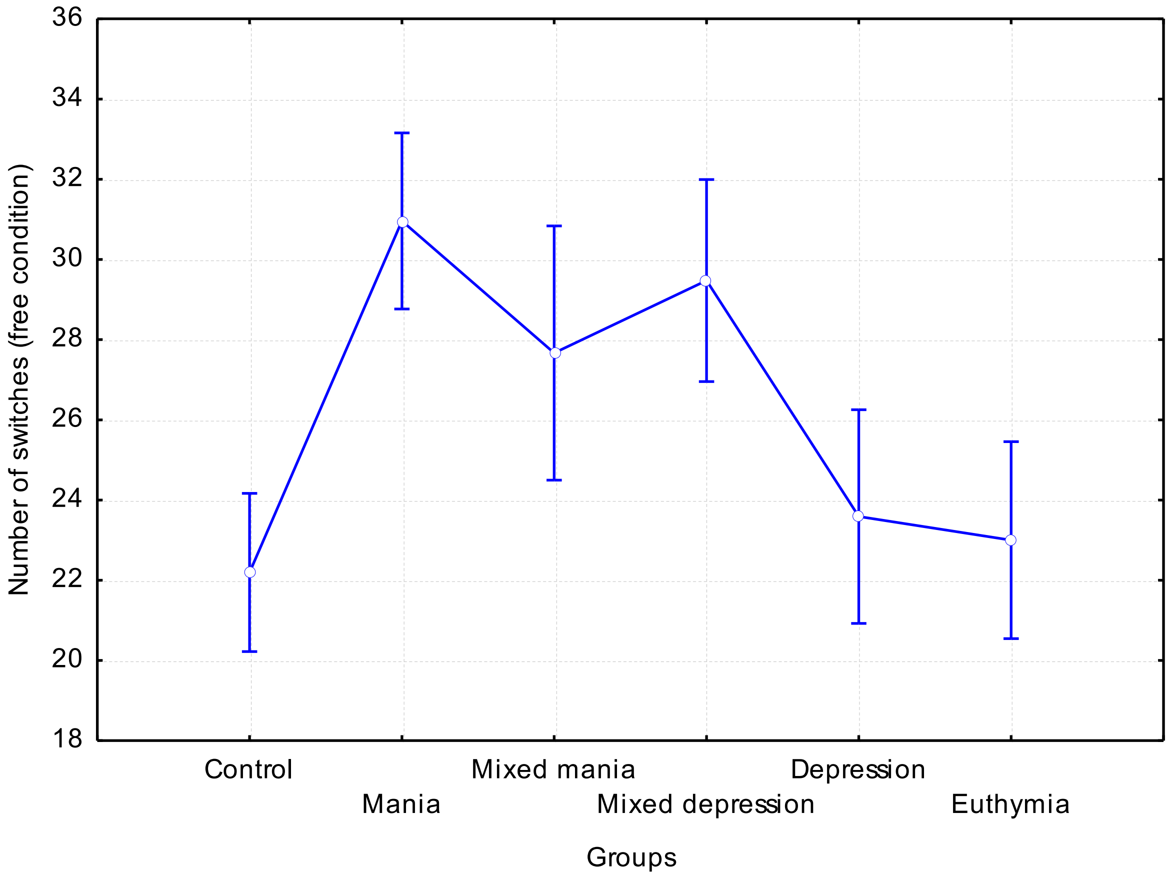

Figure 4: Number of switches in the free condition across groups

In the letter condition, there was no significant difference in the number of switches found among groups, $F < 1$, p = ns.

In the semantic condition, results tended to differ among groups, $F(5,114) = 2.27$, $p = .05$ (Figure 5). Planned comparisons showed that the number of switches was significantly higher in the manic group compared to the depressed and euthymic groups, $F(1,114) = 4.96$, $p = .03$ and $F(1,113) = 4.71$, $p = .03$, respectively, and in the control group compared to the depressed, $F(1,114) = 5.76$, $p = .02$, and euthymic groups, $F(1,114) = 5.49$, $p = .02$. However, the number of switches did not differ between the manic and the control group, $F < 1$, p = ns, and the depression and mixed depression groups, $F < 1$, p = ns.

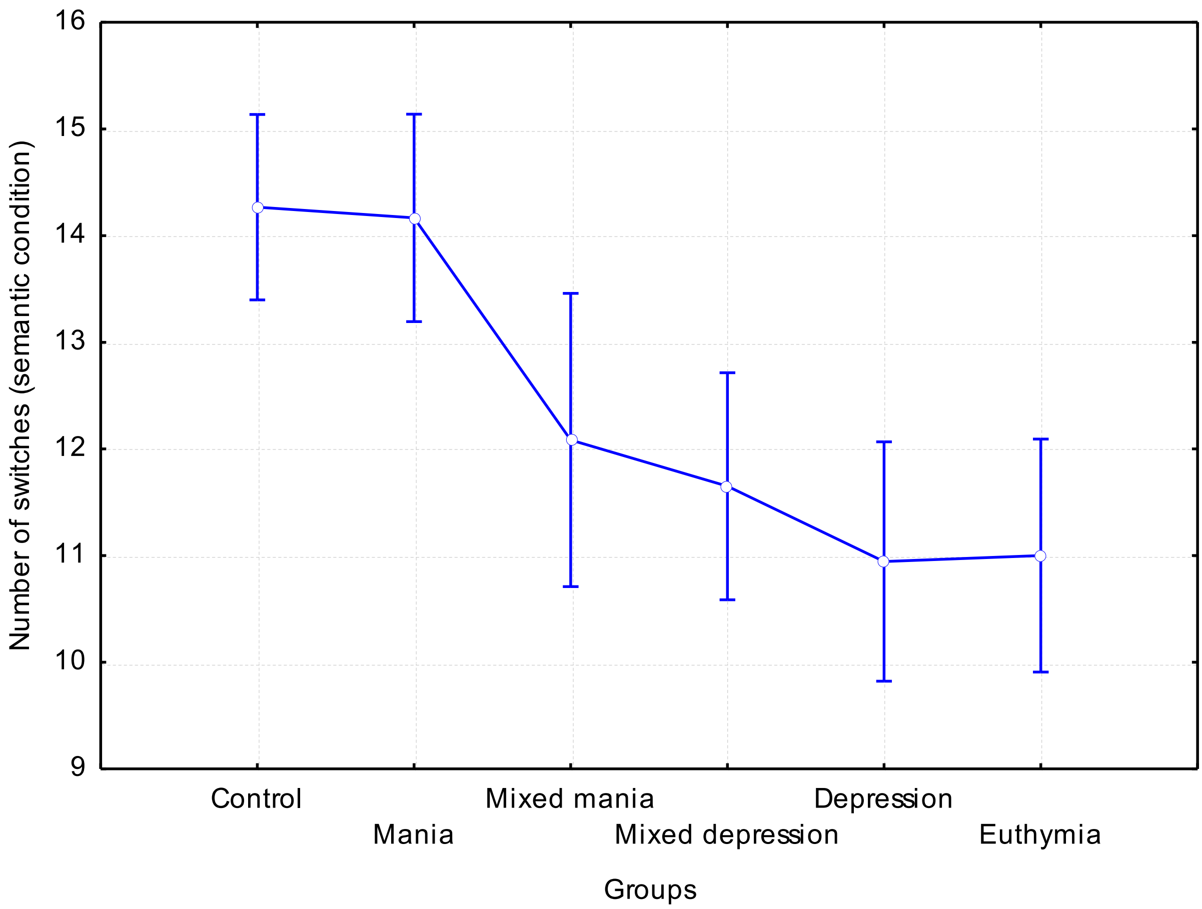

Figure 5: Number of switches in the semantic fluency task across groups

3.4 Correlation analyses

Correlation analyses were performed within the whole patient group. Regarding clinical symptoms (cf. table 3), racing thoughts, assessed via the RCTQ, were negatively associated with the phonological cluster ratio in the letter fluency task. Likewise, elevated manic symptoms were associated with decreased task-consistent ratio of phonological clusters in the letter fluency and task-discrepant cluster size in the semantic task. Racing thoughts were also negatively associated with the number of words in the letter and semantic fluency. Specifically, overexcitability, which is particularly associated with distractibility, was linked to decreased verbal output when subjects have to follow retrieval rules (semantic and letter tasks). Rumination was negatively associated with the overall number of words produced in the free and semantic conditions: the higher the brooding scores, the less the number of words.

Regarding the neuropsychological measures (cf. table 3), increased working memory, executive functioning, and processing speed abilities were related to increased verbal output in all verbal fluency tasks, whereas increased vocabulary score was only involved in semantic and letter fluency performance. Measures of phonological and semantic clustering were negatively correlated to inhibition, and, to a lesser extent, to working memory and vocabulary scores, indicating that inhibition is particularly involved in clustering. Switches were related to executive function, working memory and processing speed measures; such was especially the case in the free fluency tasks.

Table 3: Correlations between verbal fluency and neuropsychological and clinical measures in patients (n = 90)

Instruments	TMT - A	TMT-B	Digit-span	Hayling time	Hayling errors	Digit-Symbol	Vocabulary	RCTQ total	RCTQ overactivation	RCTQ burden	RCTQ overexcitability	RRS brooding	YMRS	QIDS-C16
Number of words														
Free	-.28*	-.25*	.45*	-.30*	-.30*	.28*	.12	-.15	-.08	-.17	-.14	-.31*	.09	-.14
Semantic	-.30*	-.34*	.34*	-.02	-.19	.36*	.25*	-.22*	-.15	-.20	-.24*	-.24*	.05	-.06
Letter	-.19	-.21	.32*	-.04	-.27*	.29*	.23*	-.23*	-.20	-.18	-.23*	-.19	-.15	-.05
Semantic cluster ratio														
Free	-.08	-.12	.09	.05	.01	.07	-.05	-.04	.01	-.03	-.06	-.07	-.11	-.01
Semantic	-.01	-.01	.05	.21*	.04	.08	.02	-.11	-.04	-.08	-.16	-.09	.04	-.01
Letter	-.03	.04	-.01	.24*	-.06	.04	.02	-.13	-.12	-.12	-.12	-.04	-.10	.04
Semantic cluster size														
Free	.14	.01	-.07	-.10	-.05	-.05	.14	-.11	-.12	-.10	-.09	-.16	.02	-.14
Semantic	-.01	-.02	.07	.21*	.02	.09	.04	-.11	-.04	-.08	-.17	-.09	.03	-.01
Letter	-.02	.06	-.01	.26*	-.05	.04	.03	-.14	-.13	-.13	-.13	-.04	-.11	.04
Phonemic cluster ratio														
Free	.08	.08	.15	-.03	-.07	-.06	.21*	-.20	-.13	-.23*	-.19	-.19	.01	-.17
Semantic	.01	.07	.02	-.02	-.06	.01	.05	-.10	-.05	-.14	-.06	-.20	.14	-.03
Letter	.21	.08	.02	.05	-.02	-.12	.14	-.29*	-.33*	-.23*	-.27*	-.14	-.22*	-.01
Phonemic cluster size														
Free	-.07	-.03	.23*	-.15	-.15	.02	.03	-.09	-.03	-.15	-.04	-.16	.10	-.14
Semantic	-.04	.05	-.01	.22*	-.06	.04	.02	-.12	-.12	-.11	-.11	-.04	.26*	.03
Letter	-.02	.05	-.01	.25*	-.06	.04	.02	-.13	-.13	-.12	-.13	-.12	-.10	.04
Switches														
Free	-21	-.14	.30	-.23*	.26*	.22*	-.01	-.01	.04	-.04	-.01	-.06	.10	-.06
Semantic	-.13	-.11	.09	.10	.01	.24*	.01	-.09	-.02	-.07	-.13	-.11	.10	-.05
Letter	-.16	-.12	.25*	-.02	-.19	.20	.14	-.11	-.08	-.08	-.12	-.12	-.06	-.02

Legend: TMT = Trail-Making Test;RCTQ = Racing and Crowded Thoughts Questionnaire; RRS = Rumination Reponses Scale; YMRS = Young Mania Rating Scale; QIDS-C16 = Quick Inventory of Depressive Symptomatology - Clinician version; * p<.05

4 Discussion

Word count in verbal fluency tasks could not distinguish between mood episodes in BD, with the exception of the semantic task, in which the depression and, to a lesser extent, the euthymic groups, showed decreased verbal output compared to controls. These results are consistent with those reported by Raucher-Chéné et al. (2017), suggesting greater impairment in the semantic fluency condition in subgroups of patients with BD. By contrast, the process-oriented measures proved to better capture the linguistic anomalies characteristic of mood episodes in BD, and to further delineate the cognitive processes involved in word output. Indeed, enhanced task-discrepant phonological cluster size in the semantic task, along with reduced proportion of semantic clusters and increased switches in the free task were particularly prominent in the verbal output of manic compared to the control and depression groups, hence reflecting the extremely combinatory, tangential, and sound-based speech found in mania (Hoffman et al., 1986). In other words, mania affected speech structure but not verbosity in these tasks. Importantly, in the mixed depression group, the number of switches in the free fluency task was also significantly higher than those found in non-mixed depression, indicating that subthreshold manic symptoms led to discrete structural speech anomalies.

Consistent with a previous study by Fossati et al. (2003) in unipolar depression, our results point to the fact that reduced switches, especially in the semantic condition, are involved in the verbal output of depressed patients but also, and rather interestingly, in euthymic patients, but not in the other clinical groups. Our results add to those outlined by Raucher-Chéné et al. (2017), and suggest that trait-like anomalies are found during euthymia and probably compensated for in manic and mixed states. Interestingly, our results are the first to pinpoint switching abilities as affecting semantic fluency performance, and differently so among different types of mood episodes in BD. Like Fossati et al.'s (2003) findings, switching was specifically correlated in our study to measures of executive functions and psychomotor speed, and it seems likely that both are at least partially involved in the relative decrease and increase of switches found respectively in depression and mania. However, this relationship is not as straightforward as it may seem, since different pattern of results were found in the free and letter tasks. Increased switches in mania but also mixed depression were particularly marked in the free condition of the task, which requires subjects to spontaneously generate search strategies, hence tapping more on creative processes (Phillips et al., 2002). In this task condition, compared to the depression and euthymia groups, subjects in mixed depression and manic episodes shifted at a faster rate from one discourse unit to the other, mimicking the distractibility characteristic of these states (Hoffman et al., 1986; Benazzi, 2009). Interestingly, in healthy subjects, induction of positive affect during executive tasks has been shown to promote cognitive flexibility at the expense of increased distractibility (Dreisbach & Goschke, 2004). This effect is thought to be mediated by dopamine transmission, and is supposedly involved in enhanced creativity in healthy individuals (Dreisbach, 2006). In patients with BD, Koenders et al. (2014) recently showed that hypomanic symptoms had a beneficial effect on performance in divided attention tasks, meaning that shifting the focus of attention was facilitated by hypomanic symptoms, akin to distractibility. Given that increased switching was correlated with reduced inhibition and faster processing speed, these results could be attributed to differential patterns of processing speed and inhibition abilities in acute episodes of BD. It is noteworthy however that increased switches did not amount to greater number of words produced in the free fluency task. This is probably due to the fact that they were accompanied by reduced proportion of semantic clusters in mania. Like Ross et al. (2007), semantic clustering in letter and semantic fluency was correlated to inhibition latencies in our study, and not to vocabulary scores. This suggests that, at least in tasks with retrieval rules (letter and semantic fluency), clustering performance may depend on the inhibition of interference words, namely, the spread of semantic activation primed by each word generated (Collins & Loftus, 1975). Conversely, the unrestrictive nature of the free fluency task might have enhanced diffuse semantic activation and favored the retrieval of more remotely associated words within the semantic network, which were not required to be inhibited in this task (Phillips et al., 2002). However, it might have also favored conceptual shifts, promoting the production of single words instead of clusters. Consistently, elevated racing thoughts, and its distractibility feature in particular, were related to decreased number of words in letter and semantic fluency, but not the free condition of the task. Again, this can be attributed to the fact that, in this task condition only, distractibility was not detrimental of performance, since subjects did not have to inhibit interferences unrelated to the task's rules.

Another major finding of our study is that task-discrepant phonological clustering was prominent in mania, and followed a decreasing gradient in mixed groups, until depression and euthymia. That is, when they had to produce animal names, manic subjects did so while rhyming and using other sound-based associations, more than any other group. Because healthy subjects produce proportionally more task-discrepant semantic clustering in letter fluency rather than the other way round (Vonberg et al., 2014; Ledoux et al., 2014), it has been argued that semantic clusters are more automatic, relying on spreading of activation within the semantic network, whereas phonological clustering is more laborious and relies on executive functions (Ho et al., 2002; Ledoux et al., 2014). If such is the case, increased phonological clustering in semantic fluency could be attributed to enhanced executive functions in our patients with manic symptoms (Koren et al., 2005). This was not the case in our group of patients though, as results from executive tasks were generally impaired in our manic group compared to controls. Evidence arising from patients with Alzheimer's disease (Robinson and Ceslis, 2014) and interference paradigms in healthy individuals (Navarrete and Costa, 2005) suggest that defective inhibition of unrelated phonological representations activated through semantic spreading might be related to increased sound-based associations (Levelt, 1999). Hence it is possible that both faster spreading of activation and defective inhibitory control are involved in increased phonological cluster size and switches in patients with manic symptoms. Consistently, in our study, greater task-discrepant phonological cluster size was correlated with elevated manic symptoms and greater latencies in an inhibition task, suggesting the contribution of defective inhibitory control in the results.

Elevated racing thoughts and manic symptoms were specifically associated with a decreased ratio of phonological clusters in letter fluency only. Because the letter fluency task prompts alphabetic rather than category-based search strategy through the lexicon, it relies more on executive functions (Ho et al., 2002). As a matter of fact, if subjects have to produce words starting with the a given letter, then clang associations should have facilitated their retrieval. However, elevated racing thoughts and manic symptoms were associated with reduced phonological cluster ratios in the letter task, suggesting that clang associations did not promote the controlled retrieval of phonemic-related words required by this task, but rather single words. This is consistent with the idea that racing thoughts are at least partly related to enhanced flexibility and defective inhibition of automatic processes, leading to distractibility. Interestingly, these results are consistent with recent phenomenological models suggesting that racing thoughts result from enhanced flexibility (Piguet et al., 2010). By contrast, rumination was linked to reduced verbal output. This was not the case for depressive symptoms as a whole, hence highlighting the specific contribution of rumination to poverty of speech in depression.

Our work has some limitations, the main one being the small sample of mixed manic patients, which might have limited the power of our analyses. Moreover, mixed manic patients had lower premorbid IQ compared to controls, and this might also have influenced their results.

All in all, our empirical findings are supportive of numerous phenomenological accounts attributing clang associations and enhanced topic shifts to manic symptoms in BD (e.g., Goodwin and Jamison, 2007; Sass and Pienkos, 2015), and the opposite pattern of results in typical depression (Sass and Pienkos, 2015). Interestingly, patients with mixed symptoms presented with intermediate results; increased switches in particular were greater in mixed depression than depression. More generally, we showed evidence of increased flexibility and defective inhibition in mania, and the opposite pattern of results in depression, but also, to some extent, in euthymia. Increased flexibility has a cost though, reflected by the reduced semantic organization of verbal output. Thus, it is the balance between flexibility and inhibition that seems to be altered in mood episodes of bipolar disorder (Piguet et al., 2010).

Conclusion

Switching and clustering abnormalities reflect enhanced flexibility at the expense of defective inhibition in mania, and are related to racing thoughts and manic symptoms. Switching distinguished depression from mixed depression with few hypomanic symptoms (Miller et al., 2016). Given the extremely low number of studies which have investigated language and cognition in mixed episodes of BD, our results require to be confirmed by future studies.

References

Abwender, D.A., Swan, J.G., Bowerman, J.T., Connolly, S.W., 2001. Qualitative Analysis of Verbal Fluency Output: Review and Comparison of Several Scoring Methods. Assessment 8, 323–338. doi:10.1177/107319110100800308

A.P.A, 2000. Diagnostic and Statistical Manual of Mental Disorders, 4th Edition, Text Revision, 4th edition. ed. American Psychiatric Association, Washington, DC.

Basso, M.R., Lowery, N., Neel, J., Purdie, R., Bornstein, R.A., 2002. Neuropsychological impairment among manic, depressed, and mixed-episode inpatients with bipolar disorder. Neuropsychology 16, 84–91.

Benazzi, F., 2009. What is hypomania? Tetrachoric factor analysis and kernel estimation of DSM-IV hypomanic symptoms. J. Clin. Psychiatry 70, 1514–1521. doi:10.4088/JCP.09m05090

Benazzi, F., 2007. Challenging the unipolar-bipolar division: does mixed depression bridge the gap? Prog. Neuropsychopharmacol. Biol. Psychiatry 31, 97–103. doi:10.1016/j.pnpbp.2006.08.003

Burgess, P.W., Shallice, T., 1997. The Hayling and Brixton Tests [WWW Document]. Thames Val. Test Co. Bury St Edmunds UK 1997. URL http://discovery.ucl.ac.uk/5457/ (accessed 10.31.17).

Cardebat D, Doyon B, Puel M, Goulet P, Joanette Y. Formal and semantic lexical evocation in normal subjects. Performance and dynamics of production as a function of sex, age and educational level. Acta Neurol Belg. 1990;90(4):207-17.

Collins, A.M., Loftus, E.F., 1975. A Spreading-Activation Theory of Semantic Processing. Psychol. Rev. 82, 407–428.

Cutting, J., 1997. Principles of Psychopathology: Two Worlds - Two Minds - Two Hemispheres. Oxford University Press, Oxford, New York.

Esmaeelpour, E., Sasani, F., 2016. The Effect of Bipolar Mood Disorder on Sadegh Hedayat's Letters. J. Psycholinguist. Res. 45, 367–377. doi:10.1007/s10936-015-9355-5

Favre, S., Aubry, J.-M., Gex-Fabry, M., Ragama-Pardos, E., McQuillan, A., Bertschy, G., 2003. [Translation and validation of a French version of the Young Mania Rating Scale (YMRS)]. L'Encephale 29, 499–505.

Fossati, P., Ergis, A.-M., Allilaire, J.-F., others, 2003. Qualitative analysis of verbal fluency in depression. Psychiatry Res. 117, 17–24.

Goodwin, F.K., Jamison, K.R., 2007. Manic-Depressive Illness: Bipolar Disorders and Recurrent Depression. Oxford University Press, USA.

Harrow, M., Grossman, L.S., Silverstein, M.L., Meltzer, H.Y., Kettering, R.L., 1986. A longitudinal study of thought disorder in manic patients. Arch. Gen. Psychiatry 43, 781–785.

Helmes, E., Hall, F., 2016. Performance of psychiatric diagnostic groups on measures and strategies of verbal fluency. Appl. Neuropsychol. Adult 23, 284–294. doi:10.1080/23279095.2015.1056300

Henry, J.D., Crawford, J.R., 2005. A Meta-Analytic Review of Verbal Fluency Deficits in Depression. J. Clin. Exp. Neuropsychol. 27, 78–101. doi:10.1080/138033990513654

Henry, J.D., Crawford, J.R., 2004. A meta-analytic review of verbal fluency performance following focal cortical lesions. Neuropsychology 18, 284–295. doi:10.1037/0894-4105.18.2.284

Hirschfeld, R.M. a, Williams, J.B. w, Spitzer, R.L., Calabrese, J.R., Flynn, L., Keck, P.E., Lewis, L., Mcelroy, S.L., Post, R.M., Rapport, D.J., Russell, J.M., Sachs, G.S., Zajecka, J., 2000. Development and Validation of a Screening Instrument for Bipolar Spectrum Disorder: The Mood Disorder Questionnaire. Am. J. Psychiatry 157, 1873–1875.

Ho, A.K., Sahakian, B.J., Robbins, T.W., Barker, R.A., Rosser, A.E., Hodges, J.R., 2002. Verbal fluency in Huntington’s disease: a longitudinal analysis of phonemic and semantic clustering and switching. Neuropsychologia 40, 1277–1284. doi:10.1016/S0028-3932(01)00217-2

Hoffman, R.E., Stopek, S., Andreasen, N.C., 1986. A comparative study of manic vs schizophrenic speech disorganization. Arch. Gen. Psychiatry 43, 831–838.

Jamison, K.R., 2017. Robert Lowell, Setting the River on Fire: A Study of Genius, Mania, and Character. Knopf, New York.

Joanette, Y., 2004. Impact of a right-hemisphere lesion on verbal communication
. Rééduc. Orthophonique 42, 9–26.

Kerns, J.G., Berenbaum, H., Barch, D.M., Banich, M.T., Stolar, N., 1999. Word production in schizophrenia and its relationship to positive symptoms. Psychiatry Res. 87, 29–37. doi:10.1016/S0165-1781(99)00052-9

Koenders, M.A., Spijker, A.T., Hoencamp, E., Haffmans, J.P.M., Zitman, F.G., Giltay, E.J., 2014. Effects of mood state on divided attention in patients with bipolar disorder: evidence for beneficial effects of subclinical manic symptoms. Psychiatry Res. 220, 302–308. doi:10.1016/j.psychres.2014.07.052

Koren, R., Kofman, O., Berger, A., 2005. Analysis of word clustering in verbal fluency of school-aged children. Arch. Clin. Neuropsychol. Off. J. Natl. Acad. Neuropsychol. 20, 1087–1104. doi:10.1016/j.acn.2005.06.012

Ledoux, K., Vannorsdall, T., J Pickett, E., Bosley, L., Gordon, B., Schretlen, D., 2014. Capturing additional information about the organization of entries in the lexicon from verbal fluency productions. J. Clin. Exp. Neuropsychol. 36. doi:10.1080/13803395.2013.878689

Levelt, 1999. Models of word production. Trends Cogn. Sci. 3, 223–232.

Lezak, M.D., 2004. Neuropsychological Assessment. Oxford University Press.

Mackinnon, A., Mulligan, R., 2005. [The estimation of premorbid intelligence levels in French speakers]. L'Encephale 31, 31–43.

Miller, S., Suppes, T., Mintz, J., Hellemann, G., Frye, M.A., McElroy, S.L., Nolen, W.A., Kupka, R., Leverich, G.S., Grunze, H., Altshuler, L.L., Keck, P.E., Post, R.M., 2016. Mixed Depression in Bipolar Disorder: Prevalence Rate and Clinical Correlates During Naturalistic Follow-Up in the Stanley Bipolar Network. Am. J. Psychiatry 173, 1015–1023. doi:10.1176/appi.ajp.2016.15091119

Mota, N.B., Furtado, R., Maia, P.P.C., Copelli, M., Ribeiro, S., 2014. Graph analysis of dream reports is especially informative about psychosis. Sci. Rep. 4, 3691. doi:10.1038/srep03691

Navarrete, E., Costa, A., 2005. Phonological activation of ignored pictures: Further evidence for a cascade model of lexical access. J. Mem. Lang. 53, 359–377. doi:10.1016/j.jml.2005.05.001

Nolen-Hoeksema, S., Morrow, J., 1991. A prospective study of depression and posttraumatic stress symptoms after a natural disaster: The 1989 Loma Prieta earthquake. J. Pers. Soc. Psychol. 61, 115–121. doi:10.1037/0022-3514.61.1.115

Phillips, L.H., Bull, R., Adams, E., Fraser, L., 2002. Positive mood and executive function: evidence from stroop and fluency tasks. Emot. Wash. DC 2, 12–22.

Piguet, C., Dayer, A., Kosel, M., Desseilles, M., Vuilleumier, P., Bertschy, G., 2010. Phenomenology of racing and crowded thoughts in mood disorders: a theoretical reappraisal. J. Affect. Disord. 121, 189–198. doi:10.1016/j.jad.2009.05.006

Raskin, S.A., Sliwinski, M., Borod, J.C., 1992. Clustering strategies on tasks of verbal fluency in Parkinson's disease. Neuropsychologia 30, 95–99.

Raucher-Chéné, D., Achim, A.M., Kaladjian, A., Besche-Richard, C., 2017. Verbal fluency in bipolar disorders: A systematic review and meta-analysis. J. Affect. Disord. 207, 359–366. doi:10.1016/j.jad.2016.09.039

Robinson, G., Ceslis, A., 2014. An unusual presentation of probable dementia: rhyming, associations, and verbal disinhibition. J. Neuropsychol. 8, 289–294. doi:10.1111/jnp.12041

Ross, T.P., Calhoun, E., Cox, T., Wenner, C., Kono, W., Pleasant, M., 2007. The reliability and validity of qualitative scores for the Controlled Oral Word Association Test. Arch. Clin. Neuropsychol. Off. J. Natl. Acad. Neuropsychol. 22, 475–488. doi:10.1016/j.acn.2007.01.026

Rush, A.J., Trivedi, M.H., Ibrahim, H.M., Carmody, T.J., Arnow, B., Klein, D.N., Markowitz, J.C., Ninan, P.T., Kornstein, S., Manber, R., Thase, M.E., Kocsis, J.H., Keller, M.B., 2003. The 16-Item Quick Inventory of Depressive Symptomatology (QIDS), clinician rating (QIDS-C), and self-report (QIDS-SR): a psychometric evaluation in patients with chronic major depression. Biol. Psychiatry 54, 573–583.

Sass, L., Pienkos, E., 2015. Beyond Words: Linguistic Experience in Melancholia, Mania, and Schizophrenia. Phenomenol. Cogn. Sci. 14, 475–495.

Strauss, E., Sherman, E.M.S., Spreen, O., 2006. A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary. Oxford University Press.

Suppes, T., Mintz, J., McElroy, S.L., Altshuler, L.L., Kupka, R.W., Frye, M.A., Keck, P.E., Nolen, W.A., Leverich, G.S., Grunze, H., Rush, A.J., Post, R.M., 2005. Mixed hypomania in 908 patients with bipolar disorder evaluated prospectively in the Stanley Foundation Bipolar Treatment Network: a sex-specific phenomenon. Arch. Gen. Psychiatry 62, 1089–1096. doi:10.1001/archpsyc.62.10.1089

Tombaugh, T.N., 2004. Trail Making Test A and B: Normative data stratified by age and education. Arch. Clin. Neuropsychol. 19, 203–214. doi:10.1016/S0887-6177(03)00039-8

Treynor, W., Gonzalez, R., Nolen-Hoeksema, S., 2003. Rumination Reconsidered: A Psychometric Analysis. Cogn. Ther. Res. 27, 247–259. doi:10.1023/A:1023910315561

Tröster, A.I., Fields, J.A., Testa, J.A., Paul, R.H., Blanco, C.R., Hames, K.A., Salmon, D.P., Beatty, W.W., 1998. Cortical and subcortical influences on clustering and switching in the performance of verbal fluency tasks. Neuropsychologia 36, 295–304. doi:10.1016/S0028-3932(97)00153-X

Troyer, A.K., Moscovitch, M., Winocur, G., 1997. Clustering and switching as two components of verbal fluency: evidence from younger and older healthy adults. Neuropsychology 11, 138–146.

Vonberg, I., Ehlen, F., Fromm, O., Klostermann, F., 2014. The absoluteness of semantic processing: lessons from the analysis of temporal clusters in phonemic verbal fluency. PloS One 9, e115846. doi:10.1371/journal.pone.0115846

Wechsler, D. (1997). Wechsler Memory Scale–Third Edition. San Antonio, TX: The Psychological Corporation.

Weiner, L., Weibel, S., de Sousa Gurgel, W., Keizer, I., Gex-Fabry, M., Giersch, A., Bertschy, G. submitted. Measuring racing thoughts in healthy individuals: The Racing and Crowded Thoughts Questionnaire.

Young, R.C., Biggs, J.T., Ziegler, V.E., Meyer, D.A., 1978. A rating scale for mania: reliability, validity and sensitivity. Br. J. Psychiatry J. Ment. Sci. 133, 429–435

Article 5 Appendix: Associational fluency tasks and additional process-oriented measures

We elaborated six additional verbal fluency tasks for our study, based on the associational method described in section 1.4. We are currently analyzing the data obtained in these trials in three different ways – (i) via the aforementioned qualitative method (article 5), (ii) via their temporal features, (iii) and via a clustering algorithm which used LSA[30]. In LSA, the meaning of a word in a given semantic space (e.g., *Le Monde* newspapers from the whole year) is represented by a high dimensional vector where each entry corresponds to the number of times the given word appears in each document. The semantic similarity between two words is calculated as the cosine of the angle between their respective vectors. Hence semantically related words will have a semantic similarity close to 1; and unrelated words, close to 0. This contrasts with the qualitative method whereby semantic-relatedness is based on the evaluation of independent raters (as in article 5), and might be considered more subjective. The clustering procedure utilized in our automated LSA approach is described in more detail below.

Since the analyses are ongoing, we will provide preliminary findings relative to the validity of the temporal and LSA measures by comparing them to the aforementioned qualitative measures.

Description of the associational tasks

[30] LSA posits that meaning is acquired through its use in context, and that two words are semantically related in a specific semantic space (e.g. *Le Monde* newspapers of the whole year) to the degree that they appear in the same documents (e.g., chapters, paragraphs or sentences) within that chosen semantic space. For a more detailed description of each existing semantic spaces in French, the reader can refer to http://lsa.colorado.edu/spaces.html.

In associational fluency trials, subjects were orally presented with a cue word, and they were asked to produce words, during 120s, with their eyes closed, following the presentation of the initial word. They were also instructed that the words produced could either have a tight or a loose association link with the inductive word. Following the presentation of the task instructions, subjects were provided with an example (i.e., the word 'glass'), and they were asked to produce words starting from it. Two types of inductive words were used, concrete and abstract nouns. For each type, three bisyllabic words were chosen, with a negative, neutral or positive emotional valence (for concrete words, 'snake', 'kingdom', and 'swimming pool', respectively; for abstract words, 'pain', 'beginning', and 'courage', respectively). Words within each triplet were matched in terms of their film subtitle-based frequency in French (New et al., 2007), and their concreteness ratings among French native speakers (Desrochers & Bergeron, 2000). Regarding emotional valence, according to the data reported by Syssau & Font (2004) in their sample of 600 French native speakers, nouns were judged to be neutral if their valence ranged between -1 and +1, in a 11-item Likert scale ranging from -5 and +5; they were judged to be positive if their valence was superior to +1; and they were considered to be negative, if their valence was inferior to -1. For concrete nouns, the valence for 'snake', 'kingdom', and 'swimming pool' was -1.74, .40, and +2.79, respectively. For abstract nouns, the valence for 'pain', 'beginning', and 'courage' was -3.63, .89, and +3.69, respectively. The six inductive words were presented in random order.

Comparing process-oriented measures in the 9 verbal fluency conditions

In addition to the qualitative method presented in article 5, we have analyzed our verbal fluency data in two ways: 1) temporally, via the inter-word pauses and the time course of word production (i.e., three successive time windows of 40s), and 2) via clustering algorithms which incorporated Latent Semantic Analysis (LSA) to quantify semantic similarity.

Here we will present correlation analyses between the actual number of words produced in each task, and the number of words estimated through the speech detection algorithm (1). Then we will present correlation analyses between the number of semantic clusters obtained via the qualitative method (human scoring of clusters in article 5), and the clustering algorithm that incorporated LSA (2).

Our aim is to provide preliminary findings regarding the validity of the two measures by comparing them to the aforementioned qualitative measures.

1. **Temporal analyses**[31]

Pearson correlation coefficients between the number of words produced by subjects (human scoring), and the word estimated via the speech algorithm are presented in table 1.

Table 1: Correlations word output and speech

Task condition	r
Free	.85
Letter	.73
Semantic	.70
Swimming pool	.77
Kingdom	.83
Snake	.77
Courage	.78
Beginning	.81
Pain	.82

2. **LSA clustering algorithm**[32]

[31] Collaboration with the Bioengineering Department of the University of Pisa, Italy (Professor Nicola Vanello and Dr. Andrea Guidi).
[32] Collaboration with Guilherme Frederico Lima, PhD in Pure Mathematics, Palmer, Alaska.

In short, with LSA, the semantic similarity between two words is represented as a real number between 0 and 1, within a high-dimensional semantic space composed of numerous text corpora. In order to decide which words were sufficiently similar so as to belong to the same cluster, we estimated a threshold. To this aim, we considered all the consecutive words in the control group, through the LSA-derived semantic similarities between consecutive words (i.e. the cosine values between 0 and 1 corresponding to the similarities in the LSA database). The threshold was obtained by taking the median of the LSA-derived similarities. Semantic clusters were defined as a set of consecutive words such that the similarity between each consecutive pair or words was greater than a given threshold. The size of a cluster was defined as its number of words minus 1 (n – 1). We calculated a specific threshold for each verbal fluency task by taking the median obtained from the control group for each task condition.

Pearson correlation coefficients between the number of clusters obtained through the qualitative method, and the clusters obtained via the clustering algorithm are presented in table 2.

Table 2: Correlations with LSA clusters

Task condition	r
Free	.59
Letter	.51
Semantic	.61
Swimming pool	.59
Kingdom	.73
Snake	.59
Courage	.73
Beginning	.66
Pain	.62

Discussion

Correlation values are high, especially for the temporal features, but there is still room for improvement. We are currently working on reducing the noise in the data, before further analyzing the temporal and semantic features of interest.

References

Desrochers, A. & Bergeron, M. (2000). Valeurs de fréquence subjective et d'imagerie pour un échantillon de 1,916 substantifs de la langue française. Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale, 54, 274.

New, B., Brysbaert, M., Veronis, J., & Pallier, C. (2007). The use of film subtitles to estimate word frequencies. Applied Psycholinguistics, 28(4), 661–677. https://doi.org/10.1017/S014271640707035X

Syssau, A., & Font, N. (2012). Évaluations des caractéristiques émotionnelles d’un corpus de 604 mots. Bulletin de psychologie, Numéro 477(3), 361–367.

3 – Summary and general discussion

The goal of this thesis was to investigate the racing and crowded thoughts phenomenon from two perspectives: psychopathological and cognitive. To this aim, we first developed a self-report questionnaire – the Racing and Crowded Thoughts Questionnaire (RCTQ) -- based on the phenomenological literature reviewed in section 1.3.1, and on previous studies conducted by Gilles Bertschy's team in Geneva (e.g., Keizer et al., 2014). We investigated its psychometric properties in healthy individuals in article 1, and reported preliminary findings in patients with bipolar disorder in article 2. Second, based on the phenomenological and neuroscientific literature reviewed respectively in sections 1.3.2 &3 and 1.4.2 &3, we addressed, from a cognitive perspective, the racing and crowded thoughts phenomenon via temporal and language[33] paradigms. From a temporal standpoint, we first assessed, in healthy individuals, the relationship between intrinsic and extrinsic contextual factors – respectively, psychological dimensions and the number of events occurring during the interval – and the experience of time, including duration estimation and passage of time judgment (article 3). Then, we investigated how patients with bipolar disorder experienced time in different mood episodes, and assessed the relationship between duration experience and clinical symptoms, including racing and crowded thoughts (article 4). Focusing on language, we investigated the verbal output of patients with bipolar disorder via process-oriented approaches using verbal fluency tasks, and assessed the relationship between process-oriented measures and clinical symptoms (article 5).

[33] The tasks also involved an executive component. See section 1.4.3.

3.1 – The psychopathological mechanisms of racing thoughts: single or multi-faceted? State or trait-marker of bipolar disorder? Are they different from rumination? Distractibility, an understated mechanism?

3.1.1 Racing thoughts: Single or multi-faceted?

In the first article included in this thesis (cf. article 1), we investigated the psychometric properties of the RCTQ in 197 healthy individuals. Principal component analysis yielded a three-factor solution, hence suggesting that racing and crowded thoughts are a multi-faceted phenomenon in healthy individuals. The three factors were respectively labeled in our study (i) thought overactivation, (ii) burden of thought overactivation, and (iii) thought overexcitability. Cyclothymic temperament traits were the best predictor of scores in all the three subscales, indicating that the instrument has good convergent validity, as the RCTQ addresses a phenomenon associated with mood instability even at its mildest form. Moreover, rumination was not significantly associated with the three subscores. We will further address both points below.

In the patient study, we compared CFA fit indices for the three-factor solution obtained in the healthy sample (article 1), the single-factor solution obtained through exploratory factor analysis in half of the sample, and the two-factor solution based on our a priori model of racing vs. crowded thoughts. Compared to the single and bifactorial models, the three-factor model yielded the best fit. There is still room for improvement through the removal of redundant items within factors. Nevertheless, these preliminary results are supportive of the idea according to which racing and crowded thoughts are a multi-faceted construct in patients as well as in healthy individuals.

Contrary to our initial model (see figure 3), instead of two dimensions – i.e., racing and crowded --, our results suggest that the racing and crowded thoughts phenomena encompass three psychopathological mechanisms: the first, *thought overactivation*, might be related to what Braden & Ho (1981) termed as 'ideomotor pressure' and Keizer et al. (2014) labeled as 'pressure of thoughts' in their qualitative study, and refers to the increased amount and velocity of thoughts; the second, *burden of thought overactivation*, seems to refer to 'crowded thoughts' (Piguet et al., 2010) inasmuch as it is associated with functional impairment and dysphoria (Kraepelin, 1899; Braden & Ho, 1981; Benazzi, 2007); the third, *thought overexcitability*, is related to the involuntary onset and distractible nature of racing and crowded thoughts, a feature that had already been highlighted in two of the six themes – i.e., 'information processing' and 'onset and context' – found in the qualitative reports of patients in the Geneva study (Keizer et al., 2014). As outlined by descriptive accounts provided by Kraepelin (1899) and Binswanger (1933), and, more recently, by empirical accounts by Braden & Ho (1981) and Benazzi (2009), distractibility seems to be a core mechanism involved in the racing and crowded thoughts phenomena. We will further discuss this point in 3.1.5.

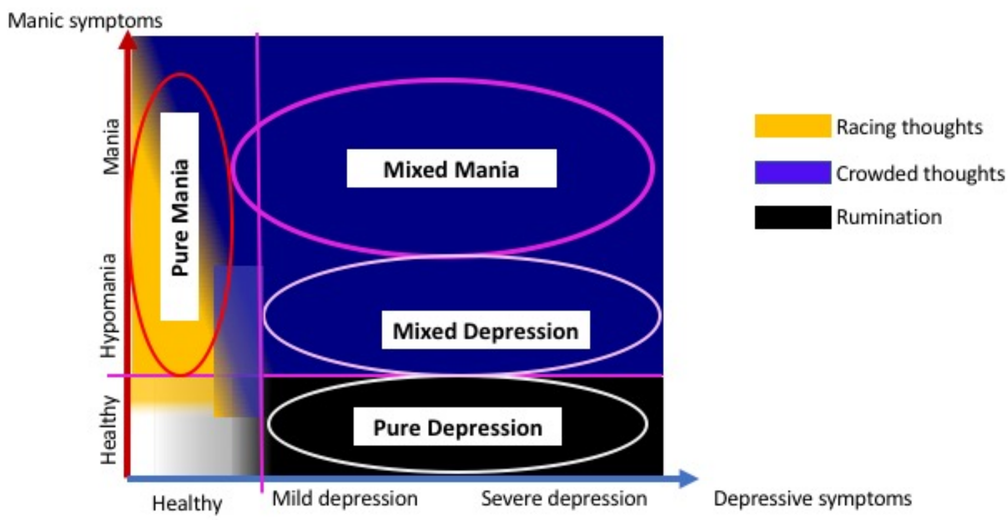

Figure 3: Our phenomenological model of racing and crowded thoughts in healthy functioning and mood disorders.

Importantly, compared to the STOQ-9[34] (Keizer et al., 2014), the RCTQ seems to better reflect the polymorphous nature of racing and crowded thoughts put forward by the qualitative findings reported by Keizer et al. (2014), with its three factors addressing most of the six themes these authors found. This might be due to several factors. First of all, the STOQ items were conceived based on clinical consensus, and the a priori hypothesis of two types of racing thoughts – i.e., racing and crowded – was the driving force behind the formulation of its items (Keizer et al., 2014). Instead, the elaboration of the RCTQ benefitted from clinical expertise, but also from the qualitative reports of patients. Thus, it covered domains highlighted by patients that were not fully addressed by the STOQ-9. When we developed the 34-item RCTQ, we knowingly conceived items that addressed similar domains with different formulations, in an attempt to provide a fine-grained analysis of the characteristics of racing and crowded thoughts. Building a comprehensive instrument that encompasses the numerous facets of the phenomenology of racing thoughts was thus a deliberate strategy. We will work on reducing the number of items in order to enhance its psychometric properties, and favor its use in clinical settings.

Another possibility that might account for the different factor structures in the STOQ and the RCTQ is the characteristics of Keizer et al.' s (2014) samples of patients with mood disorders. Indeed, Keizer et al. (2014) did not provide information regarding the clinical status of patients, which was only determined through the use of visual analog scales (i.e., the Internal States Scale or ISS, Bauer et al., 1991). Hence it is possible that most of their patients were depressed, as 26% of one of their samples had a longitudinal diagnosis of unipolar depression and among the bipolar patients many could have been depressed (they were for the most part outpatients which probably reduced the proportion of manic patients included). If such was

[34] The 9-item STOQ had a single-factor structure.

the case, then this might partially explain why the STOQ yielded a single-factor structure, as the results captured only few of the phenomenon's possible configurations (e.g., figure 3).

Lastly, our procedure differed from that of Keizer et al. (2014) inasmuch as we first assessed racing and crowded thoughts in healthy individuals, and only then did we investigate their characteristics in patients with bipolar disorder. Although this method may seem counterintuitive, since the questionnaire aimed at exploring a symptom found in full-blown mood disorders, it actually served to address two points: first, whether racing and crowded thoughts, like mood, could be conceptualized as a continuum; second, to investigate racing thoughts in healthy subjects[35]. Interestingly, the results obtained in healthy subjects was different in the first (article 1) compared to the second study (article 2) (average RCTQ scores were respectively 33 and 12). These differences point to an aspect of self-administered scales that might have influenced our results, i.e., social desirability bias (e.g., Furnham, 1986). Indeed, whereas in the patient study healthy controls were aware that they were enrolling in a study about bipolar disorder, and that racing thoughts were conceived as a symptom of the illness, such was not the case in the first study, where individuals completed self-rated scales about their functioning, and the main focus of the study was time perception. Hence, we speculate that the differences found between the two samples are due to social desirability biases: in the patient study the healthy controls did not want to present with symptoms of the illness and underestimated the occurrence of the racing thoughts phenomena. If such is the case, it is possible that, to some extent, a similar bias may have affected how patients with bipolar disorder completed the questionnaire. This is all the more likely in euthymic individuals, who might have been prone to showcase their absence of symptoms. In an

[35] It is important to add here that scales developed for the self-assessment of rumination, such as Rumination Response Scale (RRS; Nolen-Hoeksema & Morrow, 1991), and worry (e.g., the Penn-State Worry Questionnaire or PSWQ; Borkovec, Ray, & Stober, 1998) were also first applied to healthy individuals, although they aimed at addressing symptoms found respectively in depression and anxiety disorders.

ongoing study, we are investigating RCTQ results in another sample of naïve healthy individuals. Since the two healthy samples reported here also differed in terms of age, these results will help to clarify whether age and/or social desirability bias played a role in the discrepancy found between healthy samples.

All in all, our findings in healthy individuals and patients with bipolar disorder are consistent with phenomenological (e.g., Piguet et al., 2010) and some empirical (e.g., Braden & Ho, 1981) accounts which had suggested the multi-faceted nature of racing thoughts. Interestingly, we found that three, and not only two, mechanisms seem to be involved in this phenomenon (see 3.1.5). The characteristics of each mechanism were related to the current mood experienced by the subject: either elated or low in healthy functioning, or manic or depressed in patients with bipolar disorder. This implies that each of these three factors is, to a certain degree, state-dependent. We will address this point below.

3.1.2 Racing thoughts as state-dependent phenomena

The RCTQ was conceived as a state-dependent questionnaire, with items referring to the past 24-hours. This is due to the fact that racing thoughts have been typically associated with manic and mixed episodes of bipolar disorder. Our results are consistent with the idea according to which racing and crowded thoughts are exacerbated in mania and mixed episodes compared to euthymia, hence that they are to some extent state-dependent. This was particularly the case for two subscales of the RCTQ – i.e., thought overactivation and thought overexcitability --, which were linked to elated mood in the healthy sample of article 1, and in study 2 distinguished pure depression from manic episodes, but also pure depression from depression with very few manic subthreshold symptoms. However, these results were obtained only after refining our definition of pure depression episodes. Moreover, as outlined hereafter (section 3.1.3), some of our results in healthy individuals and in patients raise the question to whether racing and crowded thoughts might also be viewed as a trait-marker of the illness.

With the exception of the 'burden of thought overactivation' subscale which did not distinguish manic and depressed groups from the euthymic group, results on the other two subscales were higher in the acute groups compared to the euthymic one. The highest scores were observed in the mixed groups. As outlined above, this is consistent with current classifications, such as the DSM-5 (APA, 2013), which acknowledge that racing thoughts may be a symptom of manic or mixed episodes only. Surprisingly, however, we initially found that (i) 'burden of thought overactivation' score did not distinguish euthymia from mania and depression, but also that (ii) in all the other subscales mania and depression groups performed in a similar manner. This could be due to different possibilities: (i) the scale might either be too sensitive to slight manic symptoms or not sensitive enough to capture the different experiences of patients; (ii) racing and crowded thoughts are a trait of the disorder, irrespective of the ongoing mood episode; (iii) manic patients might have underestimated the occurrence of racing thoughts due to defective insight (Silva et al., 2016); and (iv) these results could be attributed to heterogeneity within both groups.

Braden & Ho (1981) had already reported that two core aspects of racing thoughts – i.e., 'ideomotor pressure' and 'disturbed concentration' – were equally found in depression and mania. This finding led the authors conclude that racing thoughts were "…related more to the underlying pathology of the affective illness than to the characteristics of either 'pole'", hence suggesting that these aspects could be considered a trait-marker of the illness. However, Braden & Ho (1981) and, later, Keizer et al. (2014) did not investigate racing thoughts in euthymic individuals. Thus, the assumption of racing thoughts as stable trait-phenomena found in bipolar disorder was speculative. It is worth noting that, in their study, Keizer et al. (2014) also found that racing and crowded thoughts scores, as assessed by the STOQ, were equivalent in depression and mania. While such was also initially the case in our study, when we removed the patients in the depressed group who had very few subthreshold manic symptoms (scores on the YMRS of 1 or 2)[36], we found that manic patients' total score on the RCTQ was marginally higher than those in the pure depression group (no concurrent manic symptoms): means were respectively 49.92 and 39.29, ns. These differences became significant when we focused on the RCTQ subscales: 'thought overactivation' and 'thought overexcitability' scores were higher in the manic compared to the very pure depression group (YMRS score = 0), whereas the 'burden of thought overactivation' score could not differentiate mania from depression. Thus, the lack of difference in racing thoughts between mania and depression reported by Braden & Ho (1981) and Keizer et al. (2014) could be due to the fact that their depression group included patients who experienced concurrent manic symptoms and/or that, in the case of the STOQ, racing thoughts were considered as single construct. Consistent with these interpretations, in our patient study, RCTQ total score was significantly higher in the mixed groups but also in the depression with few manic subthreshold manic symptoms group (YMRS score of 1 or 2) compared to the 'pure' depression group (YMRS=0). Regarding its subscales, 'thought overactivity' and 'thought overexcitability' scores were higher in the pure manic, mixed manic, mixed depression, and depression with few subthreshold manic symptoms compared to the depression (YMRS=0) and euthymic groups. By contrast, 'burden of thought overactivation' scores were more specific of mixed mania and mixed depression. These results are thus consistent with our model of racing and crowded thoughts, which had suggested that enhanced 'crowded thoughts'[37] were found in mixed manic and mixed depression, but not in hypomania[38] and

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[36] Based on Miller et al.'s (2016) criteria, in our study, episodes of depression (QIDS > 5) concurrent with a score > 2 on the YMRS, which assesses current manic symptoms, were classified as 'mixed depression'.

[37] We argue here that 'burden of thought overactivation' items hold some resemblance to phenomenal descriptions of crowded thoughts since both are characterized by the overwhelming and dysphoric feeling

depression. Moreover, they are consistent with past empirical results indicating that racing thoughts as a whole were more pronounced in patients with mixed symptoms (Benazzi, 2007b).

Our results are still preliminary, and remain to be confirmed. However, as they are, they add to a growing number of studies which have argued against the DSM-5 decision to exclude overlapping DIP symptoms (i.e., distractibility, irritability, and psychomotor agitation) from the 'mixed features' specifier, as these symptoms might be core mixed symptoms (e.g., Miller et al., 2016; Perugi et al., 2015). When they are observed in depressive episodes, other mixed characteristics such as dysphoria and anxiety disorder comorbidity have been described (Bertschy et al., 2007; Kim et al., 2016). In our patient study, we found that very few subthreshold manic symptoms (for instance, enhanced irritability, resulting in a YMRS score of 1) in depressive episodes could result in a significant increase in racing and crowded thoughts, suggesting that minor (overlapping or not) manic symptoms concurrent with depression may give rise to clinical pictures characteristic of mixed depression (Bertschy et al., 2008b). This suggests that the RCTQ might be particularly sensitive to 'activation' symptoms, as it captures thinking abnormalities that are associated with very few subthreshold manic symptoms in patients, but also in healthy individuals (see section 3.1.3). Moreover, these results echo those from a study by Bertschy et al. (2008) which found that the presence of only 1 manic symptom in depressive episodes was associated with an increase from 17 to 61 % of the prevalence of dysphoric symptoms (e.g., inner-tension, aggressive behavior, irritability). Thus, there might be a specific phenomenology of depressive mixed states emerging with very low levels of hypomania. These results suggest that categories might miss out on mild but relevant clinical features.

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of lack of control. However, this assumption remains to be reexamined in a more thorough manner in future studies.

[38] The subjects included in the manic group were for the most part hypomanic.

Taken together, our results are supportive of the assumption that, to some extent, racing and crowded thoughts are state-dependent phenomena. More specifically, we found evidence that very few manic symptoms (for instance, subjective enhanced irritability) – whether in depression episodes, mixed or manic episodes – were associated with elevated racing and crowded thoughts in bipolar disorder. This was particularly the case for 'thought overactivation' and 'thought overexcitability', whereas 'burden of thought overactivation' score was higher in patients with mixed mania or depression, consistent with previous phenomenological and empirical findings.

3.1.3 Racing thoughts as a trait-marker of bipolar disorder?

To our knowledge, our study is the first to show that racing and crowded thoughts can be found in healthy individuals, and, more importantly, that this symptom, usually reported in manic or mixed states of full-blown bipolar illness, is associated with elevated cyclothymic traits. This assumption had already been put forward by Dodd et al. (2010), who had found in their study that exacerbated hypomanic personality traits in healthy undergraduate students were related to enhanced activation symptoms, including racing thoughts, in visual analog scales (ISS; Bauer et al., 1991). Interestingly, we found that specific facets of racing and crowded thoughts were particularly associated with elated mood (i.e., 'thought overactivation'), low mood (i.e., 'burden of thought overactivation'), and both low and elated mood (i.e., 'thought overexcitability'). This is consistent with the phenomenological model we proposed in section 1.3.1 (figure 3), which theorized that racing and crowded thoughts should be observed in healthy individuals in association with minor low and/or elated mood. We further discuss the overexcitability component, which was not part of our model, in section 3.1.5. Although these results do not necessarily mean that racing and crowded thoughts are a trait-marker of bipolar disorder, they do point to the fact that racing and crowded thoughts are very strongly related to trait-like mood instability, even at its mildest form.

More suggestive of trait-like abnormalities, Ferrari et al. (2016) recently reported, in a pilot study, that STOQ scores were higher in euthymic patients compared to controls. In our patient study, RCTQ scores also differed between the two groups, further suggesting that racing and crowded thoughts are not only state phenomena, but that they might be intrinsically connected to trait-like vulnerability factors in the absence of major mood symptoms. This conclusion should be nuanced owing to the response bias described above. We cannot rule out that the difference between euthymic patients and controls is due to healthy subjects underestimating the importance of some symptoms. However, if such was the case, a similar social desirability bias could also have affected RCTQ scores in euthymic patients. Additionally, in line with Ferrari et al. (2016), rumination did not differ between the two groups, and there are no reasons to believe that healthy volunteers would underestimate only the occurrence of racing thoughts, and not rumination.

These results bear important clinical implications. Indeed, if racing thoughts are a trait of the disorder which might be enhanced during mood episodes, this means that a trait-version of the RCTQ should be developed in order to better address racing thoughts as a trait feature. Moreover, given that the RCTQ captured mild forms of racing and crowded thoughts in healthy individuals, it is possible that such will also be the case in subjects at-risk for the development of the illness. This hypothesis, which remains to be tested in these subjects, is of the utmost clinical relevance, as recent studies have suggested that racing thoughts are one of the most predictive symptoms of subsequent bipolar disorder diagnosis in at-risk youth (Zeschel et al., 2013; Diler et al., 2017).

3.1.4 Rumination, worry and anxiety

As outlined in the introduction, the racing and crowded thoughts phenomena received little attention from the cognitive psychology and psychopathology fields, and its contours relative to other thought patterns associated with mood disturbances, such as rumination, were still speculative. We hypothesized in our studies that the phenomenology of racing and crowded thoughts was different from that of rumination, which was characterized by repetitive thoughts circumscribed to few negative topics. While we did find that rumination, and most particularly its maladaptive component (i.e., brooding), was unrelated to the three subscales of the RCTQ in healthy individuals, such was only partially the case in patients. Indeed, in patients with bipolar disorder, rumination was not significantly related to the 'thought overactivation' and 'thought overexcitability' scores; however, along with anxiety symptoms and worry, it was one of the predictors of scores on the 'burden of thought overactivation' subscale. These results thus suggest that the two subscales that were associated with elated mood in healthy individuals, and which distinguished manic from depressed patients, measure a seemingly different thought pattern than rumination. However, 'burden of thought overactivation', which was more associated with low mood in healthy subjects (article 1), either hold some resemblance to rumination, and/or patients with bipolar disorder might have experienced both rumination and 'burden of thought overactivation' during the same episode. The latter interpretation is consistent with descriptions of patients with mixed depression provided by Kraepelin (1899). Indeed, Kraepelin (1899, p.17) quoted the following report of a depressed patient: "my thoughts are still, then suddenly they come back, by themselves, and they race all over the place." Consistently, Braden & Ho (1981) reported in their study that the conditions of occurrence of racing thoughts could differ: most patients reported that they experienced racing thoughts most of the day (83% of their sample) irrespective of their mood state (62%), but those who experienced some variation in their experience of racing thoughts reported that racing thoughts were more likely to appear when they felt anxious, worried or had some trouble sleeping. At least three points relevant to the understanding of the racing thoughts phenomenon can be highlighted here: first, racing thoughts might be either stable or transient during the course of 24 hours, which might have affected how some patients completed the RCTQ; second, racing thoughts might co-occur with rumination and worry (or these thinking styles might alternate at a very fast rate); third, and perhaps more importantly, anxiety seems to be particularly associated with racing thoughts, regardless of its subtype (i.e., 'thought overactivation', 'burden of thought overactivation', and 'thought overexcitability'). We will address these points in more depth in the subsequent paragraphs.

To our knowledge, racing thoughts variations have only been described anecdotally (e.g., Braden & Ho, 1981), and most studies have favored the idea according to which a single type of thinking was to be found in association with specific disorders, for instance, rumination in depression and worry in generalized anxiety disorder (e.g., Aldao et al., 2013). Worry and rumination are similar inasmuch as both are repetitive verbal thinking styles associated with unpleasant emotions; they differ mostly in terms of their temporal focus – rumination is past-oriented, whereas worry is future-oriented (Lewis, Yoon, & Joormann, 2017). Despite these differences, recent studies have suggested that there is an overlap between these repetitive thinking styles, which may account for the high rates of comorbidity between psychiatric disorders and, more specifically, between depression and anxiety disorders (e.g., McEvoy et al., 2013). However, such a transdiagnostic account does neither preclude the co-occurrence of distinct thinking styles nor the possibility that different thinking styles might vary over short periods of time. Consistent with this view, in patients with primary insomnia, rumination has been reported to be increased during daytime, while worry has been found to be more prominent at bedtime (e.g., Lancee et al., 2017). Similarly, a possible explanation for our results is that, in a subset of patients with bipolar disorder, 'burden of thought overactivation', worry and rumination – all of which are associated with unpleasant mood -- might either co-occur or alternate over short periods of time.

Another possibility is that rumination and 'burden of thought overactivation' are inseparable constructs. However, depressive symptoms were not correlated with 'burden of thought overactivation' scores in patients, and 'burden of thought overactivation' scores were not predicted by rumination scores in healthy individuals. Thus, these results may be interpreted in a slightly different way. Indeed, rumination has been robustly associated with measures of depression in past studies (e.g., Zetsche et al., 2012), such as the Beck Depression Inventory (BDI; Beck, Steer, & Carbin, 1988). Surprisingly, we found that depressive symptoms did not predict 'burden of thought overactivation' scores, whereas anxiety symptoms, measured via the Beck Anxiety Inventory (BAI; Beck and Steer, 1990), did so, and such was also the case for all of the RCTQ subscales. The BAI is predominantly a measure of autonomic arousal symptoms, which can be experienced first and foremost in panic disorder (Leyfer et al., 2006)[39]. Several studies have suggested that hyperarousal might be a trait of bipolar disorder, subtended by amygdala dysfunction (e.g., MacKinnon, 2008). Moreover, hyperarousal has been found to be particularly enhanced during mixed and manic episodes (for a review, Swann, 2017). Given that anxiety symptoms were the single shared predictor of scores among the three RCTQ subscales, we can assume that anxiety is particularly involved in racing thoughts, regardless of their subtypes and the predominant mood experienced by the patient. It seems relatively straightforward that anxiety may contribute to racing thoughts through increased arousal. However, it cannot explain the distinction between different types of racing thoughts. That is, there might be some phenomenological overlap between racing thoughts and anxiety, worry or rumination, but also differences, which deserve to be addressed in a

[39] Of note, panic disorder is one of the most frequent comorbidities found in bipolar disorder, and this has led authors to hypothesize that shared neurobiological mechanisms might play a role in the manic-panic association (e.g., MacKinnon & Zamoiski, 2006).

more thorough manner in future studies. To disentangle rumination, worry and racing thoughts, other features should be taken into account. In particular temporal focus may help, since racing thoughts have been associated with an over-reliance on the 'now' and the immediate future (Minkowski, 1933/2013; Gruber et al., 2012), whereas rumination is eminently past-focused, and worry is future-oriented (Aldao et al., 2013). Furthermore, future studies would probably benefit either from multiple assessments, via for example Experience Sampling Methodology (ESM), and/or from ad-hoc Likert scales addressing the circadian variability of racing and thoughts, worry and rumination as well as their relationship to the ongoing activity, level of arousal, and mood.

3.1.5 Distractibility as an understated mechanism

Although first-person accounts and descriptions of racing and crowded thoughts dating back from Kraepelin (1899/2008) and Binswanger (1933/2000) had already highlighted distractibility as one of the core mechanisms involved in racing thoughts, this feature was not clearly integrated in recent models of racing thoughts (e.g., Piguet et al., 2010). In our phenomenological model (figure 3), we also dismissed this psychopathological feature and only acknowledged two mechanisms as part of the racing thoughts phenomenon: (i) racing, linear thoughts, and (ii) crowded, disjointed thinking, associated respectively with pleasant and unpleasant mood. Yet empirical results reported by Keizer et al. (2014) in their qualitative study, and also by Braden & Ho (1981) before them, had already indicated that distractibility could be considered one of the main mechanisms involved in racing thoughts. Indeed, one of the six themes that emerged from the reports of patients in Keizer et al.'s (2014) study, labeled as 'information processing', refers to distractibility (e.g., "Each thing I come to see or hear triggers lots of thoughts"). Consistently, in our studies, we found that items referring to the distractible nature of racing and crowded thoughts (e.g., "A thought immediately leads to another, which leads to another, then another…") loaded on a specific factor that was labeled 'thought overexcitability'. In healthy subjects and patients, 'thought overexcitability' scores were predicted by elated mood. Interestingly, in bipolar disorder but also in healthy functioning, distractibility has been linked both to elated mood (e.g., Dreisbach, 2006), and to increased creativity (e.g., Johnson et al., 2012). In a recent psychopathological model, Desseilles et al. (2012) suggested that thinking and mood patterns, such as racing thoughts linked to elated mood, could underlie enhanced creativity in bipolar disorder and in healthy individuals. While we did not directly assess this hypothesis thus far, we speculate that this relationship is underlain by specific features of racing thoughts, such as thought overexcitability[40].

More importantly, the finding of this third feature of racing thoughts suggests that we should move beyond the racing vs. crowded distinction, associated with the categorical distinction between hypomania and mixed episodes, and consider racing thoughts in a more process-oriented way. As an example, in a growing number of recent studies, instead of addressing rumination and worry as categorical thinking patterns related respectively to depressive and anxious mood, these thinking styles have been considered in terms of their dimensional characteristics: e.g., lack of controllability, preparing for the future, expecting the worst, searching for causes and meaning, and dwelling on the past (e.g., Szkodny & Newman, 2017). In our work, we made a first step towards identifying the dimensions involved in the racing and crowded thoughts phenomena. Future studies will be pivotal in determining whether and how the three factors found in our studies target relevant dimensions related to racing and crowded thoughts. In this sense, as psychopathological studies inform neuropsychological investigations, the same could be stated as to the other way round interaction: studies investigating the cognitive processes implicated in racing and crowded thoughts will undoubtedly contribute to the delineation and understanding of relevant psychopathological

[40] We are investigating this assumption in an ongoing study.

dimensions[41]. In the next section, we address some of the contributions drawn from our first neuropsychological studies.

3.2 – How can neuropsychological paradigms enhance our understanding of racing and crowded thoughts?

In our work, we hypothesized that racing thoughts were involved in the anomalous experience of time and language observed in acute mood episodes of bipolar disorder, i.e., respectively (i) acceleration of the passage of time and duration distortions, and (ii) enhanced topic shifts, faster than usual speech rate, and enhanced sound-based associations. Before we address results in bipolar disorder, we will discuss our results in healthy individuals.

3.2.1 Healthy individuals

In healthy individuals, consistent with previous studies (e.g., Watt, 1991; Zakay & Block, 2004; Wittmann et al., 2014), we found that intrinsic and extrinsic contextual factors influenced duration experience, i.e., passage of time judgments – how time feels – and duration estimation – how long the interval lasted (article 3). More specifically, our results showed that longer unfilled intervals (i.e., fewer events occurring during the interval) led to a relative underestimation of durations, on the one hand, and to a slowing of the passage of time, on the other hand. Regarding intrinsic trait factors, we found that elevated adaptive rumination (i.e., reflection) and mindfulness-proneness traits were associated with opposite pattern of results: underestimation of durations and slower passage of time judgments for rumination and overestimation of durations and faster passage of time judgments for mindfulness-proneness. Hence, in line with recent studies (e.g., Wearden, 2015; Droit-Volet & Wearden, 2016), our study suggested that passage of time judgments and duration

[41] This has clearly been the case for the study of rumination, which has benefitted from a large number of neuropsychological studies focusing on executive functions and memory (e.g., Zetsche, D'Avanzato, & Joormann, 2012)

estimates could be dissociated, and that both intrinsic and extrinsic factors were linked to such a dissociation. Consistent with Zakay (2014) and Droit-Volet & Wearden (2016), we argued that boredom and alertness may explain, at least to some extent, these results (cf. article 3). Recently, other studies have put forward the effect of boredom and arousal on passage of time judgments (e.g., Droit-Volet et al., 2017; Tanaka & Yotsumoto, 2017). As we will further discuss in subsequent paragraphs, the mechanisms underlying passage of time judgments are poorly understood, making these results slightly difficult to interpret. Of note, in this first study, we did not find any significant correlations between mood symptoms nor racing thoughts[42] and time perception. However, when we compared the temporal measures of individuals with extremely low RCTQ (< 20, n = 38) to that of individuals with extremely high RCTQ scores (>40, n = 47), we found that, for passage of time judgments, the interaction Group x Duration x SOA tended to be significant (p = .055): for short durations and long unfilled intervals (32s and 16s SOA) in particular, subjects with elevated RCTQ scores reported on average a relative acceleration of the passage of time compared to those with low RCTQ scores. Interestingly, in another sample of healthy individuals (patient study, article 4), we found a negative correlation between passage of time judgments and RCTQ, meaning that the higher the RCTQ score, the faster the time seemed to have passed during the estimation task (32s and 4s SOA). Taking into account the available literature on passage of time judgments[43], and the psychopathological results we have obtained on racing thoughts, we can interpret these results as being due either to arousal or distractibility. Indeed, as discussed above, elevated racing thoughts were found to be particularly associated with anxiety and elated mood symptoms in patients, and with mood instability in healthy individuals. Given this, we can argue here that racing thoughts might be experienced as at least mildly arousing in healthy individuals (Droit-Volet et al., 2017). Enhanced arousal was associated with faster

[42] These results are presented in Article 3 Appendix.
[43] See section 1.4.2.3c for a brief review.

than usual passage of time judgments in three recent studies with healthy samples (Droit-Volet & Wearden, 2016; Droit-Volet et al., 2017; Tanaka & Yotsumoto, 2017), and is usually associated with an overestimation of durations (for a review, Droit-Volet & Meck, 2007). However, it should be noted that mild arousal might have less impact on time estimation than on passage of time judgements. For example, Droit-Volet et al. (2017) recently showed that self-rated arousal, as well as happy or sad mood, were not associated with verbal estimation of intervals ranging from 2s up to 33s (as measured in everyday situations via Experience Sampling Methodology)[44]. This may seem surprising, since the effects of enhanced arousal and emotion on duration lengthening have been reported in numerous studies using emotion stimuli (e.g., for a review, Droit-Volet & Meck, 2007), and electrodermal activity paradigms (e.g., Mella, Conty, & Pouthas, 2011). As suggested by Droit-Volet et al. (2017), this might be due to the fact that mood is more diffuse and less intense than emotion (elicited for instance via pictures displaying violent acts), hence less arousing. Thus, mild arousal states and moods are probably not intense enough to lead to duration distortions, but they can influence passage of time judgments. This might explain the mild effect of racing thoughts on passage of time judgements in healthy volunteers. Nonetheless we did not find a relationship between mood symptoms and passage of time judgments. This might be due to the fact that mild mood symptoms, as measured by depression and mania scales, referred to a prolonged period of time (past 7 days), and probably did not reflect the mood experienced by the subject during the assessment. Because of this, and to disentangle the mechanisms involved in the relationship between racing thoughts and passage of time judgments, future studies would certainly benefit from the use of visual analog scales (VAS) targeting momentary mood, arousal, and boredom states.

[44] It is noteworthy that, for long intervals only (several minutes range), arousal was a significant predictor of duration estimates, and duration estimates and passage of time judgments were correlated (Droit-Volet et al., 2017).

The fact that the RCTQ seems to be somewhat associated with the passage of time judgements, but not to mood, may also bear some significance. As already emphasized above, it may be possible that the RCTQ captures even milder 'activation' or arousal states than those reflected by mood scales or that it captures yet another psychophysiological dimension that is relevant to how we feel the passage of time. For instance, akin to mind wandering (Terhune et al., 2017), it is possible that the distractible nature of racing thoughts might have influenced our results. Indeed, Terhune et al., (2017) recently found that mind wandering states were characterized by underestimation of durations, which led them to propose that "moment-to-moment interval timing varies with transient fluctuations in attentional states". However, the authors did not investigate passage of time judgments in their study, and it is unknown whether underestimation of durations was linked to faster or slower passage of time judgments. Besides, racing thoughts were not associated with an underestimation of durations in our studies. Nevertheless, if distractibility is also associated with "transient fluctuations in attentional states", we could expect racing thoughts to have an impact on subjective experiences of time through similar attentional mechanisms. It is noteworthy that mind wandering encompasses a number of different thinking patterns selectively associated with happy and low mood (Marchetti et al., 2014), and their relationship to rumination and racing thoughts in healthy individuals is for the most part speculative (Marchetti, Koster, Klinger, & Alloy, 2016). In the future, a more precise delineation of these concepts will help enhance our understanding of the psychological dimensions affecting duration perception and passage of time judgements. Before further addressing the potential mechanisms underlying the relationship between the experience of time and racing thoughts, we will discuss below the results we have gathered in patients with bipolar disorder.

3.2.2 Bipolar disorder

3.2.2.1 Mood dependent neuropsychological findings

In both studies conducted in patients with bipolar disorder, we found mood dependent temporal and/or language anomalies. More specifically, depressive states were characterized by an underestimation of durations (study 4), and reduced word count and switches in the semantic fluency task (study 5). By contrast, in mixed depression and mania, we found increased switches compared to depression in the free fluency task (study 5). In mania only, we found increased task-discrepant phonological cluster size in the semantic fluency task compared to controls and euthymic patients, as well as reduced semantic cluster ratio in the free condition (study 5). Results in mixed mania were more inconclusive, given the small sample size. We decided nevertheless to keep this group in study 5, since very few neuropsychological studies have investigated cognition in mixed episodes. Moreover, at least some features might be of interest in these results, such as the decreasing phonological cluster size gradient, spanning from pure mania through mixed mania, mixed depression, until depression and euthymia in the semantic fluency task.

Several points can be highlighted regarding our results. First of all, both time perception, assessed by tasks such as verbal estimation and temporal production, and verbal fluency performance involve a number of cognitive processes. For duration estimation, those include, for instance, clock-related processes (which can be modulated by arousal), working memory, attention, and executive processes (Gibbon, Church, & Meck, 1984; Droit-Volet & Meck, 2007; Zakay & Block, 2004). Importantly, passage of time judgments seem to be modulated by similar mechanisms (e.g., Droit-Volet et al., 2017), but not necessarily in the same way, as one can feel that time passed slowly, and estimation durations rather accurately (Watt, 1991; Thönes & Oberfeld, 2015; Wearden, 2015). In this sense, there has been some debate in the literature as to whether and how passage of time judgments are related to duration estimates (e.g., Droit-Volet & Wearden, 2016). Because the literature is scarce on this subject matter, and methods vary greatly among studies[45], it is still very early to attempt at drawing conclusions. However, based on two recent studies by Tanaka & Yotsumoto (2017) and Droit-Volet et al. (2017), which have shown that, for long durations of several minutes, passage of time judgments were respectively related to temporal expectation and duration estimation, it is likely that passage of time judgments tap on memory processes in particular. That is, they refer to past, ongoing and expected intervals, which may only be relevant in everyday situations when these intervals last at least few minutes and/or when there is a discrepancy between expected durations and memory of actual durations[46]. Taking into account phenomenological and experimental accounts of temporal experience in bipolar disorder, we expected to find a slowing of the passage of time in depression, and the opposite in mania. While we did not find significant differences in passage of time judgment among groups, we did find that manic symptoms were associated with an acceleration of the passage of time in patients. Surprisingly, depressed mood was not associated with a slowing of the passage of time. This might be related to the fact that elated mood is more arousing than depressed mood, which is linked to a permanent loss of energy and pleasure, unlike transient sad mood. As suggested above, it is also possible that depressive mood influences passage of time judgments for longer durations, which are closer to everyday situations where time might seem to 'drag' (Tanaka & Yotsumoto, 2017). Like happy mood in healthy individuals (e.g., Droit-Volet et al., 2017), manic symptoms, in patients only, are seemingly arousing enough to have an impact on passage of time judgments. However, relative to controls, elated mood did

[45] Studies have investigated passage of time respective to the non-temporal task at hand (Tanaka & Yotsumoto, 2017), referencing passage of time during the day of the assessment (Bschor et al., 2004) or the duration of the whole experiment (Mezey & Knight, 1965), referencing temporal tasks or not (Droit-Volet et al., 2017), and for durations ranging from sub-seconds to several hours (Droit-Volet & Wearden, 2016; Droit-Volet et al., 2017; Bschor et al., 2004).

[46] In everyday situations, it is also important to note that if passage of time becomes relevant, it means that we are aware of time, and this usually happens in intervals lasting from several seconds to minutes (during waits for instance) (Fuchs, 2013; Droit-Volet et al., 2017).

not lead to an overestimation of durations in manic patients. As suggested by Droit-Volet et al. (2017), these results might be attributed to the fact that diffuse mood, unlike intense emotion, is probably not sufficiently arousing to influence duration estimation. Manic patients estimated durations like controls did in the several seconds range, and this contrasted with underestimation in depressive patients, consistent with a previous study by Bschor et al. (2004). Since this effect was not found in the more 'stimulating' condition of the task, i.e., temporal production, another possibility is that, at least to some extent, elated mood is arousing, and arousal actually compensates for attention impairment associated with manic episodes (cf. neuropsychological results reported in study 5), but also, in more stimulating tasks, in depressive episodes (for a meta-analysis of working memory in bipolar disorder, Soraggi-Frez et al., 2017). Hence, the possibility that arousal and attention/working memory dysfunction effects might cancel each other in bipolar mood episodes could account for our results, as well as for divergent findings in the depression literature (for a meta-analysis, Thönes & Oberfeld, 2015). In bipolar depression, this could mean that, in less stimulating or longer interval tasks, attention is diverted away from both the temporal and non-temporal task (as if subjects were ruminating on their problems), akin to individuals who mind-wander (Terhune et al., 2017), leading to an underestimation of durations (Droit-Volet, 2013). If such was the case, we could have expected depressed subjects to ruminate during the task, which would have led to both reduced working memory resources (Curci et al., 2013) and underestimation of durations. Of note, reflection-rumination in our study with healthy individuals was associated with underestimation of durations and slowing of the passage of time. In patients, neither rumination or racing thoughts (see 3.2.2.3), were associated with the experience of time. This might be either attributed to the fact that the rumination scale used in our patient study refer to a prolonged period of time (7 days), or that rumination is not involved in these results. To investigate both assumptions as well as the effects of other potential features, future studies could add visual analog scales targeting the experience of patients during the experiment (i.e., rumination, arousal, mood and boredom), and/or include trials where rumination is induced before the temporal experiments. Another potential feature which could have influenced our results is psychomotor retardation in depression (Droit-Volet, 2013), and impulsivity (Wittmann & Paulus, 2008), especially in manic and mixed episodes (Benazzi, 2007c). However, measures of information speed processing (e.g., TMT-A and Digit-Symbol subtest) were not correlated to performance in our temporal tasks in neither group of subjects, and had this been the case, we would have expected to find an under-production[47] of durations in mania and mixed depression, due to increased impulsivity, and an over-production in depression due to psychomotor retardation. Yet, this is not what we found, as results were similar in the production task among clinical groups and controls. Interestingly enough, we should note here that few subthreshold manic symptoms in depression seem to matter in terms of time perception, as results in the mixed depression group in the estimation task did not differ from that of manic and control subjects. However, to our knowledge, studies thus far have not measured hypomanic concurrent symptoms in depression, hence it is unknown how these features influenced results on temporal tasks in past studies (Thönes & Oberfeld, 2015).

Given that results in estimation and production tasks, at least in depression, were slightly discrepant[48], we can speculate that contextual factors play a role in how these individuals experience time. This might be particularly relevant for bipolar disorder, since affective reactivity is a prominent clinical feature of both acute and euthymic episodes (e.g., Aminoff et al., 2012; Lemaire, El-Hage, & Frangou, 2015). This means that patients with bipolar disorder might be particularly sensitive to contextual features, such as the number of events

[47] Unlike the verbal estimation task, in the production task, subjects had to provide a motor response, after having decided whether 30s had elapsed.
[48] Underestimation of duration was only observed in the estimation task.

occurring during the intervals, and how stimulating (or boring) they are perceived. Moreover, the length of intervals has been shown to lead to differential results in both bipolar disorder and depression (e.g. Bschor et al., 2004; Droit-Volet, 2013), with longer intervals being more sensitive to temporal disturbances than shorter ones. Thus, future investigations should focus on whether even longer (e.g. in the minutes range) or shorter lengths of intervals lead to similar results, and whether extrinsic contextual factors, such as the number of events occurring during the interval, play a role in how subjects experience time in bipolar disorder.

Since different brain regions have been reported to underlie sub-second and supra-second interval timing (e.g., Wiener et al., 2010), and the literature in bipolar disorder is scarce, studies in different mood episodes of bipolar disorder using different timing tasks, including sub-second timing tasks, on the one hand, and reproduction tasks, which rely more on memory processes (Mahlberg et al., 2008; Mioni et al., 2016), on the other hand, would also contribute to the understanding of the cognitive processes involved in the temporal experience of patients with bipolar disorder.

Similar to time perception, verbal fluency performance is underlain by at least two cognitive processes – i.e., lexico-semantic and executive (Troyer et al., 1997). Furthermore, according to the task instruction – e.g., semantic or orthographic --, either semantic memory or executive function is selectively more involved in performance (Henry & Crawford, 2004). Hence, to delineate the cognitive processes involved in the verbal output of patients with bipolar disorder, in our work, three different process-oriented approaches – i.e., qualitative, temporal and automated -- were applied to different types of verbal fluency tasks (cf. Article 5 Appendix). Interestingly, if we had only considered total word count in the free, semantic, and letter tasks used in study 5, we could have concluded that both temporal and verbal fluency impairments were exclusively found in depressive episodes of bipolar disorder[49]. Yet, through the use of qualitative process-oriented measures, we observed that such was not the case, since switching and clustering abnormalities, relative to controls, were found in mania, suggesting that manic patients might achieve similar verbal fluency performance through different mechanisms than controls. Specifically, on the free condition only, switches were increased whereas semantic cluster ratio was smaller in the manic relative to the control group; total word count did not differ between groups. That is, when word production was unrestricted (free condition), manic patients' verbal output was markedly more fleeting than that of controls, but also compared to that of depressive and euthymic patients. Thus, compared to controls, manic patients shifted more among conceptual units, but they were not more productive. Thus, our results are inconsistent with those reported by older studies which had linked mania to increased word output in associational fluency tasks (Giehm, 1933; Levine et al., 1996). This might be due to the fact that the cognitive underpinnings of these tasks are somewhat different: on associational tasks, a cue-word is provided, whereas such is not the case on the free fluency task. Because of this, on the free task in particular, we can speculate that semantic activation is not constrained by the task-set (Phillips et al., 2002), possibly generating less perseverance (as reflected by reduced semantic cluster ratio), and more distractibility (Dreisbach, 2006). Consistent with this view, increased switches were correlated with faster information processing speed, on the one hand, and lower scores on inhibition measures, on the other hand. Another possibility is that the choice of the cue-words in these early studies influenced the results. Indeed, in healthy individuals, the abstractness of cue-words affects the number of words produced in associational fluency tasks (e.g., Lambert, 1955). In euthymic patients with bipolar disorder, Rossell (2006) showed that the valence of

[49]Results in euthymia are discussed hereafter.

the cue-stimulus also affected word output, with the cue-word 'happy' resulting in increased fluency output in patients compared to controls[50].

Rather interestingly, similar to the temporal tasks, performance did not differ between the mixed groups and the manic group. However, compared to depression, we found that the number of switches on the free task was increased in mixed depression, hence suggesting that increased switches on this task were particularly associated with manic symptoms. In contrast, on the semantic and letter tasks, the number of switches did not differ between manic and controls subjects. On the semantic task, and not on the letter fluency task, the number of switches was higher in mania compared to depression and euthymia, suggesting that 'switching' subtends the relative 'manic advantage' in this task (Raucher-Chéné et al., 2017). Overall, these results thus indicate that, in bipolar mood episodes, spontaneously switching between different word retrieval strategies is likely to be beneficial to performance, at least in the semantic fluency task (Phillips et al., 2002 ; Ledoux et al., 2014; Aminoff et al., 2012).

According to Troyer et al. (1997), switching abilities in verbal fluency tasks are closely related to controlled word retrieval processes, such as cognitive flexibility involved in task-switching. While there has been some support for this position (e.g., Fossati et al., 2003; Sauzéon N'Kaoua, & Claverie, 2004), other studies have failed to attribute switches on the semantic task to executive functions and frontal lobe pathology. For instance, Ho et al. (2002) found that, in the longitudinal follow-up of patients with Huntington's disease, there was a decline in the number of switches in the letter task, but not in the semantic fluency task. Troyer et al. (1998) compared clustering and switching on phonemic and semantic fluency tasks in patients with Alzheimer's disease or Parkinson's disease. On both tasks, patients with

[50] Because valence and abstractness seem to influence word output in associational tasks, in our study, we controlled for both features. Results are currently being analyzed via qualitative, automated and temporal methods. See Article 5 Appendix for some preliminary findings regarding the validity of this triple approach.

Parkinson's disease made fewer switches than control subjects, whereas patients with Alzheimer's disease made fewer switches only on the semantic task. These results in patients with Alzheimer's disease have been replicated since then by a number of studies (e.g., Raoux et al., 2008; Haugrud, Crossley, & Vrbancic, 2011), raising the question whether switching on the semantic task is actually temporal-lobe dependent and reflect semantic memory abilities (Troyer et al., 1998; Raoux et al., 2008). If such is the case, then fewer switches on the semantic task could reflect reduced semantic memory store in Alzheimer's disease. Given that semantic cluster size and performance in the vocabulary task, which measures semantic memory store (Ross et al., 2007), were unimpaired in our patients relative to controls, it seems unlikely however that switching anomalies on the semantic task are due to impaired semantic storage in bipolar disorder (Rossell & David, 2006). Another possibility is that switching performance in the semantic task taps both semantic memory and executive processes indistinctively (Raoux et al., 2008) or that it taps other processes, such as processing speed (Abwender et al., 2001; Mayr, 2002). Consistent with the latter assumption, in our study, increased switches in the semantic and free tasks were both positively correlated to processing speed measures, whereas on the letter task, they were only correlated to enhanced working memory performance[51]. Increased switches on the semantic, and to a lesser extent, on the free task[52], seem to be related to automatic speed of processing, rather than controlled processes, which are more involved in switching on the letter task. Since this effect was more prominent in the semantic fluency, we can speculate that they are due to activation/inhibition abnormalities within the semantic network, i.e., spreading of activation

[51] Let us remind here that switches in the semantic task relates to shifting from one semantic unit to another, i.e., one word or cluster to another, whereas in the letter task, shifts are based on relatedness at the phonemic level, i.e., they correspond to words or clusters that are phonemically-unrelated in a sequence. It is no surprise that these two types of switches rely on distinct mechanisms.

[52] On the free task, switching performance was also correlated to inhibition measures (i.e., errors and response time on the Hayling test), further supporting our hypothesis according to which, on this task, switching scores were due to defective inhibition and enhanced flexibility, probably promoted by increased processing speed.

and inhibition of irrelevant lexical units (Sung, et al., 2013; Raucher-Chéné et al., 2017). In schizophrenia, there is some electrophysiological and behavioral evidence that activation across the semantic network spreads further within a shorter period of time and is associated with positive thought disorder (e.g., hallucinations and delusions) (e.g., Kreher et al., 2008). These results were usually obtained through semantic priming tasks and, at the neurophysiological level, the exploration of the N400 negative component (i.e., N400 peaks at around 400 ms after the stimulus and is modulated by the semantic context) (e.g., Ryu et al., 2012)[53]. To our knowledge, only two studies using both methods (i.e., Ryu et al., 2012; Cermolacce et al., 2014) have been conducted in mania, and found divergent results. Specifically, using a lexical decision task, Ryu et al. (2012) found larger N400 amplitude for congruous pairs of words in mania when compared to healthy controls, suggesting that related words were treated as unrelated by patients. In contrast, Cermolacce et al. (2014) found no electrophysiological differences between manic patients and controls using a more ecological natural discourse task. In both studies, electrophysiological results were not correlated to thought disorder scores in manic individuals. Because of these discrepant results between the two studies, Cermolacce et al. (2014) suggested that other cognitive processes, such as those related to the inhibition of semantic information, were involved in the language and thought abnormalities found in mania. Consistent with this view, in study 5, we found that larger task-discrepant phonological cluster size in the semantic fluency task was correlated to longer inhibition response times on the Hayling task, indicating that inhibition processes play a key role in some of the language abnormalities found in patients with bipolar disorder.

Taken together, our results point to the fact that both information processing speed and cognitive inhibition might underlie language abnormalities, as assessed via verbal fluency

[53] N400 amplitude is larger in response to words or sentences that are incongruous, or unexpected in the semantic context than in response to congruous ones.

tasks, in acute mood episodes of bipolar disorder. Since ours was the first study, to our knowledge, that applied the switching measure to the free fluency task, and discrepant results have been reported in the letter and semantic tasks (e.g., Abwender et al., 2001), further investigation is needed to gain a better understanding of the cognitive underpinnings of switches across different types of verbal fluency tasks.

In patients with depression only, impairment in both total word count in the semantic fluency task and duration estimation were more pronounced. Relative to time perception, Droit-Volet (2013) recently suggested that information processing speed measures may be an indicator of internal clock speed, given that increased temporal discrimination and processing speed measures in children were strongly correlated in one of her studies. We could thus hypothesize that psychomotor retardation is related to both reduced switches and underestimation of duration in depression. Rather surprisingly however, information processing speed was not correlated to duration estimates in our depressed sample, whereas working memory scores were. Taking these results into account, and the fact that rumination was negatively correlated to word count in the semantic task, it is also possible that rumination is involved in both results in depression. As outlined above, since the number of trials of our time perception tasks was reduced, these results would certainly need to be replicated using more trials, and probably other durations. As they are, our results are mostly suggestive of the involvement of different cognitive mechanisms in the subjective experience of time and language in acute episodes of bipolar disorder.

3.2.2.2 Mood independent neuropsychological findings: the case of euthymia

While most studies using verbal fluency tasks were conducted during euthymia (for a meta-analysis, Raucher-Chéné et al., 2017), time perception studies have mostly neglected bipolar disorder, and euthymia in particular[54]. Yet, as outlined in the introduction, timing abnormalities have been reported in euthymic phases of bipolar disorder as early as in 1933 (for a review, Krug et al., 2008), with patients reporting fewer switches during passive viewing of the Necker cube than controls and patients with schizophrenia. Thus, we could have expected to find trait-related time perception anomalies in patients with bipolar disorder[55]. At first sight, this is exactly what we found – i.e., an underestimation of duration in the production task. Yet, when we controlled for medication status, we found that these results could be explained by benzodiazepine intake in euthymic patients only. This in line with a previous study by Rammsayer (1992), who showed that single doses of the benzodiazepine midazolam, had no effect on timing in the milliseconds range but significantly impaired estimation in the seconds range, as well as information processing speed[56]. Given that few euthymic patients were taking benzodiazepine drugs in our study (2/20, compared to 5/25 among manic patients, for instance), these results may seem surprising. They suggest that the effects were biased by outlier results in some patients. However, they might also be explained by (i) dosage effects, which were not taken into account in our analyses, and/or by (ii) the interaction between state-dependent variables, such as arousal, and medication. Another possibility is that those patients who were under benzodiazepines also presented with more subsyndromal symptoms, as elevated depressive symptoms in euthymic patients were significantly correlated to overproduction (underestimation) of duration. Interestingly, subsyndromal manic and depressive symptoms were associated with passage of time judgments in euthymia. Again, this interaction is not as straightforward as it seems, since both depressive and manic symptoms were linked to a

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[54] Note here that only one study by Tysk (1984) included a group of patients in remission, and found that duration estimates did not differ from that of controls.

[55] It is important to note that phenomenological accounts of the experience of time in euthymia are lacking.

[56] Based on a series of studies on numerous pharmacological drugs, Rammsayer concluded that estimation of durations in the seconds range could be disrupted by any drug that impaired attention (Rammsayer et al., 2001) or memory function (Rammsayer, 1999). For a review, see Coull, Cheng, & Meck (2011).

relative acceleration of the passage of time in euthymic patients. We can speculate here that mood instability, as reflected by subsyndromal symptoms in euthymia (Aminoff et al., 2012), is sufficiently arousing to influence how fast time seems to pass. However, subthreshold depressive symptoms may only have the expected effect on passage of time judgments for longer intervals. Of course, this remains to be tested. As already emphasized above, to better address the potential mechanisms involved in patients' experience of time, it will also be crucial to add, in future studies, visual analog scales targeting arousal, boredom, thinking patterns and momentary mood during the interval.

Unlike duration estimates, verbal fluency performance was not related to medication status in patients. First of all, we found that total word count in the semantic fluency task tended to be reduced in euthymic patients compared to controls. These results add to those outlined by a recent meta-analysis by Raucher-Chéné et al. (2017), which showed that euthymic patients' performance in the semantic fluency task was disproportionally reduced compared to that of manic patients. The authors argued that this result could be either due to a deterioration of the semantic system (i.e., storage deficit hypothesis) or to a functional impairment deficit related to aberrant activation/inhibition processes within the semantic network. Our results provide evidence against the storage deficit hypothesis, as semantic cluster size was similar among groups, and vocabulary scores were actually higher on average in euthymic patients compared to any other group (they were also significantly higher than that of mixed manic patients). This is consistent with a number of studies which have shown that premorbid verbal IQ was higher than that of controls in patients with bipolar disorder (e.g., Goodwin & Jamison, 2007; Smith et al., 2015), and did not decline after the onset of the illness (Torres, Boudreau, & Yatham, 2007; Goodwin & Jamison, 2007). Moreover, as outlined above for depression, in euthymia, decreased switches also seemed to underlie word output in the semantic fluency task. Hence, we can also hypothesize that, similar to acute mood episodes, it is the functional activation/inhibition within the semantic network that is defective in euthymia. These results are in line with two previous studies using respectively automated analysis similar to LSA and hierarchical cluster analysis (Chang et al., 2011; Sung et al., 2013); these studies found less knowledge-based categories (Chang et al., 2011) and less coherent clusters in the semantic fluency task in euthymia (Sung et al., 2013), whereas the number of words were equivalent to that of healthy controls (Sung et al., 2013). Likewise, our results suggest the existence of trait-like structural anomalies (e.g., retrieval/access) within the semantic system, and underscore the importance of applying process-oriented measures to verbal fluency performance in order to address these functional anomalies[57].

3.2.2.3 Racing thoughts seen through language and time

To our knowledge, ours was the first direct investigation of the relationship between self-reported racing thoughts and the experience of time and language in patients with bipolar disorder, although this relationship had been suspected since the first experimental studies using verbal fluency and time perception tasks in these patients (e.g., Kraepelin, 1899; Mezey & Knight, 1965). Contrary to our preliminary results in healthy individuals, in patients with bipolar disorder, racing thoughts were not related to passage of time judgments, nor were they associated with duration estimation. As outlined above, this can be attributed to the fact that, in patients, two important features of racing thoughts – i.e., arousal and distractibility – might actually have opposite effects on time perception, leading to the observed results. In contrast, in healthy individuals, at least for short durations (32s), it is possible that mild racing thoughts were associated with arousal, rather than distractibility. Of course, these assumptions remain to be tested in future studies. The relationship between passage of time judgments and duration estimation has raised some recent interest (Wearden, 2015), and it should be

[57] To do so, we are currently analyzing our data through a combined temporal and automated approach. The latter is based on the semantic similarity among words (i.e., Latent Semantic Analysis, LSA; Landauer, Foltz, & Laham, 1998).

particularly relevant to further investigate whether and how they are related, on the one hand, and also whether and how intrinsic state factors such as the speed of thoughts (i.e., racing thoughts or rumination) interact with these results. These empirical results, in turn, will certainly enhance phenomenological studies targeting the experience of time in mood episodes of bipolar disorder (e.g., Bowden, 2013; Fuchs, 2013; Northoff et al., 2017). As outlined in section 1.3.2, psychiatrists have attempted at translating phenomenal accounts of racing thoughts to psychological and neuroscientific terms (e.g., Northoff et al., 2017). Increased conation in particular has been defined as intrinsically related to the speed of the flow of time, and considered to be implicit when there is no discrepancy between self- and world-time (Fuchs, 2013). Given the semantic proximity between passage of time judgments and 'speed of the flow of time', it is tempting to consider that we were referring to the same concepts. However, as outlined earlier, such an attempt at drawing a relationship between the two fields is at best speculative; this is all the more true insofar as phenomenological and psychological research on both conation (in philosophy) and passage of time judgments (in psychology) are at their early stages. Moreover, given that subjects are aware of time when they make passage of time judgments, these judgments might only be related to conation when a discrepancy exists between self and world-time.

In study 5, we found that racing and crowded thoughts, as assessed by the RCTQ, were associated with the number of words produced in the semantic and letter fluency tasks, as well as with the ratio of phonological clusters in the letter fluency task. We interpreted these results as being due to the detrimental effects of distractibility to verbal output in restrictive verbal fluency conditions (i.e., letter and semantic fluency tasks), and argued that racing and crowded thoughts were associated with executive abnormalities: the greater the scores of the

RCTQ, the smaller the ratio of phonological clusters in the letter fluency task[58]. Interestingly, differential results were found for rumination, suggesting that they tap different cognitive processes. As outlined previously, few studies have attempted at addressing the relationship between linguistic performance and thought disorder in bipolar disorder, and most have not found any correlations between the two (Ryu et al., 2012; Andreou et al., 2013; Cermolacce et al., 2014). For example, Ryu et al. (2012) and Cermolacce et al., (2014) found no correlations in manic patients between N400 amplitude and thought disorder as assessed by two items of the YMRS (Young et al., 1978). Similarly, in euthymic patients, Andreou et al. (2013) found no correlations between semantic priming performance and thought disorder as assessed by the Scale for Thought, Language and Communication (TLC; Andreasen, 1979). Recently, Nagels et al. (2016) found that word output on the semantic and letter verbal fluency tasks were negatively correlated to negative thought disorder (i.e., poverty of speech, slowed thinking and concretism), as assessed by the Thought and Language Disorder Scale (Kircher et al., 2014). However, such was essentially the case when considering schizophrenic, depressive, and manic patients together. It is thus possible that these results are not specific to bipolar disorder. Moreover, like the TLC, the TALD is a clinician-rated questionnaire that acknowledges that similar thought and language disturbances are observed in schizophrenia and bipolar disorder (Kircher et al., 2014). This is not the case of the RCTQ, which is based on self-report and was elaborated to specifically measure thought patterns associated with manic mood. Indeed, the elaboration of the RCTQ benefited from phenomenological findings which have indicated that thinking and language patterns are seemingly different in schizophrenia and mania (Sass & Pienkos, 2015), on the one hand, and that, in mixed episodes, thinking abnormalities might not be observed verbally (Binswanger, 1933/2000; see section 1.3.1 and 1.3.3). Although it is too early to draw conclusions regarding the sensitivity,

[58] Total word count in this task did not differ among groups, indicating that racing thoughts were not necessarily detrimental to overall performance.

specificity and the utility of the RCTQ, our preliminary results from study 4 suggest that RCTQ scores are related to some linguistic abnormalities found in bipolar disorder. Since the RCTQ did not focus on language specifically, it does not contain items assessing clang associations, and that is probably why task-discrepant phonological cluster size score was not correlated to RCTQ subscale scores. These results raise the question whether the RCTQ should also include more language (for example, focusing on inner-speech), but also temporal-oriented items, since both are intrinsically related to the phenomenology of racing and crowded thoughts. Through the use of additional temporal and linguistic methods (e.g., those outlined in Article 5 Appendix), we expect to gain more insights on the racing and crowded thoughts phenomena, and, ultimately, on mood disorders.

3.3 Conclusion

Our results suggest that the RCTQ is a sensitive tool, as it captured different facets of racing and crowded thoughts, both in patients and in controls. Its sensitivity is best illustrated by the difference in RCTQ scores between typical depression and depression with very few manic symptoms. Importantly, our results also point to the fact that we should address additional facets of the racing and crowded thoughts phenomena in a dimensional manner, in order to improve its delineation relative to other thinking styles, such as rumination, worry, and mind-wandering. To this aim, we proposed new ways to assess racing and crowded thoughts, as well as their relationship to anxiety, distractibility, boredom, and time perception.

Racing thoughts occur spontaneously and we have seen in the introduction that there has been a debate as to whether they can be captured in a satisfactory way through empirical means, i.e., artificial settings. Our results suggest that verbal fluency tasks may be promising tools not only as empirical means to reflect the racing and crowded thoughts phenomena, but also to provide insights relative to their cognitive underpinnings. In this respect, even if the results are preliminary and in need of replication and refinement, they seem particularly promising.

References

Abwender, D. A., Swan, J. G., Bowerman, J. T., & Connolly, S. W. (2001). Qualitative Analysis of Verbal Fluency Output: Review and Comparison of Several Scoring Methods. Assessment, 8(3), 323–338. https://doi.org/10.1177/107319110100800308

Agosti, V., & Stewart, J. W. (2008). Hypomania with and without Dysphoria: comparison of comorbidity and clinical characteristics of respondents from a national community sample. Journal of Affective Disorders, 108(1–2), 177–182. https://doi.org/10.1016/j.jad.2007.09.006

Akiskal, H. S., Djenderedjian, A. M., Rosenthal, R. H., & Khani, M. K. (1977). Cyclothymic disorder: validating criteria for inclusion in the bipolar affective group. The American Journal of Psychiatry, 134(11), 1227–1233. https://doi.org/10.1176/ajp.134.11.1227

Akiskal, H. S., Mendlowicz, M. V., Jean-Louis, G., Rapaport, M. H., Kelsoe, J. R., Gillin, J. C., & Smith, T. L. (2005). TEMPS-A: validation of a short version of a self-rated instrument designed to measure variations in temperament. Journal of Affective Disorders, 85(1–2), 45–52. https://doi.org/10.1016/j.jad.2003.10.012

Akiskal, K. K., & Akiskal, H. S. (2005). The theoretical underpinnings of affective temperaments: implications for evolutionary foundations of bipolar disorder and human nature. Journal of Affective Disorders, 85(1–2), 231–239. https://doi.org/10.1016/j.jad.2004.08.002

Akiskal, H. S., & Benazzi, F. (2006). Does the FDA proposed list of possible correlates of suicidality associated with antidepressants apply to an adult private practice population? Journal of Affective Disorders, 94(1–3), 105–110. https://doi.org/10.1016/j.jad.2006.04.002

Aldao, A., Mennin, D. S., & McLaughlin, K. A. (2013). Differentiating Worry and Rumination: Evidence from Heart Rate Variability During Spontaneous Regulation. Cognitive Therapy and Research, 37(3), 613–619.

Aldao, A., Nolen-Hoeksema, S., & Schweizer, S. (2010). Emotion-regulation strategies across psychopathology: A meta-analytic review. Clinical Psychology Review, 30(2), 217–237. https://doi.org/10.1016/j.cpr.2009.11.004

Allin, M. P. G., Marshall, N., Schulze, K., Walshe, M., Hall, M.-H., Picchioni, M., … McDonald, C. (2010). A functional MRI study of verbal fluency in adults with bipolar disorder and their unaffected relatives. Psychological Medicine, 40(12), 2025–2035. https://doi.org/10.1017/S0033291710000127

Aminoff, S. R., Jensen, J., Lagerberg, T. V., Hellvin, T., Sundet, K., Andreassen, O. A., & Melle, I. (2012). An association between affective lability and executive functioning in bipolar disorder. Psychiatry Research, 198(1), 58–61. https://doi.org/10.1016/j.psychres.2011.12.044

Anderson, J. R., & Pirolli, P. L. (1984). Spread of activation. Journal of Experimental Psychology: Learning, Memory, and Cognition, 10(4), 791–798.

Andreasen, N. C. (1979). Thought, language, and communication disorders. II. Diagnostic significance. Archives of General Psychiatry, 36(12), 1325–1330.

Andreasen, N. C. (1982). Should the term “thought disorder” be revised? Comprehensive Psychiatry, 23(4), 291–299. https://doi.org/10.1016/0010-440X(82)90079-7

Andreasen, N. C. (1986). Scale for the assessment of thought, language, and communication (TLC). Schizophrenia Bulletin, 12(3), 473–482. https://doi.org/10.1093/schbul/12.3.473

Andreasen, N. G., & Pfohl, B. (1976). Linguistic analysis of speech in affective disorders. Archives of General Psychiatry, 33(11), 1361–1367.

Andreou, C., Bozikas, V. P., Ramnalis, A., Giannakou, M., & Fokas, K. (2013). Semantic priming in remitted patients with bipolar disorder. Journal of Behavior Therapy and Experimental Psychiatry, 44(1), 48–52. https://doi.org/10.1016/j.jbtep.2012.07.014

A.P.A. (1980). DSM-III. Diagnostic and Statistical Manual of Mental Disorders (Third Edition). (2nd Printing edition). American Psychiatric Association.

A. P. A. (2000). Diagnostic and Statistical Manual of Mental Disorders, 4th Edition, Text Revision (4th edition). Washington, DC: American Psychiatric Association.

A. P. A. (2013). Diagnostic and Statistical Manual of Mental Disorders (DSM-5®). American Psychiatric Pub.

Baddeley, A. D., & Hitch, G. (1974). Working Memory. In G. H. Bower (Ed.), Psychology of Learning and Motivation (Vol. 8, pp. 47–89). Academic Press. https://doi.org/10.1016/S0079-7421(08)60452-1

Baddeley, A., Logie, R., Bressi, S., Sala, S. D., & Spinnler, H. (1986). Dementia and working memory. The Quarterly Journal of Experimental Psychology Section A, 38(4), 603–618. https://doi.org/10.1080/14640748608401616

Baldessarini, R. J., Faedda, G. L., Offidani, E., Vázquez, G. H., Marangoni, C., Serra, G., & Tondo, L. (2013). Antidepressant-associated mood-switching and transition from unipolar major depression to bipolar disorder: a review. Journal of Affec

Barbuti, M., Pacchiarotti, I., Vieta, E., Azorin, J.-M., Angst, J., Bowden, C. L., … BRIDGE-II-Mix Study Group. (2017). Antidepressant-induced hypomania/mania in patients with major depression: Evidence from the BRIDGE-II-MIX study. Journal of Affective Disorders, 219, 187–192. https://doi.org/10.1016/j.jad.2017.05.035

Baror, S., & Bar, M. (2016). Associative Activation and Its Relation to Exploration and Exploitation in the Brain. Psychological Science, 27(6), 776–789. https://doi.org/10.1177/0956797616634487

Basso, M. R., Lowery, N., Neel, J., Purdie, R., & Bornstein, R. A. (2002). Neuropsychological impairment among manic, depressed, and mixed-episode inpatients with bipolar disorder. Neuropsychology, 16(1), 84–91.

Bauer, M. S., Crits-Christoph, P., Ball, W. A., Dewees, E., McAllister, T., Alahi, P., … Whybrow, P. C. (1991). Independent assessment of manic and depressive symptoms by self-rating. Scale characteristics and implications for the study of mania. Archives of General Psychiatry, 48(9), 807–812.

Beck, A. T., Rush, A. J., Shaw, B. F., & Emery, G. (1987). Cognitive Therapy of Depression (1 edition). New York: The Guilford Press.

Beck, A. T., Steer, R. A., & Carbin, M. G. (1988). Psychometric properties of the Beck Depression Inventory: Twenty-five years of evaluation. Clinical Psychology Review, 8(1), 77–100. https://doi.org/10.1016/0272-7358(88)90050-5

Bellivier, F., Henry, C., Szöke, A., Schürhoff, F., Nosten-Bertrand, M., Feingold, J., … Laplanche, J. L. (1998). Serotonin transporter gene polymorphisms in patients with unipolar or bipolar depression. Neuroscience Letters, 255(3), 143–146.

Bellivier, F., Leroux, M., Henry, C., Rayah, F., Rouillon, F., Laplanche, J.-L., & Leboyer, M. (2002). Serotonin transporter gene polymorphism influences age at onset in patients with bipolar affective disorder. Neuroscience Letters, 334(1), 17–20.

Benazzi, F., & Akiskal, H. S. (2001). Delineating bipolar II mixed states in the Ravenna-San Diego collaborative study: the relative prevalence and diagnostic significance of hypomanic features during major depressive episodes. Journal of Affective Disorders, 67(1–3), 115–122.

Benazzi, F. (2003a). Depression with racing thoughts. Psychiatry Research, 120(3), 273–282.

Benazzi, F. (2003b). Depressive mixed state: dimensional versus categorical definitions. Progress in Neuro-Psychopharmacology & Biological Psychiatry, 27(1), 129–134.

Benazzi, F., & Akiskal, H. S. (2003). Refining the evaluation of bipolar II: beyond the strict SCID-CV guidelines for hypomania. Journal of Affective Disorders, 73(1–2), 33–38.

Benazzi, F. (2007a). Bipolar disorder--focus on bipolar II disorder and mixed depression. Lancet (London, England), 369(9565), 935–945. https://doi.org/10.1016/S0140-6736(07)60453-X

Benazzi, F. (2007b). Delineation of the clinical picture of Dysphoric/Mixed Hypomania. Progress in Neuro-Psychopharmacology & Biological Psychiatry, 31(4), 944–951. https://doi.org/10.1016/j.pnpbp.2007.02.015

Benazzi, F. (2007c). Impulsivity in bipolar-II disorder: trait, state, or both? European Psychiatry: The Journal of the Association of European Psychiatrists, 22(7), 472–478. https://doi.org/10.1016/j.eurpsy.2007.03.008

Benazzi, F. (2007d). Is there a continuity between bipolar and depressive disorders? Psychotherapy and Psychosomatics, 76(2), 70–76. https://doi.org/10.1159/000097965

Benazzi, F. (2009). What is hypomania? Tetrachoric factor analysis and kernel estimation of DSM-IV hypomanic symptoms. The Journal of Clinical Psychiatry, 70(11), 1514–1521. https://doi.org/10.4088/JCP.09m05090

Benedek, M., Könen, T., & Neubauer, A. C. (2012). Associative Abilities Underlying Creativity. Psychology of Aesthetics, Creativity, and the Arts, 6(3), 273–281. https://doi.org/10.1037/a0027059

Bertschy, G., Gervasoni, N., Favre, S., Liberek, C., Ragama-Pardos, E., Aubry, J.-M., … Dayer, A. (2007). Phenomenology of mixed states: a principal component analysis study. Bipolar Disorders, 9(8), 907–912. https://doi.org/10.1111/j.1399-5618.2007.00462.x

Bertschy, G., Gervasoni, N., Favre, S., Liberek, C., Ragama-Pardos, E., Aubry, J.-M., … Dayer, A. (2008a). Frequency of dysphoria and mixed states. Psychopathology, 41(3), 187–193. https://doi.org/10.1159/000120987

Bertschy, G., Gervasoni, N., Favre, S., Liberek, C., Ragama-Pardos, E., Aubry, J.-M., … Dayer, A. (2008b). Frequency of dysphoria and mixed states. Psychopathology, 41(3), 187–193. https://doi.org/10.1159/000120987

Binswanger, L. (2000). Sur la fuite des idées. Grenoble: Editions Jérôme Millon.

Bleuler, E., & Lewis, N. D. C. (1950). Dementia Praecox or The Group of Schizophrenias. (J. Zinkin, Trans.). International Universities Press.

Bolbecker, A. R., Hong, S. L., Kent, J. S., Forsyth, J. K., Klaunig, M. J., Lazar, E., … Hetrick, W. P. (2011). Paced finger-tapping abnormalities in bipolar disorder indicate timing dysfunction. Bipolar Disorders, 13(1), 99–110. https://doi.org/10.1111/j.1399-5618.2011.00895.x

Bolbecker, A. R., Westfall, D. R., Howell, J. M., Lackner, R. J., Carroll, C. A., O'Donnell, B. F., & Hetrick, W. P. (2014). Increased Timing Variability in Schizophrenia and Bipolar Disorder. PLoS ONE, 9(5). https://doi.org/10.1371/journal.pone.0097964

Bora, E., & Özerdem, A. (2017). Meta-analysis of longitudinal studies of cognition in bipolar disorder: comparison with healthy controls and schizophrenia. Psychological Medicine, 1–14. https://doi.org/10.1017/S0033291717001490

Borkovec, T. D., Ray, W. J., & Stober, J. (1998). Worry: A Cognitive Phenomenon Intimately Linked to Affective, Physiological, and Interpersonal Behavioral Processes. Cognitive Therapy and Research, 22(6), 561–576. https://doi.org/10.1023/A:1018790003416

Borkowski, J. G., Benton, A. L., & Spreen, O. (1967). Word fluency and brain damage. Neuropsychologia, 5(2), 135–140. https://doi.org/10.1016/0028-3932(67)90015-2

Bowden, H. (2013). A Phenomenological Study of Mania and Depression (Doctoral). Durham University. Retrieved from http://etheses.dur.ac.uk/9456/

Braden, W., & Ho, C. K. (1981). Racing thoughts in psychiatric inpatients. Archives of General Psychiatry, 38(1), 71–75.

Braden, W., & Qualls, C. B. (1979). Racing thoughts in depressed patients. The Journal of Clinical Psychiatry, 40(8), 336–339.

Bschor, T., Ising, M., Bauer, M., Lewitzka, U., Skerstupeit, M., Müller-Oerlinghausen, B., & Baethge, C. (2004). Time experience and time judgment in major depression, mania and healthy subjects. A controlled study of 93 subjects. Acta Psychiatrica Scandinavica, 109(3), 222–229. https://doi.org/10.1046/j.0001-690X.2003.00244.x

Butterworth, B. (1992). Disorders of phonological encoding. Cognition, 42(1), 261–286. https://doi.org/10.1016/0010-0277(92)90045-J

Caramazza, A. (1997). How Many Levels of Processing Are There in Lexical Access? Cognitive Neuropsychology, 14(1), 177–208. https://doi.org/10.1080/026432997381664

Causin, J., Weiner, L., & Giersch, A. (2016). Cognitive mechanisms of racing thoughts in bipolar patients. European Neuropsychopharmacology, 26, S430–S431. https://doi.org/10.1016/S0924-977X(16)31406-7

Cermolacce, M., Faugère, M., Micoulaud-Franchi, J.-A., Belzeaux, R., Maurel, M., Naudin, J., … Vion-Dury, J. (2014). Natural speech comprehension in bipolar disorders: An event-related brain potential study among manic patients. Journal of Affective Disorders, 158, 161–171. https://doi.org/10.1016/j.jad.2013.11.013

Chang, J. S., Choi, S., Ha, K., Ha, T. H., Cho, H. S., Choi, J. E., … Moon, E. (2011). Differential pattern of semantic memory organization between bipolar I and II disorders. Progress in Neuro-Psychopharmacology and Biological Psychiatry, 35(4), 1053–1058. https://doi.org/10.1016/j.pnpbp.2011.02.020

Chomsky, N. (1965). Aspects of the Theory of Syntax. MIT Press. 1965. (First Edition edition). MIT Press.

Collins, A. M., & Loftus, E. F. (1975). A Spreading-Activation Theory of Semantic Processing. Psychological Review, 82(6), 407–428.

Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. Journal of Verbal Learning and Verbal Behavior, 8(2), 240–247. https://doi.org/10.1016/S0022-5371(69)80069-1

Conrey, B., & Pisoni, D. B. (2006). Auditory-visual speech perception and synchrony detection for speech and nonspeech signals. The Journal of the Acoustical Society of America, 119(6), 4065–4073.

Correll, C. U., Hauser, M., Penzner, J. B., Auther, A. M., Kafantaris, V., Saito, E., … Cornblatt, B. A. (2014). Type and duration of subsyndromal symptoms in youth with bipolar I disorder prior to their first manic episode. Bipolar Disorders, 16(5), 478–492. https://doi.org/10.1111/bdi.12194

Costa, A., Colomé, À., & Caramazza, A. (2000). Lexical access in speech production: The bilingual case. Psicológica, 21(3), 403-437.

Coull, J., & Nobre, A. (2008). Dissociating explicit timing from temporal expectation with fMRI. Current Opinion in Neurobiology, 18(2), 137–144. https://doi.org/10.1016/j.conb.2008.07.011

Coull, J. T., Cheng, R.-K., & Meck, W. H. (2011). Neuroanatomical and Neurochemical Substrates of Timing. Neuropsychopharmacology, 36(1), 3–25. https://doi.org/10.1038/npp.2010.113

Cragg, L., & Nation, K. (2010). Language and the development of cognitive control. Topics in Cognitive Science, 2(4), 631–642. https://doi.org/10.1111/j.1756-8765.2009.01080.x

Crawford, J. R., Moore, J. W., & Cameron, I. M. (1992). Verbal Fluency: A NART-based equation for the estimation of premorbid performance. British Journal of Clinical Psychology, 31(3), 327–329. https://doi.org/10.1111/j.2044-8260.1992.tb00999.x

Crowe, S. F. (1998). Decrease in performance on the verbal fluency test as a function of time: evaluation in a young healthy sample. Journal of Clinical and Experimental Neuropsychology, 20(3), 391–401. https://doi.org/10.1076/jcen.20.3.391.810

Curci, A., Lanciano, T., Soleti, E., & Rimé, B. (2013). Negative emotional experiences arouse rumination and affect working memory capacity. Emotion (Washington, D.C.), 13(5), 867–880. https://doi.org/10.1037/a0032492

Cutting, J. (1997). Principles of Psychopathology: Two Worlds - Two Minds - Two Hemispheres. Oxford, New York: Oxford University Press.

Cutting, J. C., & Ferreira, V. S. (1999). Semantic and phonological information flow in the production lexicon. Journal of Experimental Psychology. Learning, Memory, and Cognition, 25(2), 318–344.

David, A. S., & Lucas, P. A. (1993). Auditory-verbal hallucinations and the phonological loop: a cognitive neuropsychological study. The British Journal of Clinical Psychology, 32 (Pt 4), 431–441.

Dell, G. S. (2013). Cascading and feedback in interactive models of production: A reflection of forward modeling? The Behavioral and Brain Sciences, 36(4), 351–352. https://doi.org/10.1017/S0140525X12002531

Desseilles, M., Chang, T., Piguet, C., Bertschy, G., & Dayer, A. G. (2012). A three-dimensional model of thoughts: insight into depression. Psychopathology, 45(4), 203–214. https://doi.org/10.1159/000335073

Deyne, S. D., & Storms, G. (2008). Word associations: Network and semantic properties. Behavior Research Methods, 40(1), 213–231. https://doi.org/10.3758/BRM.40.1.213

Dilsaver, S. C., Swann, A. C., Shoaib, A. M., & Bowers, T. C. (1993). The manic syndrome: factors which may predict a patient's response to lithium, carbamazepine and valproate. Journal of Psychiatry & Neuroscience: JPN, 18(2), 61–66.

Di Simplicio, M., Renner, F., Blackwell, S. E., Mitchell, H., Stratford, H. J., Watson, P., … Holmes, E. A. (2016). An investigation of mental imagery in bipolar disorder: Exploring "the mind's eye." Bipolar Disorders, 18(8), 669–683. https://doi.org/10.1111/bdi.12453

Diler, R. S., Goldstein, T. R., Hafeman, D., Merranko, J., Liao, F., Goldstein, B. I., … Birmaher, B. (2017). Distinguishing Bipolar Depression from Unipolar Depression in Youth: Preliminary Findings. Journal of Child and Adolescent Psychopharmacology, 27(4), 310–319. https://doi.org/10.1089/cap.2016.0154

Diler, R. S., Goldstein, T. R., Hafeman, D., Rooks, B. T., Sakolsky, D., Goldstein, B. I., … Birmaher, B. (2017). Characteristics of depression among offspring at high and low familial risk of bipolar disorder. Bipolar Disorders. https://doi.org/10.1111/bdi.12508

Dodd, A. L., Mansell, W., Sadhnani, V., Morrison, A. P., & Tai, S. (2010). Principal components analysis of the hypomanic attitudes and positive predictions inventory and associations with measures of personality, cognitive style and analogue symptoms in a student sample. Behavioural and Cognitive Psychotherapy, 38(1), 15–33. https://doi.org/10.1017/S1352465809990476

Dodd, S., Kulkarni, J., Berk, L., Ng, F., Fitzgerald, P. B., de Castella, A. R., … Berk, M. (2010). A prospective study of the impact of subthreshold mixed states on the 24-month clinical outcomes of bipolar I disorder or schizoaffective disorder. Journal of Affective Disorders, 124(1–2), 22–28. https://doi.org/10.1016/j.jad.2009.10.027

Douglas, L. N., McGuire, A. B., Manzardo, A. M., & Butler, M. G. (2016). High-resolution chromosome ideogram representation of recognized genes for bipolar disorder. Gene, 586(1), 136–147. https://doi.org/10.1016/j.gene.2016.04.011

Dreisbach, G. (2006). How positive affect modulates cognitive control: The costs and benefits of reduced maintenance capability. Brain and Cognition, 60(1), 11–19. https://doi.org/10.1016/j.bandc.2005.08.003

Droit-Volet, S. (2013). Time perception, emotions and mood disorders. Journal of Physiology, Paris, 107(4), 255–264. https://doi.org/10.1016/j.jphysparis.2013.03.005

Droit-Volet, S., Brunot, S., & Niedenthal, P. (2004). BRIEF REPORT Perception of the duration of emotional events. Cognition and Emotion, 18(6), 849–858. https://doi.org/10.1080/02699930341000194

Droit-Volet, S., & Gil, S. (2009). The time–emotion paradox. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1525), 1943. https://doi.org/10.1098/rstb.2009.0013

Droit-Volet, S., & Meck, W. H. (2007). How emotions colour our perception of time. Trends in Cognitive Sciences, 11(12), 504–513. https://doi.org/10.1016/j.tics.2007.09.008

Droit-Volet, S., Trahanias, P., & Maniadakis, M. (2017). Passage of time judgments in everyday life are not related to duration judgments except for long durations of several minutes. Acta Psychologica, 173, 116–121. https://doi.org/10.1016/j.actpsy.2016.12.010

Droit-Volet, S., & Wearden, J. (2016). Passage of Time Judgments Are Not Duration Judgments: Evidence from a Study Using Experience Sampling Methodology. Frontiers in Psychology, 7, 176. https://doi.org/10.3389/fpsyg.2016.00176

Droit-Volet, S. (2016). Temporalités, émotion, humeur et troubles de l'humeur. De l'humeur normale à la dépression en psychologie cognitive, neurosciences et psychiatrie. Ed : Laurent, E., & Vandel, P. De Boeck Superieur.

Droit-Volet, S., & Wearden, J. H. (2015). Experience Sampling Methodology reveals similarities in the experience of passage of time in young and elderly adults. Acta Psychologica, 156, 77–82. https://doi.org/10.1016/j.actpsy.2015.01.006

Elliott, M. A., & Giersch, A. (2015). What Happens in a Moment. Frontiers in Psychology, 6, 1905. https://doi.org/10.3389/fpsyg.2015.01905

Esmaeelpour, E., & Sasani, F. (2016). The Effect of Bipolar Mood Disorder on Sadegh Hedayat's Letters. Journal of Psycholinguistic Research, 45(2), 367–377. https://doi.org/10.1007/s10936-015-9355-5

Faedda, G. L., Marangoni, C., & Reginaldi, D. (2015). Depressive mixed states: A reappraisal of Koukopoulos' criteria. Journal of Affective Disorders, 176, 18–23. https://doi.org/10.1016/j.jad.2015.01.053

Fedorenko, E., & Varley, R. (2016). Language and thought are not the same thing: evidence from neuroimaging and neurological patients. Annals of the New York Academy of Sciences, 1369(1), 132–153. https://doi.org/10.1111/nyas.13046

Ferrari, M., Ossola, P., Lucarini, V., Accardi, V., Panfilis, C. D., Tonna, M., & Marchesi, C. (2016). Thought overactivation as a marker of bipolar disorder. European Psychiatry, 33, S264. https://doi.org/10.1016/j.eurpsy.2016.01.547

Fiedorowicz, J. G., Endicott, J., Leon, A. C., Solomon, D. A., Keller, M. B., & Coryell, W. H. (2011). Subthreshold hypomanic symptoms in progression from unipolar major depression to bipolar disorder. The American Journal of Psychiatry, 168(1), 40–48. https://doi.org/10.1176/appi.ajp.2010.10030328

First, MB., Gibbon M, Spitzer RL, Williams, JBW, Benjamin LS.: Structured Clinical Interview for DSM-IV Axis II Personality Disorders, (SCID-II). Washington, D.C.: American Psychiatric Press, Inc., 1997.

Fodor, J. A., & Pylyshyn, Z. W. (2015). Minds without Meanings: An Essay on the Content of Concepts. MIT Press. Retrieved from http://www.jstor.org/stable/j.ctt1287hw5

Fossati, P., Ergis, A.-M., Allilaire, J.-F., & others. (2003). Qualitative analysis of verbal fluency in depression. Psychiatry Research, 117(1), 17–24.

Fuchs, T. (2013). Temporality and psychopathology. Phenomenology and the Cognitive Sciences, 12(1), 75–104. https://doi.org/10.1007/s11097-010-9189-4

Furnham, A. (1986). Response bias, social desirability and dissimulation. Personality and Individual Differences, 7(3), 385–400. https://doi.org/10.1016/0191-8869(86)90014-0

Gaddy, M. A., & Ingram, R. E. (2014). A meta-analytic review of mood-congruent implicit memory in depressed mood. Clinical Psychology Review, 34(5), 402–416. https://doi.org/10.1016/j.cpr.2014.06.001

Gallagher, S. (2003). Phenomenology and Experimental Design Toward a Phenomenologically Enlightened Experimental Science. Journal of Consciousness Studies, 10(9–10), 85–99.

Gallagher, S. (2012). Time, Emotion, and Depression. Emotion Review, 4(2), 127–132. https://doi.org/10.1177/1754073911430142

Gawda, B., Szepietowska, E., Soluch, P., & Wolak, T. (2017). Valence of Affective Verbal Fluency: fMRI Studies on Neural Organization of Emotional Concepts Joy and Fear. Journal of Psycholinguistic Research, 46(3), 731–746. https://doi.org/10.1007/s10936-016-9462-y

Ghaemi, S. N. (2007). Feeling and Time: The Phenomenology of Mood Disorders, Depressive Realism, and Existential Psychotherapy. Schizophrenia Bulletin, 33(1), 122–130. https://doi.org/10.1093/schbul/sbl061

Ghaemi, S. N., & Vohringer, P. A. (2017). Athanasios Koukopoulos' Psychiatry: The Primacy of Mania and the Limits of Antidepressants. Current Neuropharmacology, 15(3), 402–408. https://doi.org/10.2174/1570159X14666160621113432

Gibbon, J., Church, R. M., & Meck, W. H. (1984). Scalar timing in memory. Annals of the New York Academy of Sciences, 423, 52–77.

Giehm, G. (1933). Experimentell-psychologische Untersuchungen der Assoziationsgeschwindigkeit bei Geisteskranken. Archiv für Psychiatrie und Nervenkrankheiten, 100(1), 432–438. https://doi.org/10.1007/BF01814750

Giersch, A., Lalanne, L., & Isope, P. (2016). Implicit Timing as the Missing Link between Neurobiological and Self Disorders in Schizophrenia? Frontiers in Human Neuroscience, 10. https://doi.org/10.3389/fnhum.2016.00303

Giorgi, A. (2012). The Descriptive Phenomenological Psychological Method. Journal of Phenomenological Psychology, 43(1), 3–12. https://doi.org/10.1163/156916212X632934

Goghari, V. M., & Harrow, M. (2016). Twenty year multi-follow-up of different types of hallucinations in schizophrenia, schizoaffective disorder, bipolar disorder, and depression. Schizophrenia Research, 176(2–3), 371–377. https://doi.org/10.1016/j.schres.2016.06.027

Gonda, X., Fountoulakis, K. N., Rihmer, Z., Lazary, J., Laszik, A., Akiskal, K. K., … Bagdy, G. (2009). Towards a genetically validated new affective temperament scale: a delineation of the temperament phenotype of 5-HTTLPR using the TEMPS-A. Journal of Affective Disorders, 112(1–3), 19–29. https://doi.org/10.1016/j.jad.2008.03.012

Goodwin, F. K., & Jamison, K. R. (2007). Manic-Depressive Illness: Bipolar Disorders and Recurrent Depression. Oxford University Press, USA.

Griffiths, T. L., Steyvers, M., & Tenenbaum, J. B. (2007). Topics in semantic representation. Psychological Review, 114(2), 211–244. https://doi.org/10.1037/0033-295X.114.2.211

Gruber, J., Cunningham, W. A., Kirkland, T., & Hay, A. C. (2012). Feeling stuck in the present? Mania proneness and history associated with present-oriented time perspective. Emotion (Washington, D.C.), 12(1), 13–17. https://doi.org/10.1037/a0025062

Gruenewald, P. J., & Lockhead, G. R. (1980). The free recall of category examples. Journal of Experimental Psychology Human Learning & Memory, 6(3), 225–240.

Harley, T. A. (2007). The Psychology of Language: From Data to Theory (3 edition). New York: Psychology Press.

Hatano, K., Terao, T., Hoaki, N., Kohno, K., Araki, Y., Mizokami, Y., … Hayashi, T. (2014). Association between affective temperaments and regional gray matter volume in healthy subjects. Journal of Affective Disorders, 155, 169–173. https://doi.org/10.1016/j.jad.2013.10.045

Haugrud, N., Crossley, M., & Vrbancic, M. (2011). Clustering and switching strategies during verbal fluency performance differentiate Alzheimer's disease and healthy aging. Journal of the International Neuropsychological Society: JINS, 17(6), 1153–1157. https://doi.org/10.1017/S1355617711001196

Heidegger, M. (1988). The Basic Problems of Phenomenology, Revised Edition. (A. Hofstadter, Trans.) (2 edition). Bloomington; Indianapolis: Indiana University Press.

Helmes, E., & Hall, F. (2016). Performance of psychiatric diagnostic groups on measures and strategies of verbal fluency. Applied Neuropsychology. Adult, 23(4), 284–294. https://doi.org/10.1080/23279095.2015.1056300

Henry, J. D., & Crawford, J. R. (2004). A meta-analytic review of verbal fluency performance following focal cortical lesions. Neuropsychology, 18(2), 284–295. https://doi.org/10.1037/0894-4105.18.2.284

Henry, J. D., & Crawford, J. R. (2005). A Meta-Analytic Review of Verbal Fluency Deficits in Depression. Journal of Clinical and Experimental Neuropsychology, 27(1), 78–101. https://doi.org/10.1080/138033990513654

Hersh, K. (2011). Paradoxical Undressing (Main edition). London: Atlantic.

Ho, A. K., Sahakian, B. J., Robbins, T. W., Barker, R. A., Rosser, A. E., & Hodges, J. R. (2002). Verbal fluency in Huntington's disease: a longitudinal analysis of phonemic and semantic clustering and switching. Neuropsychologia, 40(8), 1277–1284. https://doi.org/10.1016/S0028-3932(01)00217-2

Hoff, P. (2015). The Kraepelinian tradition. Dialogues in Clinical Neuroscience, 17(1), 31–41.

Hoffman, R. E., Quinlan, D. M., Mazure, C. M., & McGlashan, T. M. (2001). Cortical instability and the mechanism of mania: a neural network simulation and perceptual test. Biological Psychiatry, 49(6), 500–509. https://doi.org/10.1016/S0006-3223(00)01071-4

Hoffman, R. E., Stopek, S., & Andreasen, N. C. (1986). A comparative study of manic vs schizophrenic speech disorganization. Archives of General Psychiatry, 43(9), 831–838.

Holshausen, K., Harvey, P. D., Elvevåg, B., Foltz, P. W., & Bowie, C. R. (2014). Latent semantic variables are associated with formal thought disorder and adaptive behavior in older inpatients with schizophrenia. Cortex; a Journal Devoted to the Study of the Nervous System and Behavior, 55, 88–96. https://doi.org/10.1016/j.cortex.2013.02.006

Holzman, P. S., Shenton, M. E., & Solovay, M. R. (1986). Quality of thought disorder in differential diagnosis. Schizophrenia Bulletin, 12(3), 360–371.

Husserl, E. (1913/2014). The structure of lived time. *In* Arstila, V., & Lloyd, D. (Eds.). Subjective Time: The Philosophy, Psychology, and Neuroscience of Temporality (1st edition). Cambridge, MA: The MIT Press.

Husserl, E. (1970). The Crisis of European Sciences and Transcendental Phenomenology: An Introduction to Phenomenological Philosophy. Northwestern University Press.

Ivins, A., Di Simplicio, M., Close, H., Goodwin, G. M., & Holmes, E. (2014). Mental imagery in bipolar affective disorder versus unipolar depression: investigating cognitions at times of "positive" mood. Journal of Affective Disorders, 166, 234–242. https://doi.org/10.1016/j.jad.2014.05.007

Ivry, R. B., & Schlerf, J. E. (2008). Dedicated and intrinsic models of time perception. Trends in Cognitive Sciences, 12(7), 273–280. https://doi.org/10.1016/j.tics.2008.04.002

Jackendoff, R. (2003). Foundations of Language: Brain, Meaning, Grammar, Evolution (1 edition). Oxford: Oxford University Press.

Jamison, K. R. (1997). An Unquiet Mind: A Memoir of Moods and Madness (1 edition). New York: Vintage.

Jamison, K. R. (2017). Robert Lowell, Setting the River on Fire: A Study of Genius, Mania, and Character. New York: Knopf.

Jampala, V. C., Taylor, M. A., & Abrams, R. (1989). The diagnostic implications of formal thought disorder in mania and schizophrenia: a reassessment. The American Journal of Psychiatry, 146(4), 459–463. https://doi.org/10.1176/ajp.146.4.459

Jaspers, K. (1959). Truth and symbol,: From Von der Wahrheit. College and University Press.

Johnson, S. L., Murray, G., Fredrickson, B., Youngstrom, E. A., Hinshaw, S., Bass, J. M., … Salloum, I. (2012). Creativity and bipolar disorder: touched by fire or burning with questions? Clinical Psychology Review, 32(1), 1–12. https://doi.org/10.1016/j.cpr.2011.10.001

Kane, S. (2008). 4.48 Psychosis. London: Methuen Drama.

Karmarkar, U. R., & Buonomano, D. V. (2007). Timing in the Absence of Clocks: Encoding Time in Neural Network States. Neuron, 53(3), 427–438. https://doi.org/10.1016/j.neuron.2007.01.006

Keizer, I., Piguet, C., Favre, S., Aubry, J.-M., Dayer, A., Gervasoni, N., … Bertschy, G. (2014). Subjective experience of thought overactivation in mood disorders: beyond racing and crowded thoughts. Psychopathology, 47(3), 174–184. https://doi.org/10.1159/000354781

Kerns, J. G., Berenbaum, H., Barch, D. M., Banich, M. T., & Stolar, N. (1999). Word production in schizophrenia and its relationship to positive symptoms. Psychiatry Research, 87(1), 29–37. https://doi.org/10.1016/S0165-1781(99)00052-9

Kim, S., Yu, B. H., Lee, D. S., & Kim, J.-H. (2012). Ruminative response in clinical patients with major depressive disorder, bipolar disorder, and anxiety disorders. Journal of Affective Disorders, 136(1–2), e77–e81. https://doi.org/10.1016/j.jad.2011.06.034

Kircher, T., Krug, A., Stratmann, M., Ghazi, S., Schales, C., Frauenheim, M., … Nagels, A. (2014). A rating scale for the assessment of objective and subjective formal Thought and Language Disorder (TALD). Schizophrenia Research, 160(1), 216–221. https://doi.org/10.1016/j.schres.2014.10.024

Kircher, T., Whitney, C., Krings, T., Huber, W., & Weis, S. (2008). Hippocampal dysfunction during free word association in male patients with schizophrenia. Schizophrenia Research, 101(1), 242–255. https://doi.org/10.1016/j.schres.2008.02.003

Kocsis, J. H., Shaw, E. D., Stokes, P. E., Wilner, P., Elliot, A. S., Sikes, C., … Parides, M. (1993). Neuropsychologic Effects of Lithium Discontinuation. Journal of Clinical Psychopharmacology, 13(4), 268.

Kornmeier, J., & Bach, M. (2005). The Necker cube--an ambiguous figure disambiguated in early visual processing. Vision Research, 45(8), 955–960. https://doi.org/10.1016/j.visres.2004.10.006

Kornmeier, J., & Bach, M. (2012). Ambiguous Figures – What Happens in the Brain When Perception Changes But Not the Stimulus. Frontiers in Human Neuroscience, 6. https://doi.org/10.3389/fnhum.2012.00051

Kornmeier, J., Pfäffle, M., & Bach, M. (2011). Necker cube: stimulus-related (low-level) and percept-related (high-level) EEG signatures early in occipital cortex. Journal of Vision, 11(9), 12. https://doi.org/10.1167/11.9.12

Koukopoulos, A., & Koukopoulos, A. (1999). Agitated depression as a mixed state and the problem of melancholia. The Psychiatric Clinics of North America, 22(3), 547–564.

Kraepelin, E. (2008). La folie maniaco-dépressive. Bordeaux: Mollat.

Kraepelin, E. (2017). Manic-Depressive Insanity and Paranoia. S.l.: Forgotten Books.

Kreher, D. A., Holcomb, P. J., Goff, D., & Kuperberg, G. R. (2008). Neural Evidence for Faster and Further Automatic Spreading Activation in Schizophrenic Thought Disorder. Schizophrenia Bulletin, 34(3), 473–482. https://doi.org/10.1093/schbul/sbm108

Krug, K., Brunskill, E., Scarna, A., Goodwin, G. M., & Parker, A. J. (2008). Perceptual switch rates with ambiguous structure-from-motion figures in bipolar disorder. Proceedings of the Royal Society of London B: Biological Sciences, 275(1645), 1839–1848. https://doi.org/10.1098/rspb.2008.0043

Lake, C. R. (2012). Schizophrenia Is a Misdiagnosis: Implications for the DSM-5 and the ICD-11. Springer Science & Business Media.

Lalanne, L., van Assche, M., & Giersch, A. (2012a). When predictive mechanisms go wrong: disordered visual synchrony thresholds in schizophrenia. Schizophrenia Bulletin, 38(3), 506–513. https://doi.org/10.1093/schbul/sbq107

Lalanne, L., Van Assche, M., Wang, W., & Giersch, A. (2012b). Looking forward: an impaired ability in patients with schizophrenia? Neuropsychologia, 50(12), 2736–2744. https://doi.org/10.1016/j.neuropsychologia.2012.07.023

Lam, D. H., Jones, S. H., Hayward, P., & Bright, J. A. (1999). Cognitive Therapy for Bipolar Disorder: A Therapist's Guide to Concepts, Methods and Practice (1 edition). Chichester ; New York: Wiley.

Lambert, W. E. (1955). Associational fluency as a function of stimulus abstractness. Canadian Journal of Psychology, 9(2), 103–106.

Lancee, J., Eisma, M. C., Zanten, K. B. van, & Topper, M. (2017). When Thinking Impairs Sleep: Trait, Daytime and Nighttime Repetitive Thinking in Insomnia. Behavioral Sleep Medicine, 15(1), 53–69. https://doi.org/10.1080/15402002.2015.1083022

Landauer, T. K., Foltz, P. W., & Laham, D. (1998). An introduction to latent semantic analysis. Discourse Processes, 25(2–3), 259–284. https://doi.org/10.1080/01638539809545028

Langdon, R., Jones, S. R., Connaughton, E., & Fernyhough, C. (2009). The phenomenology of inner speech: comparison of schizophrenia patients with auditory verbal hallucinations and healthy controls. Psychological Medicine, 39(4), 655–663. https://doi.org/10.1017/S0033291708003978

Ledoux, K., Vannorsdall, T., J Pickett, E., Bosley, L., Gordon, B., & Schretlen, D. (2014). Capturing additional information about the organization of entries in the lexicon from verbal fluency productions. Journal of Clinical and Experimental Neuropsychology, 36. https://doi.org/10.1080/13803395.2013.878689

Lee Mortensen, G., Vinberg, M., Lee Mortensen, S., Balslev Jørgensen, M., & Eberhard, J. (2015). Bipolar patients' quality of life in mixed states: a preliminary qualitative study. Psychopathology, 48(3), 192–201. https://doi.org/10.1159/000381479

Lemaire, M., El-Hage, W., & Frangou, S. (2015). Increased affective reactivity to neutral stimuli and decreased maintenance of affective responses in bipolar disorder. European Psychiatry: The Journal of the Association of European Psychiatrists, 30(7), 852–860. https://doi.org/10.1016/j.eurpsy.2015.07.008

Levelt. (1999). Models of word production. Trends in Cognitive Sciences, 3(6), 223–232.

Levine, J., Schild, K., Kimhi, R., & Schreiber, G. (1996). Word Associative Production in Affective versus Schizophrenic Psychoses. Psychopathology, 29(1), 7–13. https://doi.org/10.1159/000284966

Lewis, E. J., Yoon, K. L., & Joormann, J. (2017). Emotion regulation and biological stress responding: associations with worry, rumination, and reappraisal. Cognition & Emotion, 1–12. https://doi.org/10.1080/02699931.2017.1310088

Leyfer, O. T., Ruberg, J. L., & Woodruff-Borden, J. (2006). Examination of the utility of the Beck Anxiety Inventory and its factors as a screener for anxiety disorders. Journal of Anxiety Disorders, 20(4), 444–458. https://doi.org/10.1016/j.janxdis.2005.05.004

Lezak, M. D. (2004). Neuropsychological Assessment. Oxford University Press.

Luria. (1976). The Working Brain: An Introduction to Neuropsychology (New Ed edition). New York: Basic Books.

MacKinnon, D. F. (2008). Bipolar disorder as maladaptive arousal: a behavioral model and evidence. Annals of the New York Academy of Sciences, 1129, 185–189. https://doi.org/10.1196/annals.1417.000

MacKinnon, D. F., & Zamoiski, R. (2006). Panic comorbidity with bipolar disorder: what is the manic-panic connection? Bipolar Disorders, 8(6), 648–664. https://doi.org/10.1111/j.1399-5618.2006.00356.x

Mahlberg, R., Kienast, T., Bschor, T., & Adli, M. (2008). Evaluation of time memory in acutely depressed patients, manic patients, and healthy controls using a time reproduction task. European Psychiatry: The Journal of the Association of European Psychiatrists, 23(6), 430–433. https://doi.org/10.1016/j.eurpsy.2007.07.001

Mahon, B. Z., & Caramazza, A. (2009). Concepts and Categories: A Cognitive Neuropsychological Perspective. Annual Review of Psychology, 60, 27–51. https://doi.org/10.1146/annurev.psych.60.110707.163532

Maina, G., Bertetto, N., Domene Boccolini, F., Di Salvo, G., Rosso, G., & Bogetto, F. (2013). The concept of mixed state in bipolar disorder: from Kraepelin to DSM-5. Journal of Psychopathology, 19, 287–295.

Malhi, G. S., Byrow, Y., Outhred, T., & Fritz, K. (2017). Exclusion of overlapping symptoms in DSM-5 mixed features specifier: heuristic diagnostic and treatment implications. CNS Spectrums, 22(2), 126–133. https://doi.org/10.1017/S1092852916000614

Marchetti, I., Koster, E. H. W., Klinger, E., & Alloy, L. B. (2016). Spontaneous Thought and Vulnerability to Mood Disorders: The Dark Side of the Wandering Mind. Clinical Psychological Science: A Journal of the Association for Psychological Science, 4(5), 835–857. https://doi.org/10.1177/2167702615622383

Marchetti, I., Van de Putte, E., & Koster, E. H. W. (2014). Self-generated thoughts and depression: from daydreaming to depressive symptoms. Frontiers in Human Neuroscience, 8, 131. https://doi.org/10.3389/fnhum.2014.00131

Marneros, A., & Angst, J. (2005). Bipolar disorders 100 years after manic-depressive insanity. Dordrecht: Kluwer Academic Publishers. Retrieved from http://accesbib.uqam.ca/cgi-bin/bduqam/transit.pl?&noMan=25127212

Martinich, A. P. (Ed.). (2006). The Philosophy of Language (5 edition). New York: Oxford University Press.

Matell, M. S., & Meck, W. H. (2004). Cortico-striatal circuits and interval timing: coincidence detection of oscillatory processes. Brain Research. Cognitive Brain Research, 21(2), 139–170. https://doi.org/10.1016/j.cogbrainres.2004.06.012

Mayr, U. (2002). On the dissociation between clustering and switching in verbal fluency: Comment on Troyer, Moscovitch, Winocur, Alexander and Stuss. Neuropsychologia, 40(5), 562–566.

McElroy, S. L., Keck, P. E., Pope, H. G., Hudson, J. I., Faedda, G. L., & Swann, A. C. (1992). Clinical and research implications of the diagnosis of dysphoric or mixed mania or hypomania. The American Journal of Psychiatry, 149(12), 1633–1644. https://doi.org/10.1176/ajp.149.12.1633

McEvoy, P. M., Watson, H., Watkins, E. R., & Nathan, P. (2013). The relationship between worry, rumination, and comorbidity: evidence for repetitive negative thinking as a transdiagnostic construct. Journal of Affective Disorders, 151(1), 313–320. https://doi.org/10.1016/j.jad.2013.06.014

McIntyre, R. S., Ng-Mak, D., Chuang, C.-C., Halpern, R., Patel, P. A., Rajagopalan, K., & Loebel, A. (2017). Major depressive disorder with subthreshold hypomanic (mixed) features: A real-world assessment of treatment patterns and economic burden. Journal of Affective Disorders, 210, 332–337. https://doi.org/10.1016/j.jad.2016.12.033

McIntyre, R. S., Soczynska, J. K., Cha, D. S., Woldeyohannes, H. O., Dale, R. S., Alsuwaidan, M. T., … Kennedy, S. H. (2015). The prevalence and illness characteristics of DSM-5-defined "mixed feature specifier" in adults with major depressive disorder and bipolar disorder: Results from the International Mood Disorders Collaborative Project. Journal of Affective Disorders, 172, 259–264. https://doi.org/10.1016/j.jad.2014.09.026

Mella, N., Conty, L., & Pouthas, V. (2011). The role of physiological arousal in time perception: psychophysiological evidence from an emotion regulation paradigm. Brain and Cognition, 75(2), 182–187. https://doi.org/10.1016/j.bandc.2010.11.012

Mellerup, E., & Kristensen, F. (2004). Mania as a dysfunction of reentry: application of Edelman's and Tononi's hypothesis for consciousness in relation to a psychiatric disorder. Medical Hypotheses, 63(3), 464–466. https://doi.org/10.1016/j.mehy.2004.03.007

Mensch, J. (2001). Derrida–Husserl: Towards a Phenomenology of Language. New Yearbook for Phenomenology and Phenomenological Philosophy, 1, 1–66.

Mensch, J. (2014). A brief account of Husserl's conception of our consciousness of time. In Arstila, V., & Lloyd, D. (Eds.). (2014). Subjective Time: The Philosophy, Psychology, and Neuroscience of Temporality (1st edition). Cambridge, MA: The MIT Press.

Merikangas, K. R., Jin, R., He, J.-P., Kessler, R. C., Lee, S., Sampson, N. A., … Zarkov, Z. (2011). Prevalence and correlates of bipolar spectrum disorder in the world mental health survey initiative. Archives of General Psychiatry, 68(3), 241–251. https://doi.org/10.1001/archgenpsychiatry.2011.12

Merleau-Ponty, M. (1976). Phénoménologie de la perception. Paris: Gallimard.

Mezey, A. G., & Knight, E. J. (1965). Time Sense in Hypomanic Illness. Archives of General Psychiatry, 12(2), 184–186. https://doi.org/10.1001/archpsyc.1965.01720320072008

Miller, E. (1984). Verbal fluency as a function of a measure of verbal intelligence and in relation to different types of cerebral pathology. The British Journal of Clinical Psychology, 23 (Pt 1), 53–57.

Miller, S. M., Gynther, B. D., Heslop, K. R., Liu, G. B., Mitchell, P. B., Ngo, T. T., … Geffen, L. B. (2003). Slow binocular rivalry in bipolar disorder. Psychological Medicine, 33(4), 683–692.

Miller, S., Suppes, T., Mintz, J., Hellemann, G., Frye, M. A., McElroy, S. L., … Post, R. M. (2016). Mixed Depression in Bipolar Disorder: Prevalence Rate and Clinical Correlates During Naturalistic Follow-Up in the Stanley Bipolar Network. American Journal of Psychiatry, 173(10), 1015–1023. https://doi.org/10.1176/appi.ajp.2016.15091119

Minkowski, E. (2013). Le temps vécu (3e edition). Paris: PRESSES UNIVERSITAIRES DE FRANCE - PUF.

Mioni, G., Stablum, F., Prunetti, E., & Grondin, S. (2016). Time perception in anxious and depressed patients: A comparison between time reproduction and time production tasks. Journal of Affective Disorders, 196, 154–163. https://doi.org/10.1016/j.jad.2016.02.047

Moscovitch, M. (1994). Cognitive Resources and Dual-task Interference Effects at Retrieval in Normal People: The Role of the Frontal Lobes and Medial Temporal Cortex. Neuropsychology, 8(4), 524–534.

Mota, N. B., Furtado, R., Maia, P. P. C., Copelli, M., & Ribeiro, S. (2014). Graph analysis of dream reports is especially informative about psychosis. Scientific Reports, 4, 3691. https://doi.org/10.1038/srep03691

Nagamine, M., Yoshino, A., Miyazaki, M., Takahashi, Y., & Nomura, S. (2009). Difference in binocular rivalry rate between patients with bipolar I and bipolar II disorders. Bipolar Disorders, 11(5), 539–546. https://doi.org/10.1111/j.1399-5618.2009.00719.x

Nagels, A., Fährmann, P., Stratmann, M., Ghazi, S., Schales, C., Frauenheim, M., … Kircher, T. (2016). Distinct Neuropsychological Correlates in Positive and Negative Formal Thought Disorder Syndromes: The Thought and Language Disorder Scale in Endogenous Psychoses. Neuropsychobiology, 73(3), 139–147. https://doi.org/10.1159/000441657

Nagels, A., Kirner-Veselinovic, A., Wiese, R., Paulus, F. M., Kircher, T., & Krach, S. (2012). Effects of ketamine-induced psychopathological symptoms on continuous overt rhyme fluency. European Archives of Psychiatry and Clinical Neuroscience, 262(5), 403–414. https://doi.org/10.1007/s00406-011-0281-8

Navarrete, E., & Costa, A. (2005). Phonological activation of ignored pictures: Further evidence for a cascade model of lexical access. Journal of Memory and Language, 53(3), 359–377. https://doi.org/10.1016/j.jml.2005.05.001

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. Journal of Experimental Psychology: General, 106(3), 226–254.

Nelson, D. L., McEvoy, C. L., & Dennis, S. (2000). What is free association and what does it measure? Memory & Cognition, 28(6), 887–899.

Nelson, D. L., McEvoy, C. L., & Schreiber, T. A. (2004). The University of South Florida free association, rhyme, and word fragment norms. Behavior Research Methods, Instruments, & Computers: A Journal of the Psychonomic Society, Inc, 36(3), 402–407.

Ngo, T. T., Mitchell, P. B., Martin, N. G., & Miller, S. M. (2011). Psychiatric and genetic studies of binocular rivalry: an endophenotype for bipolar disorder? Acta Neuropsychiatrica, 23(1), 37–42. https://doi.org/10.1111/j.1601-5215.2010.00510.x

Nicodemus, K. K., Elvevåg, B., Foltz, P. W., Rosenstein, M., Diaz-Asper, C., & Weinberger, D. R. (2014). Category fluency, latent semantic analysis and schizophrenia: a candidate gene approach. Cortex; a Journal Devoted to the Study of the Nervous System and Behavior, 55, 182–191. https://doi.org/10.1016/j.cortex.2013.12.004

Nolen-Hoeksema, S., & Morrow, J. (1991). A prospective study of depression and posttraumatic stress symptoms after a natural disaster: The 1989 Loma Prieta earthquake. Journal of Personality and Social Psychology, 61(1), 115–121. https://doi.org/10.1037/0022-3514.61.1.115

Northoff, G., Magioncalda, P., Martino, M., Lee, H.-C., Tseng, Y.-C., & Lane, T. (2017). Too Fast or Too Slow? Time and Neuronal Variability in Bipolar Disorder-A Combined Theoretical and Empirical Investigation. Schizophrenia Bulletin. https://doi.org/10.1093/schbul/sbx050

Pacchiarotti, I., Bond, D. J., Baldessarini, R. J., Nolen, W. A., Grunze, H., Licht, R. W., … Vieta, E. (2013). The International Society for Bipolar Disorders (ISBD) task force report on antidepressant use in bipolar disorders. The American Journal of Psychiatry, 170(11), 1249–1262. https://doi.org/10.1176/appi.ajp.2013.13020185

Pagel, T., Baldessarini, R. J., Franklin, J., & Baethge, C. (2013). Characteristics of patients diagnosed with schizoaffective disorder compared with schizophrenia and bipolar disorder. Bipolar Disorders, 15(3), 229–239. https://doi.org/10.1111/bdi.12057

Pakhomov, S. V. S., Eberly, L., & Knopman, D. (2016). Characterizing cognitive performance in a large longitudinal study of aging with computerized semantic indices of verbal fluency. Neuropsychologia, 89, 42–56. https://doi.org/10.1016/j.neuropsychologia.2016.05.031

Pavlickova, H., Turnbull, O., & Bentall, R. P. (2014). Cognitive vulnerability to bipolar disorder in offspring of parents with bipolar disorder. The British Journal of Clinical Psychology, 53(4), 386–401. https://doi.org/10.1111/bjc.12051

Perugi, G., Angst, J., Azorin, J.-M., Bowden, C. L., Mosolov, S., Reis, J., … BRIDGE-II-Mix Study Group. (2015a). Mixed features in patients with a major depressive episode: the BRIDGE-II-MIX study. The Journal of Clinical Psychiatry, 76(3), e351-358. https://doi.org/10.4088/JCP.14m09092

Perugi, G., Angst, J., Azorin, J.-M., Bowden, C. L., Mosolov, S., Reis, J., … BRIDGE-II-Mix Study Group. (2015b). Mixed features in patients with a major depressive episode: the BRIDGE-II-MIX study. The Journal of Clinical Psychiatry, 76(3), e351-358. https://doi.org/10.4088/JCP.14m09092

Pettigrew, J. D., & Miller, S. M. (1998). A “sticky” interhemispheric switch in bipolar disorder? Proceedings. Biological Sciences, 265(1411), 2141–2148. https://doi.org/10.1098/rspb.1998.0551

Phillips, L. H., Bull, R., Adams, E., & Fraser, L. (2002). Positive mood and executive function: evidence from stroop and fluency tasks. Emotion (Washington, D.C.), 2(1), 12–22.

Piguet, C., Dayer, A., Kosel, M., Desseilles, M., Vuilleumier, P., & Bertschy, G. (2010). Phenomenology of racing and crowded thoughts in mood disorders: a theoretical reappraisal. Journal of Affective Disorders, 121(3), 189–198. https://doi.org/10.1016/j.jad.2009.05.006

Piras, F., & Coull, J. T. (2011). Implicit, Predictive Timing Draws upon the Same Scalar Representation of Time as Explicit Timing. PLoS ONE, 6(3). https://doi.org/10.1371/journal.pone.0018203

Poncelet, P. E., & Giersch, A. (2015). Tracking Visual Events in Time in the Absence of Time Perception: Implicit Processing at the ms Level. PloS One, 10(6), e0127106. https://doi.org/10.1371/journal.pone.0127106

Pöppel, E. (1997). A hierarchical model of temporal perception. Trends in Cognitive Sciences, 1(2), 56–61. https://doi.org/10.1016/S1364-6613(97)01008-5

Pöppel, E. (1997). Temporal windows as a bridge from objective to subjective time. *In* Arstila, V., & Lloyd, D. (Eds.). (2014). Subjective Time: The Philosophy, Psychology, and Neuroscience of Temporality (1st edition). Cambridge, MA: The MIT Press.

Pöppel, E. (2009). Pre-semantically defined temporal windows for cognitive processing. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 364(1525), 1887–1896. https://doi.org/10.1098/rstb.2009.0015

Prieto, M. L., Youngstrom, E. A., Ozerdem, A., Altinbas, K., Quiroz, D., Aydemir, O., … Frye, M. A. (2015). Different patterns of manic/hypomanic symptoms in depression: A pilot modification of the hypomania checklist-32 to assess mixed depression. Journal of Affective Disorders, 172, 355–360. https://doi.org/10.1016/j.jad.2014.09.047

Rammsayer, T. (1992). Effects of benzodiazepine-induced sedation on temporal processing. Human Psychopharmacology: Clinical and Experimental, 7(5), 311–318. https://doi.org/10.1002/hup.470070503

Rammsayer, T. H. (1997). On the relationship between personality and time estimation. Personality and Individual Differences, 23(5), 739–744. https://doi.org/10.1016/S0191-8869(97)00117-7

Rammsayer, T. H., Hennig, J., Haag, A., & Lange, N. (2001). Effects of noradrenergic activity on temporal information processing in humans. The Quarterly Journal of Experimental Psychology Section B, 54(3), 247–258. https://doi.org/10.1080/713932756

Raoux, N., Amieva, H., Le Goff, M., Auriacombe, S., Carcaillon, L., Letenneur, L., & Dartigues, J.-F. (2008). Clustering and switching processes in semantic verbal fluency in the course of Alzheimer's disease subjects: results from the PAQUID longitudinal study. Cortex; a Journal Devoted to the Study of the Nervous System and Behavior, 44(9), 1188–1196. https://doi.org/10.1016/j.cortex.2007.08.019

Raskin, S. A., Sliwinski, M., & Borod, J. C. (1992). Clustering strategies on tasks of verbal fluency in Parkinson's disease. Neuropsychologia, 30(1), 95–99.

Ratcliffe, M. (2012). Varieties of Temporal Experience in Depression. The Journal of Medicine and Philosophy: A Forum for Bioethics and Philosophy of Medicine, 37(2), 114–138. https://doi.org/10.1093/jmp/jhs010

Raucher-Chéné, D., Achim, A. M., Kaladjian, A., & Besche-Richard, C. (2017). Verbal fluency in bipolar disorders: A systematic review and meta-analysis. Journal of Affective Disorders, 207, 359–366. https://doi.org/10.1016/j.jad.2016.09.039

Raymond Lake, C. (2008). Disorders of Thought Are Severe Mood Disorders: the Selective Attention Defect in Mania Challenges the Kraepelinian Dichotomy—A Review. Schizophrenia Bulletin, 34(1), 109–117. https://doi.org/10.1093/schbul/sbm035

Robinson, G., & Ceslis, A. (2014). An unusual presentation of probable dementia: rhyming, associations, and verbal disinhibition. Journal of Neuropsychology, 8(2), 289–294. https://doi.org/10.1111/jnp.12041

Roche, E., Creed, L., MacMahon, D., Brennan, D., & Clarke, M. (2015). The Epidemiology and Associated Phenomenology of Formal Thought Disorder: A Systematic Review. Schizophrenia Bulletin, 41(4), 951–962. https://doi.org/10.1093/schbul/sbu129

Rohrer, D., Salmon, D. P., Wixted, J. T., & Paulsen, J. S. (1999). The Disparate Effects of Alzheimer's Disease and Huntington's Disease on Semantic Memory. Neuropsychology, 13(3), 381–388. https://doi.org/10.1037/0894-4105.13.3.381

Rosen, V. M., & Engle, R. W. (1997). The role of working memory capacity in retrieval. Journal of Experimental Psychology. General, 126(3), 211–227. https://doi.org/10.1037//0096-3445.126.3.211

Ross, T. P., Calhoun, E., Cox, T., Wenner, C., Kono, W., & Pleasant, M. (2007). The reliability and validity of qualitative scores for the Controlled Oral Word Association Test.

Archives of Clinical Neuropsychology: The Official Journal of the National Academy of Neuropsychologists, 22(4), 475–488. https://doi.org/10.1016/j.acn.2007.01.026

Rossell, S. L. (2006). Category fluency performance in patients with schizophrenia and bipolar disorder: The influence of affective categories. Schizophrenia Research, 82(2–3), 135–138. https://doi.org/10.1016/j.schres.2005.10.013

Rossell, S. L., & David, A. S. (2006). Are semantic deficits in schizophrenia due to problems with access or storage? Schizophrenia Research, 82(2–3), 121–134. https://doi.org/10.1016/j.schres.2005.11.001

Roux, S., & Bonis, P. (2011). Comment l'information circule d'un niveau de traitement à l'autre lors de l'accès lexical en production verbale de mots ? Éléments de synthèse. Année psychologique, 111(1), 145–190.

Rozin, P., Kurzer, N., & Cohen, A. B. (2002). Free associations to "food:" the effects of gender, generation, and culture. Journal of Research in Personality, 36(5), 419–441. https://doi.org/10.1016/S0092-6566(02)00002-8

Rybakowski, J. K., Dembinska, D., Kliwicki, S., Akiskal, K. K., & Akiskal, H. H. (2013). TEMPS-A and long-term lithium response: positive correlation with hyperthymic temperament. Journal of Affective Disorders, 145(2), 187–189. https://doi.org/10.1016/j.jad.2012.07.028

Ryu, V., An, S. K., Ha, R. Y., Kim, J. A., Ha, K., & Cho, H.-S. (2012). Differential alteration of automatic semantic processing in treated patients affected by bipolar mania and schizophrenia: An N400 study. Progress in Neuro-Psychopharmacology and Biological Psychiatry, 38(2), 194–200. https://doi.org/10.1016/j.pnpbp.2012.03.009

Sass, L. (2013). Varieties of Self-Experience: A Comparative Phenomenology of Melancholia, Mania, and Schizophrenia, Part I. Journal of Consciousness Studies, 20(7–8), 103–130.

Sass, L., & Pienkos, E. (2015). Beyond Words: Linguistic Experience in Melancholia, Mania, and Schizophrenia. Phenomenology and the Cognitive Sciences, 14(3), 475–495.

Sauzéon, H., Lestage, P., Raboutet, C., N'Kaoua, B., & Claverie, B. (2004). Verbal fluency output in children aged 7-16 as a function of the production criterion: qualitative analysis of clustering, switching processes, and semantic network exploitation. Brain and Language, 89(1), 192–202. https://doi.org/10.1016/S0093-934X(03)00367-5

Sauzéon, H., Raboutet, C., Rodrigues, J., Langevin, S., Schelstraete, M. A., Feyereisen, P., … N'Kaoua, B. (2011). Verbal Knowledge as a Compensation Determinant of Adult Age Differences in Verbal Fluency Tasks over Time. Journal of Adult Development, 18(3), 144–154. https://doi.org/10.1007/s10804-010-9107-6

Savitz, J. B., Price, J. L., & Drevets, W. C. (2014). Neuropathological and neuromorphometric abnormalities in bipolar disorder: view from the medial prefrontal cortical network. Neuroscience and Biobehavioral Reviews, 42, 132–147. https://doi.org/10.1016/j.neubiorev.2014.02.008

Schriefers, H., Meyer, A. S., & Levelt, W. J. M. (1990). Exploring the time course of lexical access in language production: Picture-word interference studies. Journal of Memory and Language, 29(1), 86–102. https://doi.org/10.1016/0749-596X(90)90011-N

Shallice, T. (1982). Specific Impairments of Planning. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 298(1089), 199–209.

Shallice, T., & Burgess, P. (1996). The domain of supervisory processes and temporal organization of behaviour. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 351(1346), 1405-1411-1412. https://doi.org/10.1098/rstb.1996.0124

Shao, Z., Janse, E., Visser, K., & Meyer, A. S. (2014). What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults. Frontiers in Psychology, 5, 772. https://doi.org/10.3389/fpsyg.2014.00772

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. Psychological Review, 127–190.

Shim, I. H., Woo, Y. S., & Bahk, W.-M. (2015). Prevalence rates and clinical implications of bipolar disorder "with mixed features" as defined by DSM-5. Journal of Affective Disorders, 173, 120–125. https://doi.org/10.1016/j.jad.2014.10.061

Silva, R. de A. da, Mograbi, D. C., Bifano, J., Santana, C. M. T., & Cheniaux, E. (2016). Insight in bipolar mania: evaluation of its heterogeneity and correlation with clinical symptoms. Journal of Affective Disorders, 199, 95–98. https://doi.org/10.1016/j.jad.2016.04.019

Simon, J. R. (1969). Reactions toward the source of stimulation. Journal of Experimental Psychology, 81(1), 174–176.

Smith, D. J., Anderson, J., Zammit, S., Meyer, T. D., Pell, J. P., & Mackay, D. (2015). Childhood IQ and risk of bipolar disorder in adulthood: prospective birth cohort study. British Journal of Psychiatry Open, 1(1), 74–80. https://doi.org/10.1192/bjpo.bp.115.000455

Smith, D. J., & Ghaemi, N. (2010). Is underdiagnosis the main pitfall when diagnosing bipolar disorder? Yes. BMJ, 340, c854. https://doi.org/10.1136/bmj.c854

Snowden, J. S., Bathgate, D., Varma, A., Blackshaw, A., Gibbons, Z. C., & Neary, D. (2001). Distinct behavioural profiles in frontotemporal dementia and semantic dementia. Journal of Neurology, Neurosurgery & Psychiatry, 70(3), 323–332. https://doi.org/10.1136/jnnp.70.3.323

Solé, E., Garriga, M., Valentí, M., & Vieta, E. (2017). Mixed features in bipolar disorder. CNS Spectrums, 22(2), 134–140. https://doi.org/10.1017/S1092852916000869

Soraggi-Frez, C., Santos, F. H., Albuquerque, P. B., & Malloy-Diniz, L. F. (2017). Disentangling Working Memory Functioning in Mood States of Bipolar Disorder: A Systematic Review. Frontiers in Psychology, 8. https://doi.org/10.3389/fpsyg.2017.00574

Staddon, J. E. R. (2005). Interval timing: memory, not a clock. Trends in Cognitive Sciences, 9(7), 312–314. https://doi.org/10.1016/j.tics.2005.05.013

Stahl, S. M., Morrissette, D. A., Faedda, G., Fava, M., Goldberg, J. F., Keck, P. E., … McIntyre, R. S. (2017). Guidelines for the recognition and management of mixed depression. CNS Spectrums, 22(2), 203–219. https://doi.org/10.1017/S1092852917000165

Stroop, J. R. (1935). Studies of Interference in Serial Verbal Reactions. Journal of Experimental Psychology, 18(6), 643.

Sung, K., Gordon, B., Vannorsdall, T. D., Ledoux, K., & Schretlen, D. J. (2013). Impaired retrieval of semantic information in bipolar disorder: a clustering analysis of category-fluency productions. Journal of Abnormal Psychology, 122(3), 624–634. https://doi.org/10.1037/a0033068

Swann, A. C., Lijffijt, M., Lane, S. D., Steinberg, J. L., & Moeller, F. G. (2009). Increased trait-like impulsivity and course of illness in bipolar disorder. Bipolar Disorders, 11(3), 280–288. https://doi.org/10.1111/j.1399-5618.2009.00678.x

Swann, A. C. (2017). Mixed features: evolution of the concept, past and current definitions, and future prospects. CNS Spectrums, 22(2), 161–169. https://doi.org/10.1017/S1092852916000882

Swann, A. C., Lafer, B., Perugi, G., Frye, M. A., Bauer, M., Bahk, W.-M., … Suppes, T. (2013). Bipolar mixed states: an international society for bipolar disorders task force report of symptom structure, course of illness, and diagnosis. The American Journal of Psychiatry, 170(1), 31–42. https://doi.org/10.1176/appi.ajp.2012.12030301

Szkodny, L. E., & Newman, M. G. (2017). Delineating Characteristics of Maladaptive Repetitive Thought. Assessment, 1073191117698753. https://doi.org/10.1177/1073191117698753

Takeshima, M., & Oka, T. (2013). Association between the so-called "activation syndrome" and bipolar II disorder, a related disorder, and bipolar suggestive features in outpatients with depression. Journal of Affective Disorders, 151(1), 196–202. https://doi.org/10.1016/j.jad.2013.05.077

Takeshima, M., & Oka, T. (2015). DSM-5-defined "mixed features" and Benazzi's mixed depression: which is practically useful to discriminate bipolar disorder from unipolar depression in patients with depression? Psychiatry and Clinical Neurosciences, 69(2), 109–116. https://doi.org/10.1111/pcn.12213

Tanaka, R., & Yotsumoto, Y. (2017). Passage of Time Judgments Is Relative to Temporal Expectation. Frontiers in Psychology, 8, 187. https://doi.org/10.3389/fpsyg.2017.00187

Terhune, D. B., Croucher, M., Marcusson-Clavertz, D., & Macdonald, J. S. P. (2017). Time contracts and temporal precision declines when the mind wanders. Journal of Experimental Psychology. Human Perception and Performance, 43(11), 1864–1871. https://doi.org/10.1037/xhp0000461

Thompson-Schill, S. L., Swick, D., Farah, M. J., D'Esposito, M., Kan, I. P., & Knight, R. T. (1998). Verb generation in patients with focal frontal lesions: A neuropsychological test of neuroimaging findings. Proceedings of the National Academy of Sciences, 95(26), 15855–15860. https://doi.org/10.1073/pnas.95.26.15855

Thönes, S., & Oberfeld, D. (2015). Time perception in depression: a meta-analysis. Journal of Affective Disorders, 175, 359–372. https://doi.org/10.1016/j.jad.2014.12.057

Thurstone, L. L. (1941). Factorial studies of intellengence. Psychometric Monograph, 2. Retrieved from http://ci.nii.ac.jp/naid/10011512475/

Torres, I. J., Boudreau, V. G., & Yatham, L. N. (2007). Neuropsychological functioning in euthymic bipolar disorder: a meta-analysis. Acta Psychiatrica Scandinavica, 116, 17–26. https://doi.org/10.1111/j.1600-0447.2007.01055.x

Traxler, M., & Gernsbacher, M. A. (Eds.). (2006). Handbook of Psycholinguistics (2 edition). Boston: Academic Press.

Tremblay, C., Blais, J., Lachance, J., Ptito, A., Monchi, O., & Monetta, L. (2010). Évocation lexicale libre chez les patients atteints de la maladie de Parkinson : une analyse quantitative et qualitative des mots produits. Retrieved from http://www.cairn.info/article.php?ID_ARTICLE=RNE_024_0273

Tröster, A. I., Fields, J. A., Testa, J. A., Paul, R. H., Blanco, C. R., Hames, K. A., … Beatty, W. W. (1998). Cortical and subcortical influences on clustering and switching in the performance of verbal fluency tasks. Neuropsychologia, 36(4), 295–304. https://doi.org/10.1016/S0028-3932(97)00153-X

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: evidence from younger and older healthy adults. Neuropsychology, 11(1), 138–146.

Troyer, A. K., Moscovitch, M., Winocur, G., Leach, L., & Freedman, M. (1998). Clustering and switching on verbal fluency tests in Alzheimer's and Parkinson's disease. Journal of the International Neuropsychological Society: JINS, 4(2), 137–143.

Tulving, E. (1986). Episodic and Semantic Memory: Where Should We Go From Here? Behavioral and Brain Sciences, 9(3), 573.

Tysk, L. (1984). Time perception and affective disorders. Perceptual and Motor Skills, 58(2), 455–464. https://doi.org/10.2466/pms.1984.58.2.455

Van der Gucht, E., Morriss, R., Lancaster, G., Kinderman, P., & Bentall, R. P. (2009). Psychological processes in bipolar affective disorder: negative cognitive style and reward processing. The British Journal of Psychiatry: The Journal of Mental Science, 194(2), 146–151. https://doi.org/10.1192/bjp.bp.107.047894

van Wassenhove, V. (2009). Minding time in an amodal representational space. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 364(1525), 1815–1830. https://doi.org/10.1098/rstb.2009.0023

Vellante, M., Zucca, G., Preti, A., Sisti, D., Rocchi, M. B. L., Akiskal, K. K., & Akiskal, H. S. (2011). Creativity and affective temperaments in non-clinical professional artists: An empirical psychometric investigation. Journal of Affective Disorders, 135(1–3), 28–36. https://doi.org/10.1016/j.jad.2011.06.062

Vierck, E., Porter, R. J., Luty, S. E., Moor, S., Crowe, M. T., Carter, J. D., … Joyce, P. R. (2013). Further evidence for slow binocular rivalry rate as a trait marker for bipolar disorder. The Australian and New Zealand Journal of Psychiatry, 47(4), 371–379. https://doi.org/10.1177/0004867412474105

Vöhringer, P. A., & Perlis, R. H. (2016). Discriminating Between Bipolar Disorder and Major Depressive Disorder. Psychiatric Clinics of North America, 39(1), 1–10. https://doi.org/10.1016/j.psc.2015.10.001

Wackermann, J., & Ehm, W. (2006). The dual klepsydra model of internal time representation and time reproduction. Journal of Theoretical Biology, 239(4), 482–493. https://doi.org/10.1016/j.jtbi.2005.08.024

Watt, J. D. (1991). Effect of Boredom Proneness on Time Perception. Psychological Reports, 69(1), 323–327. https://doi.org/10.2466/pr0.1991.69.1.323

Wearden, J. H. (2015). Passage of time judgements. Consciousness and Cognition, 38, 165–171. https://doi.org/10.1016/j.concog.2015.06.005

Wearden, J.H., O'Donoghue, A., Ogden, R., Montgomery, C. (2014). Subjective duration in the laboratory and the word outside. *In* Arstila, V., & Lloyd, D. (Eds.). (2014). Subjective Time: The Philosophy, Psychology, and Neuroscience of Temporality (1st edition). Cambridge, MA: The MIT Press.

Wearden, J. H., & Lejeune, H. (2008). Scalar properties in human timing: conformity and violations. Quarterly Journal of Experimental Psychology (2006), 61(4), 569–587.

Weibel, S., & Bertschy, G. (2016). [Mixed depression and DSM-5: A critical review]. L'Encephale, 42(1), 90–98. https://doi.org/10.1016/j.encep.2015.08.006

Weilnhammer, V. A., Ludwig, K., Hesselmann, G., & Sterzer, P. (2013). Frontoparietal cortex mediates perceptual transitions in bistable perception. The Journal of Neuroscience: The Official Journal of the Society for Neuroscience, 33(40), 16009–16015. https://doi.org/10.1523/JNEUROSCI.1418-13.2013

Whitmer, A. J., & Gotlib, I. H. (2012). Switching and backward inhibition in major depressive disorder: the role of rumination. Journal of Abnormal Psychology, 121(3), 570–578. https://doi.org/10.1037/a0027474

WHO (1992). The ICD-10 Classification of Mental and Behavioural Disorders: Clinical Descriptions and Diagnostic Guidelines. World Health Organization.

Wiener, M., Turkeltaub, P., & Coslett, H. B. (2010). The image of time: a voxel-wise meta-analysis. NeuroImage, 49(2), 1728–1740. https://doi.org/10.1016/j.neuroimage.2009.09.064

Windmann, S., Wehrmann, M., Calabrese, P., & Güntürkün, O. (2006). Role of the prefrontal cortex in attentional control over bistable vision. J. Cogn. Neurosci, 456–471.

Wittgenstein, L. (1982). Wittgenstein's Lectures, Cambridge, 1930-1932: From the notes of John King and Desmond Lee (Phoenix ed edition). Chicago: University of Chicago Press.

Wittmann, M. (2011). Moments in Time. Frontiers in Integrative Neuroscience, 5. https://doi.org/10.3389/fnint.2011.00066

Wittmann, M. (2013). The inner sense of time: how the brain creates a representation of duration. Nature Reviews Neuroscience, 14(3), 217–223. https://doi.org/10.1038/nrn3452

Wittmann, M. (2015). Modulations of the experience of self and time. Consciousness and Cognition, 38, 172–181. https://doi.org/10.1016/j.concog.2015.06.008

Wittmann, M., & Paulus, M. P. (2008). Decision making, impulsivity and time perception. Trends in Cognitive Sciences, 12(1), 7–12. https://doi.org/10.1016/j.tics.2007.10.004

Wittmann, M., Peter, J., Gutina, O., Otten, S., Kohls, N., & Meissner, K. (2014). Individual differences in self-attributed mindfulness levels are related to the experience of time and cognitive self-control. Personality and Individual Differences, 64, 41–45. https://doi.org/10.1016/j.paid.2014.02.011

Wixted, J. T., & Rohrer, D. (1994). Analyzing the dynamics of free recall: An integrative review of the empirical literature. Psychonomic Bulletin & Review, 1(1), 89–106. https://doi.org/10.3758/BF03200763

Woods, D. L., Wyma, J. M., Herron, T. J., & Yund, E. W. (2016). Computerized Analysis of Verbal Fluency: Normative Data and the Effects of Repeated Testing, Simulated Malingering, and Traumatic Brain Injury. PloS One, 11(12), e0166439. https://doi.org/10.1371/journal.pone.0166439

Woolf, V. (2003). A Writer's Diary (1 edition). Mariner Books.

Wykes, T., & Leff, J. (1982). Disordered speech: differences between manics and schizophrenics. Brain and Language, 15(1), 117–124.

Yalincetin, B., Bora, E., Binbay, T., Ulas, H., Akdede, B. B., & Alptekin, K. (2017). Formal thought disorder in schizophrenia and bipolar disorder: A systematic review and meta-analysis. Schizophrenia Research, 185, 2–8. https://doi.org/10.1016/j.schres.2016.12.015

Young, R. C., Biggs, J. T., Ziegler, V. E., & Meyer, D. A. (1978). A rating scale for mania: reliability, validity and sensitivity. The British Journal of Psychiatry: The Journal of Mental Science, 133, 429–435.

Zakay, D. (2014). Psychological time as information: the case of boredom. Frontiers in Psychology, 5, 917. https://doi.org/10.3389/fpsyg.2014.00917

Zakay, D., & Block, R. A. (2004). Prospective and retrospective duration judgments: an executive-control perspective. Acta Neurobiologiae Experimentalis, 64(3), 319–328.

Zeschel, E., Correll, C. U., Haussleiter, I. S., Krüger-Özgürdal, S., Leopold, K., Pfennig, A., … Juckel, G. (2013). The bipolar disorder prodrome revisited: Is there a symptomatic pattern? Journal of Affective Disorders, 151(2), 551–560. https://doi.org/10.1016/j.jad.2013.06.043

Zetsche, U., D'Avanzato, C., & Joormann, J. (2012). Depression and rumination: relation to components of inhibition. Cognition & Emotion, 26(4), 758–767. https://doi.org/10.1080/02699931.2011.613919

Zimbardo, P. G., & Boyd, J. N. (2015). Putting Time in Perspective: A Valid, Reliable Individual-Differences Metric. In Time Perspective Theory; Review, Research and Application (pp. 17–55). Springer, Cham. https://doi.org/10.1007/978-3-319-07368-2_2

Zimmerman, M. (2017). Measures of the DSM-5 mixed-features specifier of major depressive disorder. CNS Spectrums, 22(2), 196–202. https://doi.org/10.1017/S1092852916000857

Les mécanismes psychopathologiques et cognitifs de la tachypsychie

RESUME DETAILLE DE LA THESE EN FRANÇAIS

L'objet de cette thèse est de préciser la nature psychopathologique et neuropsychologique d'un phénomène psychopathologique encore peu étudié – la tachypsychie. Habituellement décrite dans les états maniaques chez des patients présentant un trouble bipolaire, la tachypsychie est définie comme une accélération de la pensée ou « *racing thoughts* », car les idées se succèdent rapidement, contrairement au ralentissement psychomoteur et la rumination caractéristiques de la dépression (Piguet et al., 2010). Toutefois, la tachypsychie peut se trouver également associée à des états dépressifs, dans le cadre de tableaux mixtes combinant des symptômes maniaques et dépressifs concomitants (APA, 2013). Tandis que jusqu'au DSM-IV-TR (APA, 2000) la tachypsychie figurait uniquement parmi les symptômes des états maniques ou maniaques mixtes (critères concomitants d'un épisode maniaque et dépressif), ce n'est que depuis l'avènement du DSM-5 (APA, 2013) qu'elle peut être l'un des symptômes purement maniaques (non *overlapping*) pouvant être associé à des états dépressifs « avec caractéristiques mixtes ». Il s'agirait alors d'un symptôme maniaque clé, qui pourrait permettre de distinguer des états dépressifs typiques de la dépression dite « mixte », ; cette dernière nécessite une approche thérapeutique différentielle et se caractérise notamment par une majoration du risque suicidaire (e.g., Benazzi, 2003a ; Benazzi, 2007b ; Perugi et al., 2015). De plus, en tant que symptôme clé, elle pourrait favoriser le diagnostic d'épisodes dépressifs s'inscrivant dans le cadre d'un trouble bipolaire et, par conséquent, participer à la réduction du délai du diagnostic de cette pathologie chronique (e.g., Zeschel et al., 2013).

Contrairement à l'accélération et l'augmentation de la fluidité des idées associée à la tachypsychie « *racing* » ou linéaire, la phénoménologie de la tachypsychie associée à la dépression serait alors différente : les patients décrivent une impression de tête pleine de pensées qui se bousculent, ce qui a été décrit par le terme « *crowded thoughts* » (Piguet et al., 2010). Or, bien que la phénoménologie suggère la nature composite et polymorphe de la tachypsychie, seul le terme unitaire 'racing thoughts' est employé par le DSM-V (APA, 2013) pour la désigner, que la tachypsychie soit associée à la manie ou à la dépression. Au-delà de son association avec ces états d'humeur pathologiques, la tachypsychie a également été décrite chez des sujets sains présentant des symptômes sous-syndromiques du trouble bipolaire (Dodd et al., 2010). Elle serait alors l'un des facteurs prédictifs de son développement ultérieur (Correll et al., 2014). Dans notre travail, nous avons proposé un nouveau modèle psychopathologique de la tachypsychie (cf. Figure 3), basée sur la littérature psychiatrique du 19ème et du début du 20ème siècle (e.g., Kraepelin, 1899), la littérature phénoménologique (e.g., Binswanger, 1933), les récits des patients (e.g., Jamison, 1997), ainsi que les contributions scientifiques plus récentes (Braden & Ho, 1981 ; Koukopoulos & Koukopoulos 1999 ; Benazzi, 2003a ; Goodwin & Jamison, 2007 ; Piguet et al., 2010). Une revue exhaustive de cette littérature est disponible dans le chapitre 1.3 de cette thèse. Au-delà de la littérature phénoménologique psychopathologique autour de la tachypsychie, nous avons également intégré à notre travail une revue de la littérature phénoménologique autour de l'expérience subjective temporelle et langagière des patients avec trouble bipolaire (e.g., Minkowski, 1933 ; Binswanger, 1933 ; Bowden, 2013 ; Sass & Pinkos, 2015) afin de pouvoir présenter, dans un deuxième temps, les modèles cognitifs et les résultats expérimentaux qui nous ont permis de développer nos paradigmes expérimentaux d'évaluation de la tachypsychie – paradigmes temporels et langagiers, car ce phénomène touche les propriétés temporelles de la pensée et se manifeste essentiellement dans le langage des patients via le symptôme de la fuite des idées.

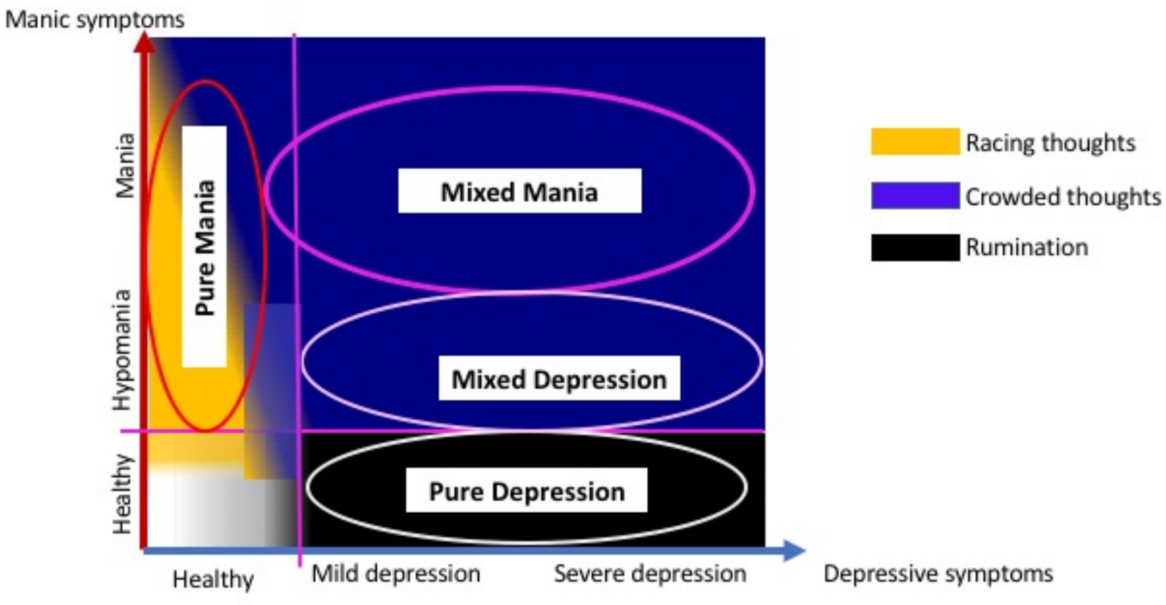

Figure 3 : Notre modèle psychopathologique de la tachypsychie, intégrant le continuum allant du normal au pathologique

Sur le plan psychopathologique, une meilleure caractérisation de la tachypsychie pourrait avoir deux intérêts cliniques majeurs : (i) favoriser l'identification des états dépressifs mixtes chez les patients avec trouble de l'humeur et (ii) favoriser l'identification et le suivi de sujets sains pouvant être à risque de développement d'un trouble bipolaire. Sur le plan neuropsychologique, une meilleure caractérisation de ce phénomène pourra contribuer à l'élucidation des mécanismes physiopathologiques jouant un rôle dans son émergence.

Le premier objectif, psychopathologique, de cette thèse était d'évaluer les caractéristiques de la tachypsychie en fonction des états d'humeur – exaltée ou déprimée – chez des patients avec trouble bipolaire, mais également chez des sujets sains (cf. Figure 3 pour notre modèle de la tachypsychie). Pour ce faire, nous avons élaboré un auto-questionnaire, le *Racing and Crowded Thoughts Questionnaire* (RCTQ ; voir Figure 9) et nous avons évalué ses propriétés psychométriques, à savoir sa structure factorielle, sa fiabilité et sa validité convergente et discriminante.

Item No	RCTQ Question
1	J'ai trop de pensées en même temps.
2	Mes pensées vont à 200 à l'heure.
3	Mes idées se mélangent et s'embrouillent.
4	Les pensées s'accumulent dans ma tête.
5	Mes pensées changent trop souvent ou trop vite de sujet.
6	Quand je parle je suis moins gêné(e) par le flot de pensées dans ma tête.
7	Mes idées s'emballent toutes seules.
8	J'ai une succession de pensées qui filent l'une derrière l'autre avec une incroyable facilité.
9	Une multitude de pensées me viennent à l'esprit en même temps.
10	L'intensité de mon activité mentale est insupportable.
11	Mon esprit saute sans arrêt d'une pensée à une autre.
12	Chaque objet, chaque détail autour de moi fait surgir une nouvelle pensée.
13	Mon cerveau n'arrive pas à gérer toutes les pensées qui arrivent en même temps.
14	Je suis gêné(e) dans ma vie quotidienne par mes pensées nombreuses ou rapides.
15	Je n'arrive pas à stopper le mécanisme qui produit des flots de pensées dans ma tête.
16	A chaque instant de nombreuses pensées vont et viennent dans ma tête.
17	Mes pensées s'emballent dès qu'une activité capte moins mon attention.
18	Mes pensées débordent : ça fait comme un trop-plein.
19	Mon cerveau va plus vite que mon corps.
20	A tout instant de nouvelles pensées, semblant venir de nulle part, jaillissent dans mon esprit.
21	Tout ce que je vois ou entends déclenche immédiatement une nouvelle pensée.
22	Je n'ai pas le temps de saisir une pensée qu'une autre arrive déjà.
23	Rester concentré au milieu de ce trop-plein de pensées est une lutte permanente.
24	Les pensées s'empilent les unes sur les autres dans ma tête.
25	Une pensée en induit instantanément une autre, qui en induit une autre, puis une autre, puis une autre…
26	Mes pensées vont dans tous les sens.
27	J'ai de la peine à m'exprimer en raison de l'abondance ou de la vitesse de mes pensées.
28	Mes pensées vont à toute vitesse.
29	Mon hyperactivité mentale m'épuise.
30	Je n'arrive pas à ralentir ou réduire le flot de mes pensées.
31	Mes pensées m'amènent sans arrêt très loin de mon point de départ.
32	Quand mes pensées s'emballent, je me déconnecte de ce qui se passe autour de moi
33	Mes idées se bousculent dans ma tête.
34	C'est le défilé permanent des pensées :l'une chasse l'autre, sans fin

Figure 9 : version Française du RCTQ

Dans un premier article (Weiner et al., 2018 ; article 1, p. 134) auprès de 197 sujets sains, nos résultats ont montré que le RCTQ était un instrument tri-factoriel, avec des facteurs que nous avons nommés : (i) suractivation mentale, incluant des items faisant référence à l'accélération et au surnombre des pensées (par exemple, « mes pensées vont à 200 à l'heure »), (ii) poids de la suractivation mentale, composé d'items liés à l'impact fonctionnel de la tachypsychie, et (iii) surexcitabilité mentale, regroupant des items se référant à la distractibilité caractéristique de la tachypsychie. De plus, le questionnaire présentait de bonnes qualités psychométriques chez les sujets sains, à savoir une excellente consistance interne (alpha de Cronbach) pour les trois sous-échelles (> à .90) ; une bonne validité convergente, avec les résultats aux trois sous-facteurs particulièrement associés aux traits cyclothymiques, évalués via l'autoquestionnaire TEMPS-A (Akiskal et al., 2005) et des corrélations sélectives entre les symptômes sous-syndromiques dépressifs et maniaques et les résultats aux trois- facteurs ; et une bonne validité divergente, étant donné que les scores à un autoquestionnaire évaluant les ruminations dépressives n'étaient pas corrélés aux scores obtenus aux trois facteurs du RCTQ. De façon générale, nous avons montré que le RCTQ était donc particulièrement sensible à des symptômes minimes d'instabilité affective présents chez les sujets sains.

Dans un deuxième article (en préparation ; article 2, p. 161), nous avons évalué les propriétés psychométriques du RCTQ auprès de patients avec trouble bipolaire. Au total, 341 sujets (221 patients et 120 sujets sains) ont été inclus dans quatre centres francophones en France et en Belgique, ainsi que dans un centre en Italie. Dans cette étude, nous avons tout d'abord scindé l'échantillon (n = 341) en deux, puis nous avons réalisé une analyse factorielle exploratoire dans l'un des deux ; celle-ci était évocatrice d'une solution à facteur unique. Néanmoins, le modèle à un seul facteur a dégagé un fit modeste lorsque nous avons réalisé l'analyse factorielle confirmatoire auprès du deuxième échantillon. Nous avons comparé alors les indices de fit du modèle à un facteur à ceux des deux modèles a priori – le modèle à trois facteurs obtenu chez les sujets sains (article 1) et modèle bi-factoriel, basé sur le modèle phénoménologique supposant l'existence de deux types de tachypsychie, *racing* et *crowded*. Comparé aux modèles uni et bi-factoriel, le modèle tri-factoriel a obtenu les meilleurs indices de fit, suggérant que la tachypsychie est un phénomène multi-dimensionnel chez les patients également. A l'instar de ce qui a été observé chez les sujets sains (article 1), la consistance interne (alpha de Cronbach) des trois sous-échelles étaient excellents (>. 90). De façon importante, lorsque nous avons comparé les résultats aux RCTQ entre les groupes de patients (en fonction des états cliniques – manie, manie mixte, dépression mixte, dépression et euthymie) et les sujets sains, les résultats aux sous-échelles du RCTQ étaient similaires entre les groupes de patients en état aigu (états mixtes, manie et dépression), mais supérieurs à ceux obtenus par les patients en état euthymique et les sujets contrôles sains. Néanmoins, lorsque nous avons scindé le groupe « dépression » en deux sous-groupes – le premier sans aucun symptôme manique (score = 0 à l'échelle permettant l'évaluation des symptômes maniaques, le YMRS) et le second avec très peu de symptômes maniaques à la même échelle (YMRS = 1 ou 2) – nous avons observé que le score total obtenu au RCTQ était significativement augmenté dans les groupes mixtes, mais également dans le groupe « dépression » avec YMRS = 1 ou 2, comparés au groupe dépressif pur (YMRS = 0). En ce qui concerne les trois sous-échelles du RCTQ, les scores à la sous-échelle « suractivation mentale » et « surexcitabilité mentale » étaient augmentés dans les groupes maniaque, mixtes, ainsi que dépression avec YMRS à 1 ou 2, comparés au groupe dépressif pur (YMRS = 0) et euthymique. En revanche, le score à la sous-échelle « poids de la suractivation mentale » était similaire entre les groupes maniaque et dépressif, alors qu'ils étaient augmentés dans les groupes mixtes comparés à la dépression pure (YMRS = 0). Les scores obtenus par les patients euthymiques étaient significativement supérieurs à ceux des sujets contrôles aux trois sous-échelles du RCTQ. Enfin, nous avons investigué les liens entre différentes dimensions cliniques – à savoir, l'anxiété, les ruminations, les inquiétudes, la dépression et la manie – et les résultats aux sous-échelles du RCTQ. A travers des analyses de régression multiple, nous avons trouvé que le score à l'échelle d'anxiété étaient des prédicteurs des résultats aux trois sous-échelles du RCTQ. Les scores à l'échelle de manie étaient quant à eux des prédicteurs significatifs des sous-échelles « suractivation mentale » et « surexcitabilité mentale ». Le score au questionnaire évaluant les inquiétude était un prédicteur des sous-échelles « surexcitabilité mentale » et « poids de la suractivation mentale », alors que le score à l'échelle de rumination n'était un prédicteur significatif que de l'échelle « poids de la suractivation mentale ». De façon générale, nous avons donc répliqué certains résultats obtenus dans l'article auprès des sujets sains (article 1), à savoir la structure tri-factorielle et l'excellente consistance interne. Chez les patients, nous avons montré ici que le RCTQ était particulièrement sensible à la présence de symptômes maniaques mineurs (YMRS à 1 ou 2) chez des patients déprimés. Ceci suggère que l'instrument pourra être particulièrement utile dans la discrimination entre dépression pure et dépression avec des symptômes maniaques sous-syndromiques mineurs (inférieurs au seuil proposé par le DSM-5 pour la dépression avec caractéristiques mixtes).

Contrairement à notre modèle initial (cf. figure 3), au lieu de deux dimensions – i.e., racing et crowded --, nos résultats suggèrent que le phénomène tachypsychique comprend trois mécanismes psychopathologiques : le premier, la suractivation mentale, peut être lié à ce que Braden & Ho (1981) ont dénommé 'pression idéomotrice' et Keizer et al. (2014) ont appelé 'la pression de la pensée' dans leur étude qualitative , se référant à l'exacerbation de la vélocité et la quantité de pensées ; le deuxième, le poids de la suractivation mentale, semble se référer aux 'crowded thoughts' (Piguet et al., 2010), compte tenu de ses liens avec l'impact fonctionnel et la dysphorie (Kraepelin, 1899; Braden & Ho, 1981; Benazzi, 2007); le troisième, la surexcitabilité mentale, est associée à l'émergence involontaire et la nature distractible de la tachypsychie, une caractéristique qui avait déjà été soulignée dans deux des six thèmes– i.e., 'traitement de l'information' et 'début et contexte' – observés dans les récits qualitatifs des patients dans l'étude de Genève (Keizer et al., 2014). Comme cela a été décrit par Kraepelin (1899) et Binswanger (1933), et, plus récemment, par des études empiriques réalisées par Braden & Ho (1981) et Benazzi (2009), la distractibilité semble être une mécanisme clé impliqué dans la tachypsychie.

De façon importante, cette troisième dimension associée à la tachypsychie suggère que nous devrions aller au-delà de la distinction *racing vs. crowded*, qui est liée à la distinction catégorielle entre manie et épisodes mixtes, pour considérer la tachypsychie de manière processuelle. A titre d'exemple, dans un nombre croissant d'études, à la place d'une distinction catégorielle de la rumination et des inquiétudes, associées à l'humeur dépressive et anxieuse respectivement, ces styles de pensées sont étudiés à partir de leurs dimensions catégorielles, à savoir le manque de contrôle, l'anticipation du futur, l'attente du pire, la recherche de causes et de sens, et le focus dans le passé (e.g., Szkodny & Newman, 2017). Dans notre travail, nous avons fait un premier pas dans l'identification des dimensions impliqués dans la tachypsychie. Les études futures seront cruciales pour déterminer si et comment les trois facteurs trouvés dans nos études ciblent des dimensions pertinentes dans le phénomène tachypsychique. Dans ce contexte, de la même manière que les études psychopathologiques peuvent nourrir les investigations neuropsychologiques, tel pourrait également être le cas dans l'interaction dans le sens inverse : les études ciblant les processus cognitifs impliqués dans la tachypsychie vont sûrement contribuer à la délimitation et à la compréhension des dimensions psychopathologiques pertinentes. Nous aborderons désormais quelques unes des contributions de nos études neuropsychologiques à la compréhension de la tachypsychie.

Le deuxième objectif de cette thèse était de préciser les mécanismes neuropsychologiques impliqués dans la tachypsychie. Cette exploration neuropsychologique avait pour but d'objectiver, de manière expérimentale, l'accélération de la pensée décrite par les patients, en se focalisant sur les aspects temporels et linguistiques de ce phénomène. Les aspects temporels peuvent être impliqué dans la tachypsychie à plusieurs titres, à savoir (i) la vitesse de l'enchaînement des événements et l'attention qui y est portée influencent la durée perçue (le sentiment que le temps passe vite ou lentement ainsi que l'estimation des durées) et (ii) la structure temporelle du flux de conscience, supposée constituée d'unités de temps (les 'maintenant'), qui représenteraient chacune un événement, par exemple, les mots dans une phrase. D'un point de vue à la fois linguistique et temporel, la tachypsychie est par ailleurs manifeste dans les particularités du langage maniaque, à la fois prosodiques – e.g., rapidité du débit - et lexico-sémantiques – e.g., verbosité, allitérations, jeux de mots et digressions. Nous allons tout d'abord présenter ici deux articles (articles 3 et 4) qui ont investigué la tachypsychie d'un point de vue temporel. En effet, étant donné que la tachypsychie concerne les propriétés temporelles de la pensée, elle pourrait être impliquée dans l'expérience subjective du temps notamment dans les phases maniaques, où les patients rapportent un sentiment d'accélération du passage du temps (e.g., Bschor et al., 2004). Ensuite, nous présenterons un article qui allie l'approche temporelle et linguistique de la tachypsychie, via des tâches de fluence verbale (article 5). L'analyse présentée dans cet article s'est focalisée sur des aspects lexico-sémantiques de la production verbale des patients. Les analyses prosodiques et temporelles, dont notamment le débit, sont en cours (article 5 appendix).

Dans l'article 3 (Weiner et al., 2016 ; p. 182), nous avons évalué l'expérience temporelle des sujets sains et, plus spécifiquement, l'impact de facteurs endogènes et contextuels sur l'estimation de durées et le sentiment de passage du temps d'un groupe de 117 individus sains. Les facteurs endogènes incluaient des traits de personnalité (i.e., *mindfulness*, impulsivité et tendance à la rumination), l'humeur actuelle, ainsi que la tachypsychie. Les facteurs contextuels ont été évalués via la quantité d'informations traitées au cours de la durée évaluée. Nos résultats ont montré un effet de la quantité d'informations -- faible (stimuli présentés toutes les 16 s) ou élevée (4 s) – sur l'estimation des durées (i.e., sous-estimation relative) et le sentiment du passage du temps (i.e., ralentissement). Plus les sujets avaient des traits de personnalité élevés de *mindfulness*, plus ils surestimaient les durées et jugeaient que le temps avait passé rapidement. Le pattern de résultats inverse a été trouvé pour la tendance à la rumination – plus les sujets avaient tendance à ruminer, plus ils sous-estimaient les durées et jugeaient que le temps avait passé lentement. Nos résultats ont été interprétés sur la base des modèles cognitifs, qui suggèrent l'implication de l'*arousal*, de l'attention et des fonctions exécutives dans la perception des durées (e.g., Zakay & Block, 2004). Nos résultats ont par ailleurs permis de montrer une dissociation entre deux types de jugements temporels – l'estimation des durées et le sentiment du passage du temps --, suggérant qu'il s'agit de paramètres temporels distincts. Plusieurs mécanismes cognitifs sont impliqués dans les jugements temporels. Par exemple, dans l'estimation de durées, ils comprennent des mécanismes liées à l'horloge interne (qui est modulée par l'arousal), la mémoire de travail, l'attention et les fonctions exécutives (Gibbon, Church, & Meck, 1984; Droit-Volet & Meck, 2007; Zakay & Block, 2004 ; voir figure 11). Il est important de souligner que les jugements du passage du temps sont modulés par des mécanismes similaires (e.g., Droit-Volet et al., 2017), mais pas nécessairement de la même manière, étant donné que nous pouvons juger que le temps a passé lentement et estimer correctement les durées correspondant à l'intervalle en question (Watt, 1991; Thönes & Oberfeld, 2015; Wearden, 2015). Notre étude est l'une des seules à avoir évalué la contribution de facteurs endogènes et contextuels à propos de l'expérience temporelle.

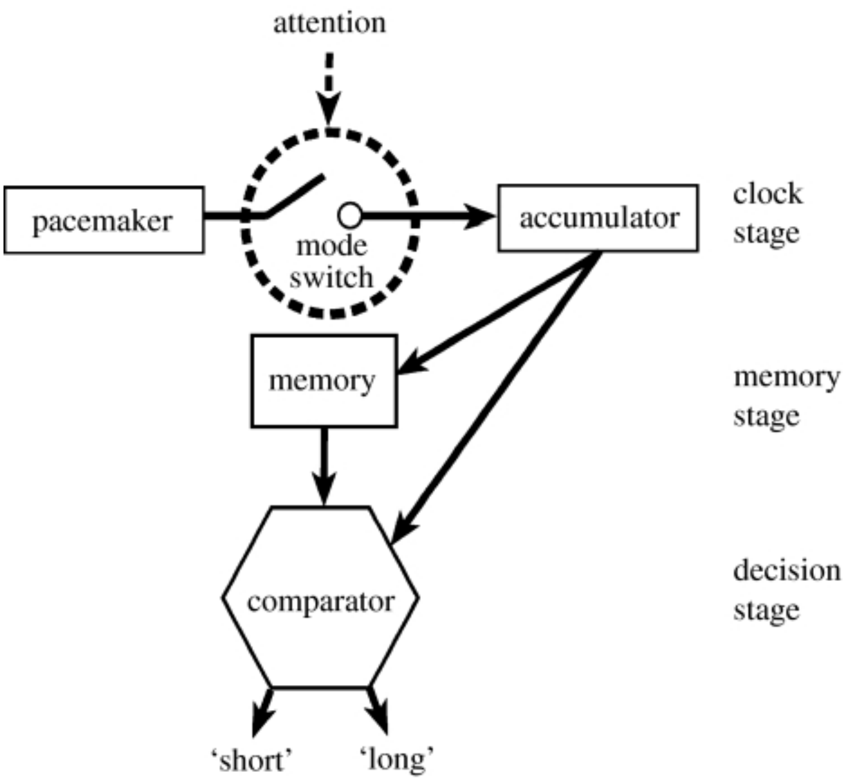

Figure 11: The temporal model outlined by Gibbons et al. (1984). Source: Droit-Volet & Gil (2009)

Pour évaluer la contribution de la tachypsychie à ces résultats, dans les analyses complémentaires (article 3 *appendix*, p. 194) que nous avons réalisées, nous avons scindé notre échantillon de sujets sains (n = 117) en trois, sur la base de la distribution des résultats au RCTQ : (i) des résultats totaux faibles < 20, (ii) des résultats totaux modérés, allant de 20 à 40, et (iii) des résultats totaux élevés > 40. Nous avons comparé les résultats aux tâches de perception de durées citées précédemment chez les deux groupes avec des résultats extrêmes au RCTQ, à savoir le groupe RCTQ faible et élevé, n = 32 et n = 47, respectivement. Nous avons trouvé que l'effet de l'interaction SOA x Intervalle x Groupe tendait à être significatif ($F(1, 83) = 3.79$, $p = .055$) sur les jugements du passage du temps. Autrement dit, les sujets avec des scores élevés au RCTQ ont rapporté une relative accélération du passage du temps comparés à ceux présentant des scores RCTQ faibles (pour les durées courtes avec une quantité d'informations faibles, ou 32s et SOA de 16s).

Dans un quatrième article (en préparation, p. 198), nous avons comparé l'expérience temporelle à deux conditions des tâches présentées précédemment (estimation de durées et jugement du passage du temps) auprès de patients avec trouble bipolaire en phase aiguë ou stabilisée et d'un groupe de sujets sains. Nous avons trouvé que les patients en phase dépressive sous-estimaient les durées comparativement aux sujets sains et aux patients en phase maniaque. Ces résultats sont en accord avec d'autres obtenus chez les patients présentant un trouble bipolaire en phase dépressive (e.g., Bschor et al., 2004), mais pas chez les patients présentant une dépression unipolaire qui, selon une méta-analyse récente de Thönes & Oberfeld (2015), ne présenteraient pas de distorsions temporelles comparés aux sujets sains. De façon intéressante, chez les patients déprimés, ces performances à la tâche d'estimation de durées étaient corrélées aux résultats à une tâche de mémoire de travail : plus les patients sous-estimaient les durées, plus les troubles de la mémoire de travail étaient sévères. Nos résultats suggèrent donc que les distorsions temporelles liées à la dépression sont dues, là aussi, à des difficultés d'ordre attentionnel : les patients encodent une durée plus courte, du fait que leur attention est distraite de la tâche en cours (Derhune et al., 2017). En revanche, nous n'avons pas trouvé de corrélations entre les ruminations ou la tachypsychie et les performances aux tâches temporelles chez les patients. En revanche, chez les sujets sains, plus les sujets étaient tachypsychiques, évalué via le RCTQ, plus ils jugeaient que le temps avait passé rapidement au cours de l'intervalle. Ces résultats sont cohérents avec ceux obtenus chez un autre échantillon de sujets sains (article 3 *appendix*) et suggèrent que, dans le fonctionnement sain uniquement, la tachypsychie peut être associée à une accélération du sentiment du temps qui passe.

Enfin, dans un cinquième article (en préparation, p. 214), nous avons comparé la production verbale de patients avec trouble bipolaire et celle de sujets contrôles à des tâches de fluence verbale, en utilisant une méthode qualitative qui permet d'évaluer les processus impliqués sémantiques et exécutifs impliqués (e.g., Troyer et al., 1997). Sur le plan linguistique, la tachypsychie se caractérise notamment par une accélération du débit, un élargissement des associations sémantiques ainsi qu'une augmentation des associations basées sur des critères phonologiques (ou « clanging » ; Sass & Pinkos, 2015). Alors que ces anomalies de la pensée ont été bien décrites par des phénoménologues depuis la fin du 19ème, peu d'études se sont intéressées à ses corrélats neuropsychologiques (Binswanger, 1933). Dans l'étude présente, nous avons utilisé trois tâches de fluence verbale classiques (libre, orthographique et catégorielle) ainsi que des tâches d'association originales pour évaluer les processus cognitifs associés à la production verbale des patients et leurs liens avec la tachypsychie auto-rapportées, évaluée par le RCTQ. Nous avons plus particulièrement cherché à distinguer dans quelle mesure les sujets peuvent émettre des mots liés les uns aux autres (*clustering* phonologique et sémantique) et quelle est la fréquence des changements d'un mot à l'autre, d'un mot vers un cluster ou entre clusters (switchs). 94 patients avec trouble bipolaire en état maniaque, maniaque mixte, dépressif mixte, dépressif et euthymique et 31 sujets témoins ont participé au protocole. Nos résultats suggèrent une réduction du nombre de mots produit à la condition sémantique (noms d'animaux) par les sujets en dépression comparés aux sujets contrôles, ainsi qu'une réduction du nombre de switchs chez les déprimés à cette même condition. Dans la condition libre (sans critère de recherche fourni par l'expérimentateur), nous avons trouvé une dissociation entre la capacité à émettre des mots sémantiquement liés (i.e., clustering) et le nombre de switchs : à savoir, les patients maniaques utilisent plus de « switch » et un ratio réduit de clusters sémantiques (ratio nombre de clusters/nombre de mots) comparativement aux patients dépressifs et aux sujets contrôles, suggérant un marqueur d'état, qui correspond aux observations phénoménologiques de la manie – i.e., distractibilité, tangentialité et fuite des idées (e.g., Binswanger, 1933). De façon intéressante, à cette tâche de fluence libre, le nombre de switchs était également augmenté dans la dépression mixte comparée à la dépression, suggérant, là aussi, qu'il pourrait refléter la distractibilité qui caractérise la dépression avec caractéristiques mixtes. Cette capacité à switcher était quant à elle corrélée aux performances à des tâches de vitesse de traitement et de fonctions exécutives, suggérant la contribution de ces deux mécanismes à ces résultats.

Un autre résultat intéressant est lié aux clusters phonologiques dans la tâche de fluence verbale sémantique. En effet, nous avons trouvé que, dans la cette condition de la tâche où il fallait produire un maximum de noms d'animaux, les patients en phase maniaque regroupaient davantage les mots de manière phonologique (rimes, allitérations) comparativement aux sujets sains. Ces particularités de clustering étaient quant à elles corrélées à un déficit du processus d'inhibition cognitive chez les patients, évalué via le test de Hayling (Belleville et al., 2006). De manière générale, ceci reflète, là aussi, les descriptions phénoménologiques du langage maniaque évoquées précédemment (*clang associations*).

A l'instar de la perception du temps, les performances aux tâches de fluences verbales sont multi-factorielles, sous-tendues par au moins deux processus cognitifs : la mémoire sémantique et les fonctions exécutives (Troyer et al., 1997). De plus, selon les critères de recherche fournis au sujet dans la consigne – par exemple, sémantique, orthographique ou libre --, l'un de ces deux processus peut être davantage impliqué dans les performances (Henry & Crawford, 2004). C'est pourquoi nous avons utilisé dans nos études plusieurs conditions des taches de fluence verbal, d'une part, et plusieurs modalités d'analyse de résultats – i.e., qualitative, temporelle et automatisée --, d'autre part (cf. Article 5 Appendix).

De façon intéressante, si nous avions considéré uniquement le nombre de mots dans nos travaux, nous aurions pu conclure que les perturbations langagières et temporelles étaient observées uniquement dans les phases dépressives du trouble bipolaire. Or, via les mesures processuelles qualitatives, nous avons trouvé que tel n'était pas le cas, étant donné que les anomalies de *switching* et *clustering*, comparativement aux sujets sains, étaient présentes dans la manie, suggérant donc que les patients en phase maniaque parviennent à produire un nombre similaire de mots à cette tâche via des mécanismes différents. Plus spécifiquement, dans la condition de fluence libre, le nombre de switchs était augmenté alors que le ratio de clusters sémantiques était diminué comparés au groupe contrôle; le nombre total de mot était similaire entre les deux groupes. Autrement dit, quand la production verbale était libre (sans restriction fournie par l'expérimentateur), la production des patients maniaques était plus fugace et distractible que celle des sujets contrôles, mais également comparée à celle des patients en phase dépressive ou euthymique. Comparés aux contrôles sains, nos patients maniaques changeaient donc plus souvent d'unités conceptuelles, mais n'étaient pour autant pas plus productifs en termes de nombre de mots. Ceci était particulièrement le cas dans la tâche de fluence libre. Dans cette tâche, nous pouvons faire l'hypothèse que, du fait que l'activation sémantique n'est pas restreinte par le *task-set* (Phillips et al., 2002), ceci est à l'origine d'une persévérance réduite (reflétée par les ratios de clusters sémantiques réduits), et de plus de distractibilité (Dreisbach, 2006). En accord avec cette hypothèse, l'augmentation du nombre de switches chez les patients était corrélée avec un traitement de l'information plus rapide, d'une part, et des scores réduits aux mesures d'inhibition, d'autre part.

De façon intéressante, à l'instar des résultats aux tâches de perception de durées, les performances aux tâches de fluence verbale étaient similaires entre les groupes maniaque et mixte. Néanmoins, comparé à la dépression, nous avons observé que le nombre de switchs était significativement supérieur à la tâche de fluence libre dans la dépression mixte, suggérant que l'augmentation de switchs dans cette tâche est particulièrement liée à la présence de symptômes maniaques, même lorsque ceux-ci sont présents *a minima*.

A notre connaissance, nos études 4 et 5 ont été les premières investigations directes de la relation entre la tachypsychie auto-rapportée et l'expérience temporelle et langagière des patients avec trouble bipolaire, bien que cette relation ait été suspectée depuis les premières études expérimentales qui ont utilisées des tâches de fluence verbale et de perception du temps chez ces sujets (e.g., Kraepelin, 1899; Mezey & Knight, 1965). Contrairement à nos résultats préliminaires chez les sujets sains, chez les patients avec trouble bipolaire, la tachypsychie auto-rapportée via le RCTQ n'était pas liée au sentiment de passage du temps ou l'estimation des durées. Comme nous l'avons souligné dans les articles, ceci peut être dû au fait que deux caractéristiques importantes de la tachypsychie, à savoir l'arousal et la distractibilité, ont pu avoir des effets opposés dans la perception du temps, ce qui expliquerait ces résultats. En revanche, chez les sujets sains, au moins pour des courtes durées (32s), il est possible qu'une tachypsychie modérée ait été associée à l'arousal et non à la distractibilité.

Ces hypothèses doivent bien évidemment être testées dans des études futures. In contrast, in healthy individuals, at least for short durations (32s), it is possible that mild racing thoughts were associated with arousal, rather than distractibility. L'intérêt suscité par la relation entre les jugements du passage du temps et les estimations de durées s'est récemment accru (Wearden, 2015), et ce serait intéressant d'investiguer si et comment ces deux jugements sont liés, mais également quel est leur relation avec la tachypsychie. Ces résultats expérimentaux contribueront à leur tour aux études phénoménologiques autour de l'expérience du temps dans les épisodes aigus du trouble bipolaire (e.g., Bowden, 2013; Fuchs, 2013; Northoff et al., 2017). Récemment, des psychiatres ont tenté de traduire les études phénoménologiques autour de la tachypsychie en des termes neuroscientifiques (e.g., Northoff et al., 2017). Néanmoins, ces tentatives demeurent spéculatives car la recherche phénoménologique et psychologique autour des jugements du passage du temps est encore jeune.

Dans l'étude 5, nous avons trouvé que la tachypsychie, évaluée par le RCTQ, était associée au nombre de mots produit dans certaines taches de fluence verbal, ainsi qu'au ratio de clusters phonologiques à la tâche de fluence orthographique. Nous avons interprété ces résultats comme étant dus aux effets de la distractibilité sur la production verbale des patients dans des tâches avec des consignes restrictives (ici, la tâche orthographique), et nous avons argumenté que la tachypsychie auto-rapportée pouvait être associée à des anomalies exécutives. De façon intéressante, nous avons trouvé des résultats différents pour la rumination, suggérant qu'elle sous-tendue par des processus cognitifs distincts. Comme nous l'avons montré dans notre revue de la littérature, peu d'études se sont intéressées aux liens entre trouble de la pensée et performance langagière chez les patients avec trouble bipolaire. La majorité de ces étude n'a par ailleurs pas trouvé de corrélations entre les deux (Ryu et al., 2012; Andreou et al., 2013; Cermolacce et al., 2014). Par exemple, Ryu et al. (2012) et Cermolacce et al., (2014) n'ont trouvé aucune corrélation entre l'amplitude N400 amplitude et les troubles de la pensée évalués par deux items de l'échelle YMRS (Young et al., 1978) chez les patients maniaques. De la même manière, chez des patients euthymiques, Andreou et al. (2013) n'ont trouvé aucune corrélation entre les performances à des tâche d'amorçage sémantique et les troubles de la pensée tels qu'ils ont été évalués le *Scale for Thought, Language and Communication* (TLC; Andreasen, 1979). Récemment, Nagels et al. (2016) ont trouvé des correlations negatives entre la production verbale à des taches de fluence sémantique et orthographique et les caractéristiques négatives des troubles de la pensée (i.e., pauvreté du discours, ralentissement de la pensée et concrétisme), telles qu'elles ont été évaluées par le *Thought and Language Disorder Scale* (Kircher et al., 2014). Néanmoins, ceci était essentiellement le cas lorsque les auteurs ont rassemblé des patients schizophrènes, dépressifs et maniaques. Il est donc possible que ces résultats ne soient pas spécifiques du trouble bipolaire. De plus, le TLC et le TALD sont des hétéroquestionnaires qui ont été construits sur la base du postulat que des altérations de la pensée et du langage sont similaires dans la schizophrénie et le trouble bipolaire (Kircher et al., 2014). Ceci n'est pas le cas du RCTQ, qui est un autoquestionnaire construit pour mesurer spécifiquement les troubles de la pensée du trouble bipolaire. En effet, le RCTQ a été élaboré sur la base de la littérature phénoménologiques qui a montré que les anomalies de la pensée et du langage des patients maniaques sont différentes dans la manie et dans la schizophrénie (Sass & Pienkos, 2015), d'une part, et que ces anomalies peuvent toucher la pensée sans concerner le langage expressif des patients (Binswanger, 1933).

Dans l'ensemble, nos résultats suggèrent que la tachypsychie, tel qu'évaluée par le RCTQ, est un phénomène composite, tri-factoriel, présent même chez les sujets sains en cas d'instabilité mineure de l'humeur. Chez les patients avec trouble bipolaire, l'instrument que nous avons développé est par ailleurs très sensible à des symptômes maniaques mineures associés à des états dépressifs, indiquant qu'il pourra devenir un outil clinique précieux dans la détection des états de dépression avec caractéristiques mixtes. Sous un angle psychopathologique, nos études ont également permis de mieux cerner les mécanismes impliqués dans ce phénomène, dont notamment la distractibilité.

Sur le plan neuropsychologique, nos résultats ont permis pour la première fois de mettre en évidence, de manière expérimentale, des anomalies liées à la tachypsychie, en suggérant des pistes neuropsychologiques pour la compréhension de ce phénomène.