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**INFORMATION PROCESSING IN HEALTHY PEOPLE WITH
DELUSIONAL-LIKE IDEATION**

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degree of Ph.D. in Neuroscience

by

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À la mémoire de Marcella Bride Azincourt,

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Abstract

Experiences that resemble delusions of psychiatric patients can be observed in the general healthy population. These experiences, named hereafter delusional-like ideations, are not the only fact in line with the idea that there is a continuum between clinical delusions and normality. Previous research suggests that at least two types of cognitive bias could be common to patients and healthy subjects: first, a tendency to jump to conclusions, which can play a role in the formation of delusional ideation and second, abnormal semantic processes, which could lead to the maintenance of these ideations. The present thesis was aimed at further investigating these two biases in the general population to see whether further support can be obtained for the continuum view. In addition, the impact of current paranoid feelings on these cognitive biases was assessed in these healthy participants.

The tendency to jump to conclusion was evaluated with a reasoning task. Healthy people with delusional-like ideation needed less information to reach a conclusion than people without or with few delusional-like ideations, replicating findings obtained in deluded patients. Furthermore, paranoid feelings strengthened the relationship between delusional-like ideation and this jump to conclusion style of thinking. Results also show that people with delusional-like ideation jump to *new* conclusions when they experienced paranoid feelings, a finding that only tended to be significant when no paranoid feelings were induced. These results provide further

support to the continuum idea and to the hypothesis that the jump to conclusion bias may be involved in delusion formation.

On the other hand, semantic processes of healthy participants were investigated by recording the N400 event-related brain potential in a semantic categorization task. When paranoid feelings were induced, delusional-like ideation scores were associated with smaller raw N400 amplitudes, as was found in schizophrenia patients with delusions. The analysis of the independent components of the N400 potential showed that delusional-like ideation had an influence on the N400 even when no paranoid feelings were induced. These results suggest that semantic processing of people with delusional-like ideation can be modulated by their current mental state. The implications for delusion formation and maintenance are explored.

In conclusion, both the results of the jump to conclusion and those of the semantic processes studies lend further support to the idea of a continuum between clinical delusions and delusional-like ideation.

Résumé

Des expériences qui ressemblent aux idées délirantes psychiatriques peuvent être observées dans la population générale saine. Ces expériences, ci-nommées idées de type délirantes, ne sont pas les seuls faits en accord avec l'idée qu'il existe un continuum entre les idées délirantes et la normalité. Des études précédentes suggèrent qu'au moins deux types de biais cognitif sont communs aux patients et aux personnes saines: 1/la tendance à tirer des conclusions hâtives qui pourrait jouer un rôle dans la formation des idées délirantes et 2/les processus sémantiques anormaux qui pourraient conduire à la persistance de ces idées. La présente thèse a pour objectif d'explorer ces deux biais et d'évaluer s'ils soutiennent l'idée de continuum. De plus, l'influence de sentiments paranoïdes sur ces biais cognitifs est évaluée chez ces participants sains.

La tendance à tirer des conclusions hâtives a été testée avec une tâche de raisonnement. Les personnes saines ayant des idées de type délirantes nécessitaient moins d'information pour arriver à une conclusion que ceux sans idées de type délirantes, ce qui réplique les résultats trouvés chez les patients délirants. De plus, les sentiments paranoïdes renforçaient le lien entre les idées de type délirantes et le saut aux conclusions des participants. Les résultats montrent aussi que les participants avec des idées de type délirantes tirent de *nouvelles* conclusions hâtives, ce qui n'était pas significatif lorsque les sentiments paranoïdes n'étaient pas induits. Ces résultats soutiennent l'idée du continuum ainsi que l'hypothèse proposant que tirer des conclusions hâtives pourrait participer à la formation des idées délirantes.

D'autre part, les processus sémantiques des participants sains ont été évalués en enregistrant le potentiel cérébral évoqué qu'est la N400, dans une tâche de catégorisation sémantique. Quand des sentiments paranoïdes étaient induits, les scores d'idées de type délirantes étaient associés à de plus petites amplitudes brutes de N400, rappelant les résultats observés chez les patients. L'analyse des composantes indépendantes du potentiel N400 montre que les idées de type délirantes avaient une influence sur la N400, même lorsque les sentiments paranoïdes n'étaient pas induits chez les participants. Ces résultats suggèrent que les processus sémantiques des personnes avec des idées de type délirantes pourraient donc être modulés par leur état mental. Les implications pour la formation et la maintenance des idées délirantes sont explorées.

En conclusion, les résultats des études sur le fait de tirer des conclusions hâtives et ceux des études sur les processus sémantiques soutiennent l'idée de continuum entre les idées délirantes pathologiques et les idées de type délirantes.

Rationale and objectives

In 1913, Karl Jasper was the first to define criteria to distinguish a belief from a delusion: a delusion was said to be held with certainty; it cannot be rationalized away; and the content of the delusion is very implausible (1997). Today, the definition of delusion follows Jasper's: they are fixed and false beliefs that persist despite contradictory evidence (DSM-IV). The two fundamental questions that remain unanswered are how delusions are formed and why they persist.

Studies repeatedly show that delusions are correlated to a 'jump to conclusion' style of thinking (for review, see Fine et al., 2007), meaning that deluded patients need less evidence than non-deluded patients or controls to reach a conclusion. This robust finding might explain the emergence of delusions. Patients would jump from a hypothesis to a false belief based on little evidence and thus create a delusion. According to the continuum view (van Os et al., 2000), experiences in healthy participants that resemble delusions, named hereafter delusional-like ideations, are associated with cognitive disturbances similar to those observed in delusional patients. The jump to conclusion bias has also been investigated in healthy participants with delusional-like ideation showing the same relationship between this schizotypal trait and the amount of evidence needed to make a decision (Freeman et al., 2008; white & Mansell, 2009). However, results are not as consistent in healthy participants as they are in patients (Warman, 2008; Lincoln et al., In press). Chapters 2 and 3 address these

findings and offer a possible explanation for the discrepancy of the literature in healthy participants.

Concerning the persistence of delusions, recent studies have reported a bias against disconfirmatory evidence in deluded patients (Moritz & Woodward, 2006; Woodward et al., 2006). As such, deluded patients might not integrate contradictory information as well as non-deluded people. A neurophysiologic index of the processing of meaningful information, and possibly of its integration, is the N400 event-related potential. This potential has been showed to be reduced in more-deluded schizophrenia patients compared to non- or less-delusional schizophrenia patients (Debruille et al., 2007), suggesting a shallower processing of semantic information. Whether the delusional-like ideations in healthy participants are accompanied by the same anomalies in the processing of meaningful information has never been tested. Chapters 4 to 6 explore this possible correlate of delusional-like ideation.

The presence of similar relationships between delusional-like ideas and the two above-mentioned cognitive biases would bring further support to the continuum view (Johns & van Os, 2001). A major consequence of the continuum view, in opposition with the dichotomous view, is the possible early detection of cognitive anomalies in the healthy population that could help screen possible 'at risk' population for psychosis. In addition, it could help define which protective mechanisms are at work in healthy people with delusional-like ideas who never go on developing full-blown psychiatric disorder.

The first aim of the present thesis was to evaluate the jump to conclusion style of thinking thought to be important in delusion formation, and the processing of semantic information thought to contribute to delusions maintenance in healthy participants with delusional ideation. The jump to conclusion style of thinking was evaluated with a psychometric task, the beads task (chapters 2 and 3), whereas the processing of meaningful information was evaluated using a N400 protocol (chapters 4 to 6).

The second aim of the present thesis was to test the extent to which the jump to conclusion bias and the processing of semantic information can be influenced by environmental manipulations that trigger paranoid feelings in participants. It was hypothesized that paranoid feelings would exaggerate the cognitive biases of participants with delusional-like ideations (Chapters 3 and 5). This difference in environmental conditions could help reconcile the divergent results observed in the literature.

In chapter 1, I define delusions in patients and delusional-like ideations in the healthy population, while reviewing the main theories about delusion formation and maintenance. I show the relevance of a continuum view of delusional experiences in understanding this psychiatric symptom and in helping psychosis-prone people who might later develop clinical delusions.

In chapter 2, healthy participants underwent a reasoning task to assess a possible jump to conclusion style of thinking and thus determine how much information is needed to reach a decision. Subjects with higher scores on delusional-like ideations scale need less information to make a decision. In addition, those who changed their

mind about their initial decision were more likely to have higher scores on measures of delusional ideations, a finding that has never been shown before. These findings confirm the possible implication of this reasoning bias in delusions formation.

In chapter 3, the environment was modified to induce paranoid feelings in healthy participants. The same task as in chapter 2 was used and the jump to conclusion bias was tested again. As expected, the correlation between the amount of evidence need to reach a conclusion and delusional-like ideation is strengthened in this specific condition. For those with delusional-like ideation, the jump to new conclusion that was only a trend in chapter 2 is now significant when participants are experiencing paranoid feelings, confirming this new result. Not only people with delusional-like ideation need less evidence to reach a conclusion but they also need less evidence to abandon this conclusion and reach a new one.

In chapter 4, I show that delusional-like ideation is not correlated with N400 amplitudes, and thus with semantic information processing, whereas disorganization and interpersonal factors, two schizotypal personality traits (Raine, 1994), are correlated to N400 amplitudes. In usual laboratory conditions, delusional-like ideation seems to have no influence on semantic information processing, which does not support the continuum view.

In chapter 5, the same task as in chapter 4 is used but with an induction of paranoid feelings. Under this specific condition, delusional-like ideation is correlated with diminished N400 amplitudes. Healthy subjects with delusional-like ideation have thus similar cognitive biases to delusional patients, when experiencing paranoid feelings. This

different processing of semantic information could participate in delusional-like ideations persistence. These results suggest that the continuum view is state-dependent for semantic information processing in healthy people with delusional-like ideation.

In chapter 6, data from chapters 4 and 5 are submitted to an independent component analysis. Delusional-like ideation was found to be associated with a centro-parietal sub-component of the N400 event related potential, even without the induction of paranoid feelings. This result was not visible when analyzing only the N400 amplitudes. In addition, when paranoid feelings are induced, this sub-component is sensitive to the semantic relationship between meaningful words. In people with delusional-like ideation, experiencing paranoid feelings could thus influence the way they process meaningful information in relation to its context.

In conclusion, the present work supports a continuum of delusional experiences, as both cognitive biases assessed were found to be correlated to delusional-like ideation of healthy participants, similar to what was observed in deluded patients. Processes that likely participate in delusion formation (reasoning bias) and maintenance (semantic information processing) are present at all times in healthy people with delusional-like ideation and temporarily intensified by a paranoid mental state. Both formation and persistence of delusions could thus be explained by the interaction of personality trait (i.e. delusional-like ideation) and the environment (i.e. threats).

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Chapter 1

Delusions and delusional-like ideation

One of the core symptoms of psychosis is delusion. Currently defined as a false belief that is firmly sustained and that resists contradictory evidence (DSM-IV), the content of delusions can vary greatly from patient to patient. These apparently very different beliefs all share this sense of 'weirdness', the firm conviction with which they are held and the impossibility to be rationally thought of. For example, one will be convinced that someone can read his/her thoughts, another one believes he/she is being followed by the government, and another will believe that he/she is not in control of his/her own actions. Table 1 presents a list of the common themes of delusions, as described in the Scale for the Assessment of Positive Symptoms (SAPS, Andreasen et al., 1984) and the Schedule for Affective Disorders and Schizophrenia (SADS, Spitzer & Endicott, 1978). Delusions are mostly observed in schizophrenia, a psychiatric disorder whose prevalence is 1% and up to 47% for monozygotic twins of schizophrenia patients (Kaplan & Sadock, 1998). In delusional disorders, whose prevalence is much lower (0.03%), delusions themes are quite similar (Table 2). However, contrary to some of the delusions found in schizophrenia, delusional beliefs are not always bizarre and impossible, but rather very unlikely (Kaplan & Sadock, 1998). Some highly specific and less common delusions have been given specific appellation. They include: the Capgras' syndrome, where a close relative is thought to have been replaced by an impostor; the Fregoli's syndrome, where different people are believed to be one and unique person who would change faces; the Cotard's syndrome, where patients think they have lost everything, including organs or strength. In the general non-psychiatric population, clinical delusions have a prevalence of 1 to 4% (Freeman, 2006).

Themes	Description	Prevalence ¹
Persecutory delusion	Delusions of being attacked, harassed, cheated, persecuted or conspired against	61%
Delusions of reference	Delusions that events, things or people have a specific and unusual meaning	27%
Grandiose delusion	Delusions of being exaggeratedly important, powerful or knowledgeable	26%
Delusion of mind-reading	Delusions that others can read one's thoughts	26%
Delusions of alien control	Delusions where one's own perceptions and actions are controlled by an external agent	25%
Religious delusion	Delusions of a specific relationship with God or concerning religion	17%
Somatic delusion	Delusions concerning the functioning of a body part	16%
Delusion of thought insertion	Delusions where someone else's thought are inserted one's own mind	14%
Delusion of thought withdrawal	Delusions where one's own thoughts have been removed	14%
Delusions of guilt or sin	Delusions of having committed a sin or being responsible of catastrophic consequences	12%
Delusion of thought broadcasting	Delusions where thoughts are broadcast for everyone to hear	9%
Delusional jealousy	Delusion where the sexual partner is unfaithful	2%

Table1: Common delusional themes in schizophrenia and their prevalence. ¹From Andreasen (1987), data from 111 consecutive schizophrenia patients assessed with the SAPS, from moderate to extreme symptoms

Themes	Prevalence
Persecutory type	38%
Erotomantic type ¹	36%
Jealous type	5%
Mixed	5%
Grandiose type	2%
Somatic type	0%
Unspecified	13%

Table 2: Common themes of delusions in delusional disorders and their prevalence, from Manschreck & Khan (2006), data from 224 patients from research articles published between 1994 and 2004. ¹Delusion of being loved by someone usually famous.

For years, delusions have fascinated researchers and therapists. While healthy people can have weird beliefs, they can rationalize about them, admit that they are very unlikely, and usually take into account evidence that contradicts their beliefs. Two major questions have thus emerged concerning delusions: How someone go on and develop clinical delusions? And why this new fixed and false belief cannot be rationalized away? The causes of delusions can be numerous but they often remain mysterious. Amongst the known causes of delusions are drugs, some neurological disorders, brain tumour or endocrine disorders (for a review, see Kunert et al., 2007). Because in many cases none of these causes are found, researchers have focused on emotional and cognitive disturbances that could contribute in delusions formation and maintenance. I will first briefly review the emotional correlates of delusions before a more thorough review of the cognitive processes involved in delusion formation and persistence.

The emotional component of delusions

Many studies have showed that emotional factors contribute greatly to the development of psychosis, a state defined by the emergence of delusions (false beliefs) and hallucinations (false perceptions) (for reviews, see Fotopoulou, 2009; Freeman & Garety, 2003). Krabbendam and colleagues (2002) showed that neuroticism and low self-esteem were predictors of psychosis onset. Others showed that anxiety level was predicting delusions and hallucinations (Tien & Eaton, 1992) and schizophrenia (Jones et al., 1994; Kugelmass et al., 1995). High depression scores and low self-esteem are associated with the severity of persecutory delusions (Smith et al., 2006). In addition, anxiety, followed by depressive symptoms, would immediately precede the early stage

of psychosis (Birchwood et al., 1992; Docherty et al., 1978), suggesting a direct influence. Similarly, psychosis is accompanied by anxiety and depression in at least half of patients (Cosoff & Haffner, 1998; Siris, 2000), although anxiety might be more closely related to delusions and hallucination than depressive symptoms (Norman et al., 1998). The co-occurrence of mood related symptoms and delusions in many patients suggests that emotions might play a major role in the persistence of delusions. However, the exact role of emotions remains uncertain. As shown in Freeman's theoretical model (Figure 2), anxiety that is likely caused by delusional beliefs could lead to avoid taking into account information that could disconfirm the belief. Similarly, depression also likely caused by delusions would also lead to a cognitive bias, that is, patients would try to obtain information that confirms the delusional beliefs. In this case, emotional disturbances could be caused by delusions and are likely to participate in their maintenance to lower the anxiety and depressive intensity associated to them (Freeman, 2007).

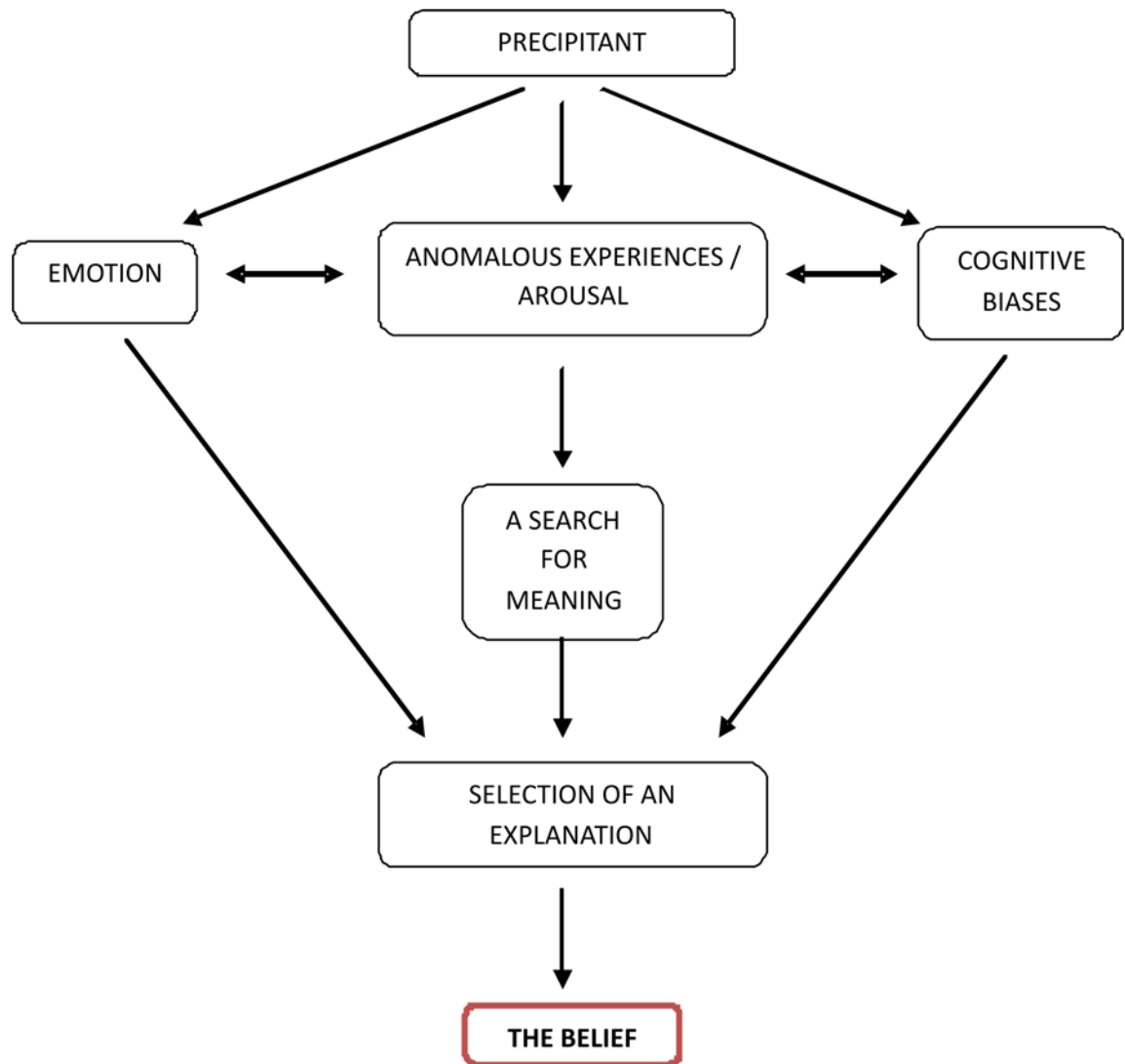


Figure 1: Delusion formation (adapted from Freeman, 2007)

A parallel with delusions maintenance can be made for delusions formation. According to Maher (1988), perceptual anomalies cause the emergence of delusions as an explanation for these unusual perceptions. The distress caused by the anomalous experiences will precipitate the choice of an explanation and thus the formation of a delusion (Figure 1). In this view, delusions are a way to diminish the emotional distress caused by the uncertainty associated with the perceptual anomalies. In addition, the anxiety of people with these anomalous experiences might come from the fear of 'going mad', a fear found in 70% of people with psychotic experiences (Morrison, 2001). One study showed that traumatic events are predictive of paranoia, mediated by anxiety levels (Freeman & Fowler, 2009), confirming the role of anxiety the emergence of delusions. From a psychoanalytic perspective, Freud suggested that delusions serve as a protective mechanism. Repressed memory that cannot enter consciousness would be the cause of delusions, which carry a personal historic truth trying to emerge (Freud, 1938). There is thus a fundamental unconscious motivation to avoid a memory that one cannot recollect due to its emotional load. However, empirical evidence to support this approach is missing.

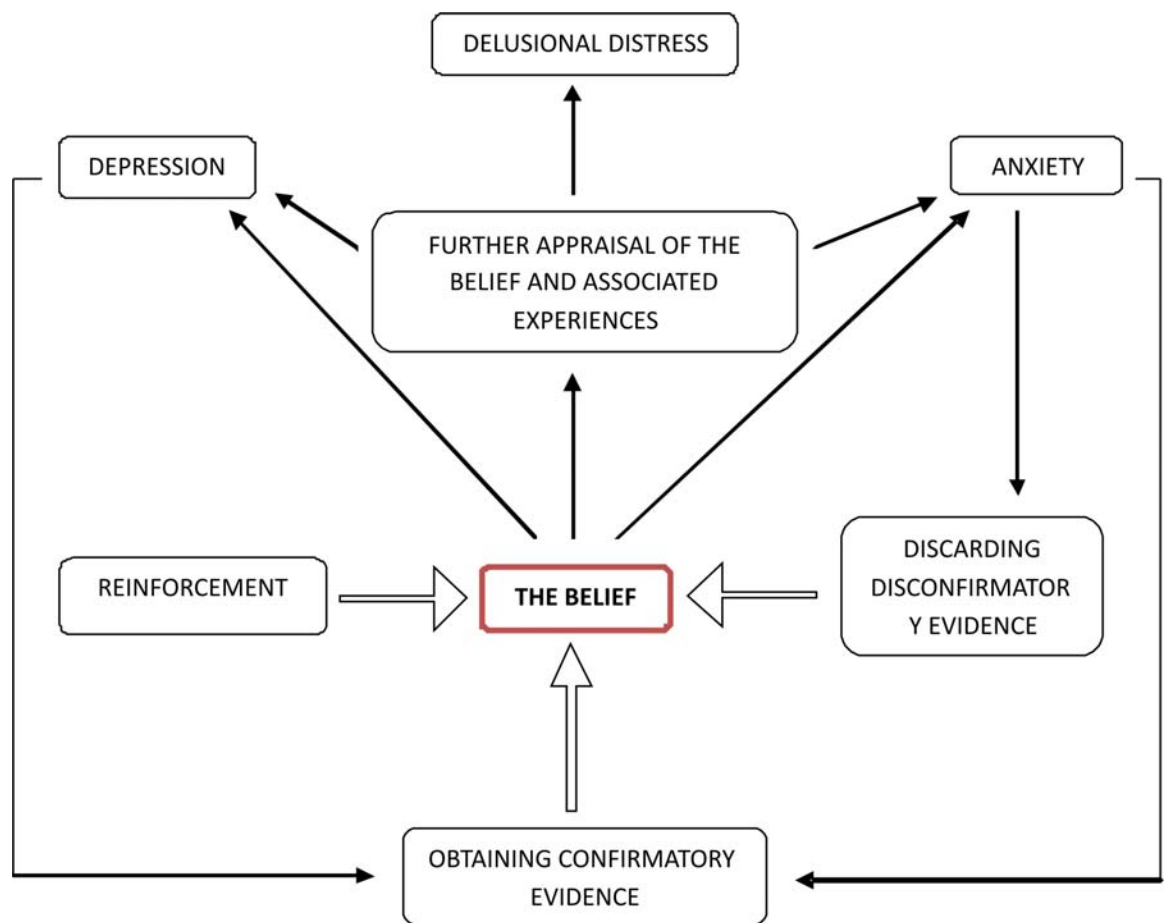


Figure 2: Delusion persistence (adapted from Freeman, 2007)

Nevertheless emotions are well-recognized to have a fundamental role in delusional pathology. Holt and colleagues (2006) showed that delusional schizophrenia patients attribute affective meaning, especially unpleasant emotions, to neutral words more often than non-delusional patients and healthy controls. Similarly, delusions have been associated to a tendency to attend threat-related or emotional stimuli (Bentall & Kaney, 1989; Fear et al., 1996), even though patients with anxiety disorders and depression present the same bias (Grant & Beck, 2006; Martin et al., 1991; for a review, see Williams, 1996). The experience of emotions and the perception of emotions might be deviant in delusional patients. In any case, it is likely that the interaction of emotions with other mechanisms could better explain delusions (Figures 1 and 2).

Delusions caused by a perceptual deficit

At the end of the 19th century, James (1890) suggested that deluded patients were trying to make sense of their abnormal perceptions, reminiscent of schizophrenia patients' reports of experiencing unusual perceptions (Bunney et al., 1999). In other words, these unexplained perceptual anomalies would trigger distress and actively push patients to find a way to account for them, hence the delusions. In this view, emotions such as distress, and cognition are tightly interconnected to create and maintain delusions. Later, as mentioned above, Maher (1988, 2005, 2006) developed this theory where the cognitive processes of deluded people would be mostly intact but the real cause of delusions would be the disturbed perceptual system. As long as the perceptions remain abnormal, the delusion will be reinforced. Following this view,

Coltheart (2007) proposed that delusions could be defined by two factors: a factor explaining why the patient does not reject his belief, and a factor explaining the content of the delusion. Delusional contents would vary according to the patient personal history and culture (Maher, 2005). On the other hand, the persistence of the delusion is dependent on the persistence of the perceptual anomalies and the variation of intensity of these anomalies. Evidence, such as the co-occurrence of delusions and hallucinations, supports this view. Numerous studies report anomalous perceptions in patients. Indeed, patients with psychosis have difficulties in time discrimination for external events (Waters & Jablensky, 2009) but also for internal events, such as their own motor imagery (Maruff et al., 2003). Delusions have also been associated with reduced discrimination and salience detection of auditory events (Turetsky et al., 2009) or abnormal asymmetry of the event-related potential indexing this detection (Renoult et al., 2007). The basic capacity we all have to disregard sensations coming from our own actions seems to be compromised in schizophrenia patients (Ford et al., 2001a, 2001b) and this deficit is thought to be related to delusions formation (Feinberg, 1978; Mathalon & Ford, 2008). Self-perception and self-monitoring thus seem disturbed in patients with delusions (Blakemore et al., 2000; Johns et al., 2006; for reviews, see Blakemore & Frith, 2003 and Frith et al., 2000).

More recently, Kapur (2003) provided a review suggesting that high level of dopamine in psychotic patients causes abnormal salience of external and internal events, an idea that has been supported by recent results (Menon et al., 2005; Roiser et al., 2009). As an attempt to explain this abnormal salience, patients created delusions.

This salience grabs attention and influences goal directed behaviours. As such, new meaning and abnormal explanations are likely to emerge, if this salience is heightened in psychotic patients. The cognitive mechanisms associated to this subtle anomalous salience are likely involved in delusions formation and maintenance.

Garety and colleagues (1991) proposed that delusions would emerge because of abnormal reasoning processes. They showed that patients with delusions require less information to reach a conclusion than controls (e.g., Huq et al., 1988; Startup et al., 2008; van Dael et al., 2006; for a review, see Fine et al., 2007; Garety & Freeman, 1999) and this hastily decision has been specifically linked to delusions and to the level of conviction in delusions (Moritz & Woodward, 2005; Peters et al., 2008). However, the first hypothesis of a reasoning bias was challenged, as patients do not perform worse than controls (their conclusion is accurate) but base their decision on less evidence than controls. To date, the role of this hastily decision making in delusions is not clear, even though it is the most robust and replicated correlate of delusions to date (Freeman, 2007). An explanation could be drawn from the salience theory of Kapur (2003), where patients would overweight pieces of evidence and thus reach conclusion quicker than controls. The jump to conclusion could explain the quick acceptance of everyday information as if it was evidence confirming a belief.

Inference mechanisms of delusions

Fletcher and Frith (2009) proposed that the basic mechanism of inferences which allows us to predict events and to learn from events is disrupted in patients with

delusions and hallucinations. As such, patients would not properly integrate relevant information and would make false predictions. Supporting this view are the findings that paranoid patients (with persecutory delusions) predict a very high occurrence of negative events in their lifetime (Bentall et al., 2008; Corcoran et al., 2006; Kaney et al., 1997). Also in line with these results are the studies of latent inhibition deficit in schizophrenia patients (Gray et al., 2005). When a stimulus is repeatedly associated to an event, people learn quickly to recognize this contingency and will predict that this particular event follows this particular stimulus. However, if people are first exposed to a stimulus alone, thus learning that there is no event associated to it, the subsequent exposure to the same stimulus followed by an event will not produce the same learning process. On the contrary, the learning process of this new association is inhibited by the pre-exposure to the stimulus alone (hence the term 'latent inhibition', (Lubow & Moore, 1959)). In schizophrenia patients, the latent inhibition is almost absent, meaning that they learn the new association more quickly than healthy controls (Escobar et al., 2002). These findings support Hemsley's theory (1987) that schizophrenia patients have trouble using past regularities to interpret current events. More specifically, this latent inhibition was found absent in patients with acute psychosis episode (Baruch et al., 1988). In other words, patients with delusions infer hastily associations between events, not using pre-established contextual information, as controls do.

The inference disruption that can be observed with neutral stimuli is extended to more socially relevant conditions. Interestingly, delusions are often related to interpersonal dimensions, either directly involving others (persecutory delusions,

thoughts broadcasting, mind reading, jealousy) or indirectly related to others, like one's position in the social world (grandiosity, religious delusions). Not surprisingly, in the field of social cognition, false inference about others' mental state and intentions was thought central to paranoid and persecutory delusions (Frith & Corcoran, 1996; Langdon & Coltheart, 1999; Langdon et al., 2008). The severe deficit in 'theory of mind', a term covering the inference of others' intentions (Premack & Woodruff, 1978), would tend to make them pathologically paranoid. Evidence suggests that patients are 'over-mentalizing', that is, they see intentions where none should be seen (Abu-Akel, 1999; Abu-Akel & Bailey, 2000). This finding is reminiscent of Blakemore et al.'s study (2003) showing that patients with delusions see contingencies between moving shapes when there is none to see. However, a specific link to positive symptoms of schizophrenia, that is, to delusions and hallucinations, remains debated (Harrington et al., 2005; Sprong et al., 2007) and often failed to be found (Corcoran et al., 1995; Sarfati et al., 1997). Theory of mind deficit thus seems to be strongly involved in schizophrenia but not specific of delusions (Corcoran et al., 2008).

Still in the social dimension, an attributional style was proposed to account for delusions emergence (Bentall et al., 2001), especially in the case of persecutory delusions. Patients wrongly attribute to others the causes of negative events (Ellis & Young, 1996; Fear et al., 1996; Fornells-Ambrojo & Garety, 2009; Kaney & Bentall, 1989; Sharp et al., 1997). Depending on the attributional style but also on the personality of the patient, the attribution can be toward somebody else or toward oneself. For instance, the delusion of a suspicious person will pertain to others whereas a person

who tends to have a depressive personality will experience delusions focused on oneself (Coltheart, 2007). This attributional style might be a way to circumvent the discrepancies between the 'ideal' and the 'experienced' self, a theory close to the psychoanalytic view. Attributing to others the cause of negative events would protect the self-esteem (Bentall et al., 1994; 2001; McKay et al., 2007), which is found low in some paranoid patients (Bowins & Shugar, 1998). Echoing a deficit in theory of mind, this false inference could stem from the inability to understand others' behaviours, and especially contextual information that shapes others' behaviours (Craig et al., 2004; Kinderman et al., 1997).

The dimensionality of delusions

It has been proposed that psychotic symptoms lie on a continuum from normal to pathology (Claridge, 1985, 1997; Strauss, 1969), in opposition with the usual dichotomy between non-clinical and clinical conditions. As stated by Claridge (1985), there is a range of personality traits that are distributed from pathology to normality that are accompanied by a range of cognitive styles and perceptual experiences underlying them. Supporting this idea, studies in the general population have reported a noticeable prevalence of experiences similar to delusions (Table 3) or psychotic symptoms (Freeman et al., 2005; Johns et al., 2004; Shevlin et al., 2007; van Os et al., 2000), albeit of milder forms (Verdoux et al., 1998a). These experiences similar to schizophrenia symptoms could be referred to as schizotypal traits (Meehl, 1962; Claridge, 1997). However, to fully support a continuum of psychotic-like experiences,

schizotypal traits should be associated to cognitive, emotional and behavioural features that resemble those of patients with psychosis (Johns & van Os, 2001). Studies have reported that psychotic-like experiences are more prominent in younger than elder (Peters et al., 1999; Verdoux et al., 1998b), similar to what is observed in patients (Galdos & van Os, 1995; Schultz et al., 1997). In addition, socio-economic status and areas of residence are also factors that modulate the risk of developing psychotic experiences (Schultz et al., 1997) and are associated with psychotic-like experiences (Johns et al., 2004).

Psychotic-like experiences	Endorsement rate (N=5854)
Being spied upon or being followed	12.9%
Visual hallucinations	8.4%
Auditory hallucinations	8.3%
Reading your mind	7.4%
Unusual bodily feelings	7%
Olfactive hallucinations	4.3%
Being the subject of a conspiracy	3.6%
Being under the control of some external power	3.1%
Being sent special messages through television or radio	2.4%
Thoughts insertion or stolen by others	2.2%
Being hypnotized or magic performed on you	1%

Table 3: Prevalence of psychotic-like experience in the general population, from Shevlin and colleagues (2007).

Concerning the emotional component of delusional-like experiences, findings are close to what is reported for deluded patients. Anxiety and depression are highly related to positive schizotypy (Lewandowski et al., 2006; Mohanty et al., 2008) and especially to delusional-like experiences (Combs & Penn, 2004; Freeman et al., 2008). Two

longitudinal studies showed that psychosis prone individuals have higher risk of developing major depressive disorder (Chapman et al., 1994; Kwapil et al., 1997). In a cross-sectional study, depression scores, but not anxiety scores, are predictive of delusional-like ideations (Chapter 2). One study showed that people with both high level of schizotypy and high level of depressive symptoms contrasted from people with high schizotypy and low depressive symptoms by their high suspiciousness (Spitznagel et al., 2004), suggesting that subtypes of schizotypy might be associated to different mood related features.

Based on recent findings supporting the continuum view, the major cognitive theories trying to account for delusions might also have some ground to account for delusional ideations in the non-clinical population. The cognitive biases associated with clinical delusions have also been observed in healthy participants with delusional-like ideations. The reduced latent Inhibition has been associated to schizotypy and especially to positive dimensions (Gray et al., 2002; Lubow et al., 2001; Tsakanikos & Reed, 2004), suggesting that schizotypal traits, like positive symptoms of schizophrenia, are associated to a quick learning of new associations. The same implications can thus be drawn from Hemsley's proposal for delusions, that people with schizotypal traits do not use previously learned information to process new one. The attributional style of deluded patients has also been replicated in non-clinical people with paranoid ideations (Fornells-Ambrojo & Garety, 2009; Kinderman & Bentall, 1996), although some studies could not find significant associations (Combs & Penn, 2004; Martin & Penn, 2001). In parallel with results obtained in clinically deluded patients, some evidence showed poor

performance on theory of mind tasks to be associated with delusional-like experiences (Meyer & Shean, 2006) or high level of schizotypy (Langdon & Coltheart, 1999), although it was not replicated elsewhere (Fyfe et al., 2008). The tendency to see connections between random events was associated with delusional-like ideation in one of the two tasks used in Fyfe and colleagues' study (2008), reminiscent of the 'over-mentalizing' style of deluded patients. Taken together, these findings show that delusional-like ideation is likely underlain by cognitive mechanisms similar to those underlying clinical delusions.

Concerning reasoning processes, most studies found that people with delusional-like ideation need less evidence to reach a conclusion (Colbert & Peters, 2002; Freeman et al., 2008; White & Mansell, 2009). However, some studies had difficulties replicating the correlations between delusional-like ideation and the amount of evidence necessary to make a decision (Lincoln et al., In Press; McKay et al., 2006; Warman, 2008). The mental state of participants might influence greatly their data gathering bias and explain why results are sometimes not significant (Chapter 3).

Recent studies have showed a bias against disconfirmatory information unrelated to the themes of participants' delusions but nonetheless associated to the presence of delusional beliefs (Mortiz & Woodward, 2006; Woodward et al., 2006a; Woodward et al., 2006b). Two studies measuring neurophysiologic indexes of semantic information processing showed that delusions are related to abnormal processing of this type of information (Debruille et al., 2007; Kiang et al., 2007). Such a bias can have major consequences in the way beliefs are maintained in patients and might point to

the cognitive mechanism that underlies how delusions resist contradictory evidence. This bias has recently been observed in non-clinical participants with delusional-like ideation (Woodward et al., 2007). These participants would not integrate information that disconfirm a (neutral) belief as well as people without delusional-like ideations do. An electrophysiological index of semantic information processing, the N400 event related potential was found to be reduced in patients with delusions (Debruille et al., 2007; Kiang et al., 2007). In healthy participants, the reduction of N400 amplitudes are also correlated to delusional-like ideations, although in specific conditions (Chapters 4 and 5).

Implications of the continuum view

The presence of a continuum of psychotic experiences has major implications for detecting people who are at risk to develop psychiatric disorders. Psychotic-like experiences in non-clinical people increase the risk of developing real psychosis and mood disorders (Chapman et al., 1994, Kwapil et al., 1997). In Poulton's study (2000), 25% of teenagers with psychotic-like experiences developed a psychotic disorder. One longitudinal study reported that the risk to develop psychosis was increased if hallucinatory experiences were associated with delusional-like experiences (Krabbendam et al., 2005a, 2005b). This study also suggested that people who do not develop delusional-like experiences have a reduced risk for psychosis. Interestingly, another study showed that these psychotic-like experiences in young adults (14 to 17 years old) were transitory in most of them and recurrent or persistent in only 30 to 40%

of their cohort (Dominguez et al., In Press). This persistence of the psychotic-like experiences was predictive of later clinical states, suggesting that for some individuals, psychosis emerge from a continuum from sub-clinical experiences to clinical ones. From a recent longitudinal study, delusional-like experiences themselves are more likely to be present at age 21 if high level of psychopathology was observed at age 5 and 14 (Scott et al., 2009). The results of these longitudinal studies suggest that lifespan continuum within individuals exists for psychotic-like experiences, in agreement with Meehl's view of the continuum (1962, 1990).

The implications of a dimensionality of delusional experiences are multiple. First, based on Meehl's approach of the continuum, it can help detect people at high risk to develop psychosis (Koutsouleris et al., 2009; Riecher-Rössler et al., 2009), even though the signs that precede schizophrenia (and possibly delusions) across life can be subtle and difficult to evaluate (Welham et al., 2009). Indeed, there is some evidence that early detection of prodromes, and thus early treatment, can reduce the risk of and sometimes prevent a clinical outcome (McClaghan et al., 2006; McGorry et al., 2002; for a review see McGorry et al., 2009). More pragmatically, it can even be cost saving for the health care system (Valmaggia et al., 2009). Second, close to Claridge's view of the continuum, it could help find 'protective' mechanisms that prevent healthy people with these types of experiences from developing full-blown clinical symptoms. Third, schizophrenia, psychosis and delusions are still very poorly understood and the continuum offers a broad range of facilitations for empirical studies. Compared to patients, healthy

participants are easier to recruit and to test. Findings from this population cannot be biased by medication or long-term illness effects.

The aim of the present thesis is thus to see whether further evidence can be brought showing that healthy people experiencing delusional-like ideations and patients with delusions share similar cognitive disturbances. This work proposes to help understand delusions formation and maintenance through the parallel that can be made with the correlates of delusional-like ideations and those of delusions.

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Bridging Chapter 1 to Chapter 2

One of the most robust finding concerning the cognitive biases associated to delusions is the jump to conclusions style of thinking (Huq et al, 1988; for a review, see Fine et al., 2007). Patients with delusions need less evidence to reach a conclusion than patients without delusions or healthy controls. This data gathering deficit has been proposed to participate in delusions formation, as patients would require less evidence to accept a belief (Garety, 1991; Freeman, 2007). This bias has also been observed in healthy participant with delusional-like ideation (Colbert & Peters, 2002; Freeman et al., 2008). A few studies explored whether patients with delusions maintain their conclusion or would jump to a new conclusion as quickly as they did initially. Results are mitigated to date (Fine et al., 2007). However, this jump to new conclusion has never been investigated in healthy people with delusional-like ideation. Chapter 2 uses the classic beads task to explore the jump to conclusions bias of healthy people with delusional-like ideation, but also a modified version of the beads task, to explore the jump to new conclusions.

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Chapter 2

The Relative Contributions of Reasoning Style and Emotions in Predicting Delusional Ideation in the General Population

Abstract

Abnormal reasoning and emotional disturbances have been shown to be correlated with delusional beliefs in patients. Similar results have been observed in the general healthy population with delusional ideation. We aimed to assess the relative contributions of these cognitive and emotional factors in the prediction of delusional ideation. We sampled a population of 80 healthy subjects. Questionnaires measured levels of delusional ideation, depression, anxiety, and cognitive distortions. Reasoning style was examined using a classic and a modified version of the 'beads task'. These variables were entered into a linear regression model to predict delusional thinking, yielding two independent predictors: developing certainty about an alternate belief after a previous belief was held, and depression score ($r = .56, p = 0.004$, for both factors taken together). Such findings in a healthy population sample are supportive of significant, yet independent roles of emotion and reasoning biases in predicting delusional ideation.

Introduction

Delusional thinking has been the focus of many investigations and theoretical formulations in recent years (for reviews, see Garety & Hemsley, 1994; Bental & Kinderman, 1998; Garety & Freeman, 1999; Bentall et al., 2001; Fine et al., 2007; Freeman, 2007). Much of the discussion has centered on the cognitive, affective, and characterological features that underlie both the development and maintenance of delusions. Although biological factors play an established role in the etiology of psychosis, much of the literature looks at these factors separately, as the 'biological milieu' in which the other factors exert their influence. Compelling evidence suggests that people with delusional thinking have both a distinct reasoning style and a more affective symptomatology than people without delusions.

The distinct reasoning style seen in delusional patients is characterized by a tendency to 'jump to conclusions' (JTC). That is, they tend to draw conclusions based on less evidence than non-delusional subjects. The experimental paradigm used to assess this JTC phenomenon has been the 'beads task' where subjects are shown two jars containing mixtures of two colours of beads. One jar has mainly beads of one colour and a small proportion of beads of another colour while the second jar contains the opposite proportions. Subjects are then presented a series of beads from a single jar and are asked to guess from which jar these beads are being drawn. Delusional patients have been shown to require fewer beads before they decide which jar is being used, that is, fewer 'draws to decision' (e.g., Huq et al., 1988; Garety et al., 1991). However, when subjects are asked to provide estimates of their level of certainty that a particular jar is

being used, delusional participants perform no differently from controls (Fear & Healy, 1997; for a review see Fine et al., 2007). This suggests that while delusional patients are hastier in their decision-making, they may not think about probabilities in a different manner. They make abnormal interpretations of probabilities in order to draw conclusions. This variant reasoning-style persists once delusions have remitted (Peters & Garety, 2006), implicating the JTC bias more strongly in delusion-*formation* rather than *maintenance*, since most patients go on to develop acute delusions again in the future.

In a different beads test methodology, Moritz and Woodward (2005) examined the possibility that if delusional patients jump to conclusions, perhaps they also jump to *new* conclusions more frequently. They presented subjects with series of beads that initially appeared to come from one jar and then examined subjects' responses to disconfirmatory beads, that is, to beads that seemed to come from the second jar. They found that delusional schizophrenic patients were more likely than non-delusional psychiatric controls and non-patients to reduce their level of certainty about which jar was used when presented with disconfirmatory evidence. Other studies did not find differences between the way delusional and control groups reacted to disconfirmatory evidence (Fear & Healy, 1997; Dudley et al., 1997; Young & Bentall, 1997). The jury is still out on whether delusional thinking is associated with an inclination to 'jump to *new* conclusions'.

Another way to investigate the role of the JTC bias in delusional beliefs and convictions has been to examine the reasoning style of individuals having non-clinical delusional ideas. Although delusions are typically observed as symptoms of psychiatric

illness, there is evidence that similar experiences also manifest in the well-functioning portion of the population (Peters et al., 1999; Verdoux & van Os, 2002). Several investigators have used the Peters et al. Delusions Inventory (PDI, Peters et al., 1999; Peters et al., 2004) and the Schizotypal Personality Questionnaire (SPQ, Raine, 1991) to identify non-clinical individuals with delusional thoughts or ideas. Longitudinal studies have demonstrated that delusional ideas scores are associated with increased incidence of clinical delusions at 10 year follow-up (Chapman et al., 1994; Kwapil et al., 1997). Colbert and Peters (2002) reported a JTC bias in healthy subjects with high scores on the PDI, supporting the hypothesis that JTC bias is involved in the formation of delusions. Other studies found similar results in healthy participants (McKay et al., 2006; Freeman et al., 2008; White & Mansell, 2009). However, no study to our knowledge has explored the 'jump to *new* conclusions' (JTNC) bias in healthy subjects to date.

More recent conceptualizations of the formation and maintenance of delusions consider the role of emotion. Several studies have demonstrated that low mood and low self-esteem, as well as negative schemas about the self and others, may contribute to the presence of psychotic symptoms (e.g. Close & Garety, 1998). Krabbendam et al. (2005) found that patients who were hallucinating at baseline were more likely to continue having psychotic symptoms three years later if they also exhibited depressed mood at baseline. Barrowclough et al. (2003) found that schizophrenic patients with a negative self-evaluation scored higher on the positive subscale of the Positive and Negative Symptoms Scale (PANSS), a subscale that measures the severity of delusions and hallucinations. Smith et al. (2006) examined patients who suffered relapses in

psychosis and showed that those with worse depression, self-esteem, and negative beliefs, had persecutory delusions of greater severity. In healthy subjects, two longitudinal studies reported that psychosis-prone individuals had higher rate of Major Depressive Disorder than controls (Chapman et al., 1994; Kwapil et al., 1997).

To our knowledge, there has yet been no study of the relative contributions of factors predicting delusional ideation in non-clinical populations. Examining non-clinical subjects allows for the assessment of reasoning and emotional factors under conditions free from the effects of long-term illness on mood and cognition. The aim of the present study was thus to examine normal subjects, relating their delusional ideation to measures of reasoning and emotion.

First, using the beads task, it was expected that healthy subjects with delusional ideations would exhibit a JTC bias. In light of the mixed findings regarding whether delusional patients tend to jump to *new* conclusions, no predictions were made as to the effect changing jars would have. We aimed to clarify this tenuous concept. Second, we investigated the link between emotional states and delusional thinking. We expected that, similar to patients, depression scores and the degree of cognitive distortion would correlate with delusional ideation in our healthy population. We hypothesized that a linear model predicting delusional ideation would thus have both emotion and reasoning style as significant contributors.

Methods

Participants

Eighty (45 females) non-psychiatric participants, aged between 18 and 50 years, were recruited using advertisements in two Montreal newspapers (one French and one English). Subjects were screened by phone to exclude those who reported past or current diagnosed psychiatric disorders, neurological disease, psychotropic drug use, and substance use disorders. All subjects had a minimum of college level education. The procedure to recruit the participants included a quick questionnaire made of 16 items from the schizotypal personality questionnaire (SPQ, Raine, 1991; Appendix 1) that was used to pre-assess delusion over the phone. These 16 items constitute two subscales of the SPQ described by Raine and colleagues (1994) as 'ideas of reference' and 'odd beliefs and magical thinking'. In the first phase of the recruitment, only 35 subjects who scored 5 or more out of 16 (the maximum score), were asked to participate in the study, in order to have enough participants with high delusional ideations scores. 45 no- or low-delusional ideation participants were recruited in a second phase among people with delusional ideations scores smaller than five. As such, all subjects were recruited in an identical manner but at different times.

Each participant gave written informed consent in accordance with the Douglas Institute Research Ethics Board's criteria.

Questionnaires

All questionnaires were presented in the subjects' mother tongue or their preferred written language if considered fully bilingual (English or French only).

Delusional ideation was assessed using the Peters et al. Delusions Inventory (PDI-21, Peters et al., 1999; Peters et al., 2004; Appendix 2) which includes questions asking whether or not the subject has a particular idea and for each of these ideas, a) How often do they think about this delusional content? b) How distressed are they by these thoughts? and c) How much conviction do they feel about these thoughts? Delusional ideation was measured using, first, the total number of Yes responses on the PDI for the questions asking whether or not the subject has a particular idea. Then, three PDI sub-scores were computed for each subject: the degree of conviction (PDI-Conv), of distress (PDI-Distr), and of preoccupation (PDI-Preoc).

To estimate participants' emotional states, we administered the Beck Depression Inventory (Beck et al., 1961; Appendix 3) and the 'State' part of the State-Trait Anxiety Inventory form Y (STAI, Spielberger et al., 1983; Appendix 4), which we will refer to herein as the SAI. Total scores for the SAI were used as a measure of anxiety level and total scores for the Beck Depression Inventory were used as a measure of depression level.

The Cognitive Error Questionnaire (CEQ, Lefebvre, 1981; Appendix 5) was administered to measure levels of common cognitive distortions. In this questionnaire, subjects are presented a series of short vignettes followed by a dysphoric cognition and

are asked to what degree they would have thought the same thing (on a 5-point scale). Scores generated were the sum of all 5-point scores.

Intelligence was estimated using the short form of the verbal subtest of the Wechsler Adult Intelligence Scale—III (WAIS-III, Wechsler, 1997). The WAIS-S subscale examines abstract thinking by a test of *Similarities* between items. The WAIS-K subscale looks at level of *Knowledge* base in a variety of domains.

Beads Task

We used a beads task design based on that of Garety et al. (1991) to measure subjects' tendency to 'jump-to-conclusions'. The task was run using a Microsoft PowerPoint slideshow. Participants were presented with two jars: jar A contains 85% of green beads and 15% of yellow beads, whereas jar B has the opposite proportions. Beads were drawn from one of the two jars and the subject had to guess the jar from which the beads were drawn. All subjects were provided a specific fixed sequence (figure 1), as described in Colbert and Peters (2002). The sequence was stopped as soon as the subject reached a conclusion and was as certain as possible about the jar of origin. The task was conducted first as a practice run (with different colors) and then again for data collection (Part 1). Subjects were given basic feedback (examiner repeated the instructions to the participants, stating that all beads come from a single jar) during the practice sequence to optimize their understanding of the task.

Part 2 of the beads task tested subjects' tendencies to maintain or change their conclusions in the face of disconfirmatory evidence. Subjects were presented with a

new sequence of 38 beads and were told that all beads were coming from a single jar, as in Part 1. However, the first half of the sequence had a majority of green beads whereas the second half had a majority of yellow beads (figure 1). Participants were asked to guess after each bead from which jar the beads are being drawn and how certain they are of their guess.

For part 1 of the beads task, we measured the number of beads presented before a decision was made; this was termed the draws to decision (DTD). For part 2 of the beads task, certainty percentages were collected for each bead, as in Fear and Healy (1997). This yielded four measures: Max 1, Max2, Jar Change, and Beads to Change (BTC). The Max1 and Max2 measures were based on the hypothesis that certainty values on the beads task are related to a person's degree of conviction in beliefs. We examined these potential correlates of conviction during the accumulation of supporting (Max1) and disconfirmatory (Max2) evidence. Max1 corresponded to the maximum certainty (%) attained in first half of the sequence. Max2 corresponded to the maximum certainty (%) attained in second half of the sequence (only for subjects who switched to the alternate jar). We also examined two measures of belief reversal as a way of testing the degree of belief rigidity. The first was the occurrence of a change of belief about which jar was being used, regardless of which jar was chosen at the end ('Jar Change'). For instance, a participant could switch to the alternate jar after seeing a series of disconfirmatory beads, but then switch back. The second was the BTC which corresponded to the number of beads needed to change jar in the second half of the sequence.

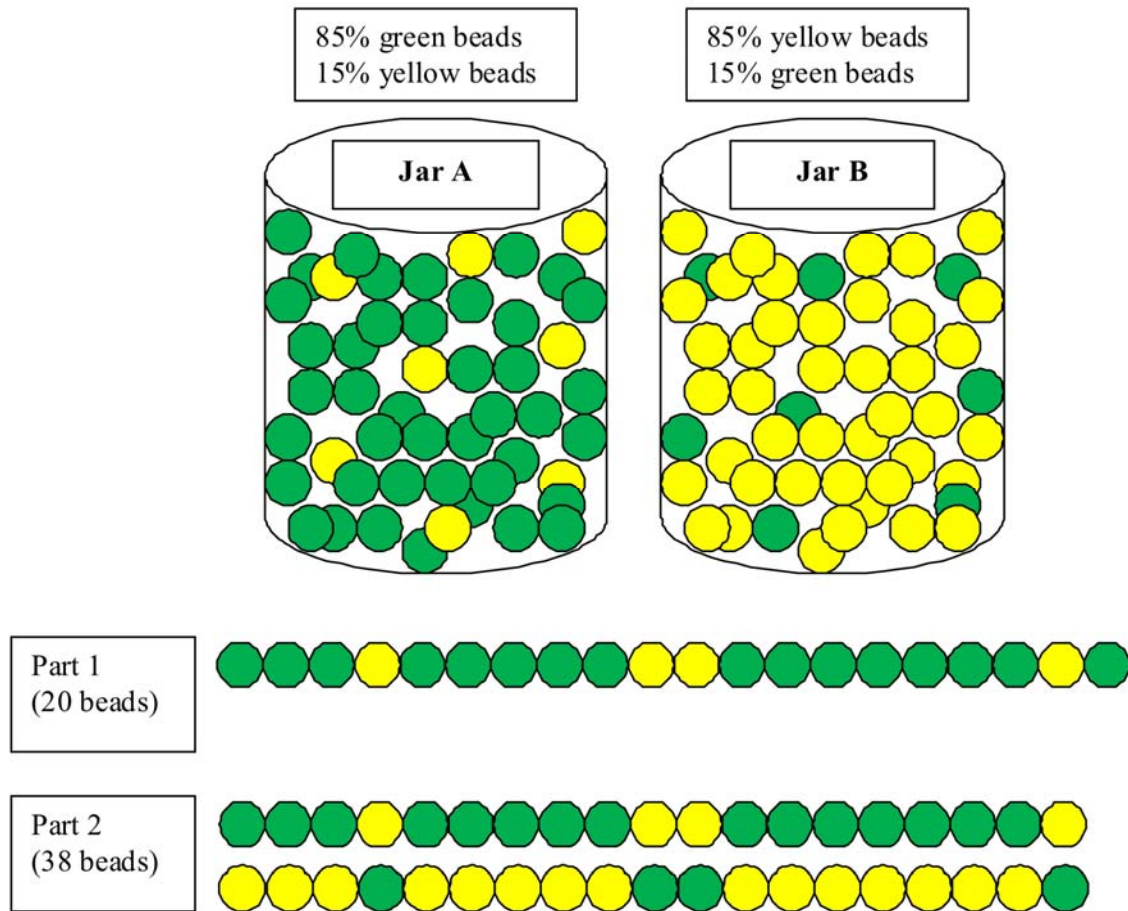


Figure 1: Summary of the sequences used for the beads task.

Analyses and Statistics

The hypothesis that delusional ideation was correlated with distinct reasoning styles and emotional states was tested by examining, first, partial correlations between PDI scores and both performance measures on the beads tasks and measures of emotional states. All correlations were done controlling for age, WAIS-K, and WAIS-S. Most of the correlations were examined as two-tailed except for those with substantial

a priori evidence of directionality (as indicated in Table 3). Once significant correlations were uncovered, each significant factor was entered in a stepwise manner into a linear regression model. It is worth noting that the choice to add only significant correlating variables in the linear regression does not exclude the possibility that other variables could explain delusional ideation. Independent samples t-test were used to test the differences found between the means of a measure when there was a clear need to divide the population into two groups (e.g., those who switched jars vs. those who did not in the second half of the Part 2 sequence).

Results

Demographics

Table 1 shows the means, standard deviations, and possible ranges for each of the measures assessed with the questionnaires. Data were examined to determine if there were effects of demographic characteristics on our measures. We found a significant effect of age on PDI-Distr ($r = -.23$, $p < 0.05$). Younger subjects thus experienced higher levels of distress associated with delusional ideation.

	Possible Range	Mean	S.D.
Age	18-50	29.4	9.73
WAIS-S	0-38	23.5	3.97
WAIS-K	0-28	19.1	4.26
Beck	0-63	3.5	4.33
CEQ	0-96	14.0	9.68
SAI	0-60	24.3	13.32
PDI	0-21	5.4	3.57
PDI-Distr	0-105	12.1	12.00
PDI-Preoc	0-105	12.6	12.37
PDI-Conv	0-105	17.8	14.06
Max1	0-100	87.2	17.80
Max2 *	0-100	72.4	19.35
BTC *	20-38	28.6	5.8
DTD	1-20	9.2	7.26

Table 1: Assessment scores

* Max2 and BTC applied only to subjects who switched jars (N = 32) in the second sequence. Beck = Beck Depression Score; CEQ = Cognitive Error Questionnaire; SAI = State part of the State/Trait Anxiety Inventory; PDI = Peter's et al, Delusions Inventory; PDI-Distr = PDI Distress subscale; PDI-Preoc = PDI preoccupation subscale; PDI-Conv = PDI conviction subscale; Max1 = Maximum certainty (%) attained in first half of the sequence; Max2 = Maximum certainty (%) attained in second half of the sequence; BTC = number of beads needed to change decision in the second half of the sequence; DTD = number of beads needed to reach a decision; S.D. = Standard Deviation

Jumping to Conclusions

We found a negative correlation between the number of draws to decision (DTD) and PDI and all subscales (Table 2). DTD was also correlated with WAIS-S ($r = .31, p < 0.01$). To check whether intelligence accounted for the relationship between DTD and PDI (and subscales), we ran a 2-step linear regression to predict PDI using DTD as the first step and WAIS-S as the second step. DTD remained a significant predictor of all PDI measures even after intelligence was controlled for ($p < 0.05$). There were no correlations between DTD and Beck, SAI, or CEQ. When we looked at the maximum percentage of certainty reached in the first half of the sequence, before the jar was switched (Max1), no correlation was found between these certainty values and measures of delusional ideations.

Jumping to New Conclusions (JTNC) and Reversal of Beliefs

Participants who changed jars in the second half of the sequence of Part 2 (JTNC) scored significantly higher on the PDI ($t(78) = -2.2, df = 78, p < 0.05$) but were not more distressed by, more preoccupied by, or more convinced of their thoughts. Table 2 shows that the strongest correlation regarding the JTNC hypothesis was between PDI-Conv and the maximum percentage of certainty reached after switching jars (Max2). The more subjects believed their delusional ideations to be true, the more certain they became that the alternate jar was being used. Max2 was also correlated with PDI score. There were no significant correlations between intelligence estimates and Max2. It should be noted that only subjects who changed their mind about which jar was used were

included in these analyses ($N = 32$). Interestingly, the BTC (the number of beads needed to change jar in the Part 2) was positively correlated to the DTD (number of beads needed to reach a decision in the Part 1) ($r = .508$, $p < 0.01$). However, BTC only tended to correlate with PDI-conviction and did not correlate with the other PDI scores.

	<i>SAI</i>	<i>CEQ</i>	<i>Beck</i>	<i>PDI</i>	<i>PDI-Distr</i>	<i>PDI-Conv</i>	<i>PDI-Preoc</i>
DTD	.12 (.29)	.021 (.86)	.040 (.73)	-.21 (.032)*	-.20 (.042)*	-.18 (.058)*	-.23 (.021)*
Max1	-.031 (.79)	.21 (.075)	.037 (.75)	.10 (.39)	.092 (.43)	.11 (.33)	.097 (.41)
Max2	-.20 (.31)	-.17 (.38)	.080 (.68)	.47 (.010)	.41 (.028)	.50 (.006)	.36 (.052)
BTC	-.21 (.27)	-.29 (.13)	-.11 (.56)	-.20 (.14)*	-.24 (.11)*	-.26 (.088)*	-.22 (.13)*
Beck	.29 (.006)*	.32 (.003)*	1	.43 (<.001)	.41 (<.001)	.31 (.006)	.37 (.001)
CEQ	.31 (.007)	1		.24 (.037)	.32 (.008)	.22 (.057)	.25 (.030)
SAI	1			.070 (.55)	.060 (.61)	-.031 (.79)	-.006 (.96)

Table 2: Partial Correlations among Measured Factors, indicated as $r(p)$, controlling for IQ and Age

Bonferroni corrections for multiple comparisons were not used, neither for the correlation analyses with a priori hypotheses (see introduction) nor for the other analyses because of their exploratory nature. Boldface indicates $p < .05$. * Identifies correlations that were calculated as 1-tailed.

CEQ = Cognitive Error Questionnaire; Beck = Beck Depression Score; SAI = State part of the State/Trait Anxiety Inventory; PDI = Peter's et al, Delusions Inventory; PDI-Distr = PDI Distress subscale; PDI-Conv = PDI conviction subscale; PDI-Preoc = PDI preoccupation subscale; DTD = Draws to Decision; Max1 = Maximum certainty (%) attained in first half of the sequence; Max2 = Maximum certainty (%) attained in second half of the sequence; BTC = number of beads needed to change jar in the second half of the sequence (note: Max2 and BTC correlations apply only to subjects who switched jars)

Emotion as it Relates to Delusional Ideation and Beads Task Performance

Our measures of 'emotion' were the scores for depression, cognitive distortion, and anxiety. Table 2 displays that there were several positive correlations between Beck scores and PDI and its subscales. As expected, Beck scores were positively correlated with the degree of cognitive distortion (CEQ) and anxiety levels (SAI). Table 2 shows positive correlations between cognitive distortions and all measures of delusional ideation. CEQ levels were correlated with SAI. SAI was also positively correlated with PDI and PDI-Distr. Most interestingly, neither depression nor anxiety correlated with any measures on the beads test. However, cognitive distortion tended to correlate with the maximal certainty values on the first half of the test (Max1).

	Model	r (p)	B (p)
Excluding those who stayed with original jar, N = 32			
PDI	Max2	.42 (.017)	.42 (.017)
	Max2, Beck	.56 (.004)	.40 (.015), .37 (.022)
PDI-Preoc	Beck	.40 (.024)	.40 (.024)
	Beck, DTD	.53 (.008)	.38 (.023), -.35 (.035)
PDI-Distr	Beck	.42 (.016)	.42 (.016)
	Beck, DTD	.56 (.005)	.40 (.014), -.36 (.026)
PDI-Conv	Max2	.47 (.008)	.47 (.007)
Including those who stayed with original jar, N = 80			
PDI	Beck	.43 (<.001)	.43 (<.001)
	Beck, DTD	.49 (<.001)	.44 (<.001), -.24 (.021)
PDI-Preoc	Beck	.37 (.001)	.37 (.001)
	Beck, DTD	.47 (<.001)	.38 (.001), -.28 (.007)
PDI-Distr	Beck	.39 (<.001)	.39 (<.001)
	Beck, Age	.47 (<.001)	.41 (<.001), -.27 (.010)
PDI-Conv	Beck	.32 (.004)	.32 (.004)

Table 3: Linear Regression Models Predicting PDI total and subscales

PDI = Peter's et al, Delusions Inventory; PDI-Distr = PDI Distress subscale; PDI-Conv = PDI conviction subscale; PDI-Preoc = PDI preoccupation subscale Max2 = Maximum certainty (%) attained in second half of the sequence; Beck = Beck Depression Score; DTD = Draws to Decision

Models Predicting Delusional Thinking

The dependent variables were set as PDI and its subscales. Independent variables were entered in a stepwise manner and included all variables that significantly correlated with delusional ideation. In predicting PDI, two independent factors emerged as significant contributors: Max2 and Beck (Table 3). Taken together, these two factors accounted for 31.4% of the variance. As for the PDI subscales, PDI-Conv was predicted only by Max2, while PDI-Preoc and PDI-Dist were each predicted by both depression and DTD. By virtue of the fact that we included Max2 as an independent variable in the regression, we were limiting the analysis to the 32 subjects who changed their minds about which jar was being used in the second beads task. We suspected that this could bias the results and we re-ran the same regression analyses while excluding the Max2 variable, which enriched the N to 80. In this second analysis, PDI was predicted by two independent variables: depression and DTD. PDI-Conv was predicted best by depression alone; PDI-Preoc by depression and DTD; and PDI-Distr by depression and age.

Discussion

In this study, we investigated the relationship between measures of delusional thinking, reasoning styles, and emotional states in a non-psychiatric population. We then examined the relative contributions of these factors in predicting delusional thinking. We found that reasoning abnormalities and depression symptoms both contributed independently to the likelihood of having delusional ideation. Anxiety and

cognitive distortions did not emerge as significant variables in predicting delusional thinking.

We replicated the finding of Colbert and Peters (2002) that non-clinical subjects who are more delusional have a tendency to gather less evidence before drawing a conclusion. Participants who scored higher on the measures quantifying delusional ideation requested fewer beads before deciding which jar the beads were coming from. These findings lend further support to the notion that reasoning abnormalities may underlie the formation rather than the maintenance of delusional thinking.

In the second half of the beads task where the beads sequence suggested that the other jar was being used, novel findings emerged for participants who changed their mind about which jar was used. Those who had more delusional ideas had a propensity to become more convinced that the alternate jar was being used after having already become sure of the first jar. Notably, participants who changed their belief about which jar was being used were more likely to have higher delusional ideations scores. In addition, higher delusional ideations scores tended to correlate with needing to see fewer beads before changing jars. This suggests that delusions may be associated with a tendency to jump to *new* conclusions. The concept of jumping to new conclusions has been considered with reservation (Fine et al., 2007) as it is often regarded as being at odds with an element of the usual definition of delusions: that they are “fixed false beliefs” (Sadock & Sadock, 2003). The current findings suggest a potential reconciliation of this discrepancy between having a “fixed belief” and being more likely to draw new conclusions.

However, the more-delusional subjects who considered an alternate hypothesis did so with a greater sense of certainty (i.e. higher Max2). The strong correlation we found between this measure and the degree of delusional conviction is reminiscent of the results of Woodward et al. (2006) These authors showed that schizophrenic patients exhibited a hindsight bias, that is, a tendency to disregard past errors and act as though they “knew it all along” (the ‘KIA effect’). The patients in that study were inclined to place more importance on the evidence that was currently presented while disregarding past errors and previous accumulations of evidence. This is similar to our findings in subjects with delusional ideation where they were more likely to disregard the fact that they were previously highly certain of one hypothesis and then became sure of an alternate hypothesis. It supports the idea that delusional thinking is related to a tendency to attach too much importance to current/recent evidence while relatively ignoring past events.

Warman and Martin (2006) reported that more delusion-prone subjects were more likely to be overconfident about their ideas yet also more ‘self-reflective’ and more willing to consider the fallibility of their beliefs. Our beads task findings may help to clarify the seemingly paradoxical co-occurrence of ‘overconfidence’ and ‘consideration of fallibility’. Our replication of the classic JTC effect supports the notion that subjects with more delusional ideation are ‘overconfident’ since they form conclusions using less evidence. However, they are also more likely to develop high certainty about alternate hypotheses. We speculate that these subjects have a tendency to consider multiple possibilities simultaneously, making them more likely to mentally

toggle between beliefs. This idea is supported by the results of Laroi and colleagues (2006) where delusion-proneness was correlated with 'openness' to ideas. It is possible that under appropriate conditions, high levels of 'openness' lead to a vacillation between potential beliefs or to consider multiple beliefs simultaneously. This cannot be explored with the beads task where it is difficult for participants to hold two beliefs at once. They are 'pressured' to commit to one belief at a time. Nevertheless, the fact that the participants with higher delusional thinking scores were more likely to consider alternate ideas with more certainty suggests that they actually considered both possibilities (jars) more seriously and were thus more inclined to rapidly change beliefs.

Another component of our study was an investigation of the link between emotional measures and delusional thinking. Depression scores correlated with PDI and all its subscales, a result that echoes findings in psychotic patients, reviewed by Freeman and Garety (2003). In this current cross-sectional study, 'cause and effect' of this association cannot be evaluated, however, it is interesting to note that this correlation exists in a healthy population sample, suggesting that non-clinical emotional disturbances might play a role in the formation or maintenance of delusional thoughts.

As expected, Beck depression scores correlated with levels of cognitive distortion (CEQ). This is in accordance with Beck and colleagues' claim (1979) that depression is associated with negative distortions in thinking. This claim has been supported by empirical studies that examined the association between cognitive errors and depressed mood (e.g. Deal & Williams, 1988; Haaga et al., 1991). CEQ scores also correlated with all PDI measures, except for the conviction subscale for which it was only a trend,

supporting the presence of a link between common cognitive distortions and delusional thinking. Cognitive distortion could be considered an intermediate measure between reasoning bias (distorted appraisals of the likelihood of negative events) and emotional bias (the affective component of the cognitive distortion). Nevertheless, cognitive distortion was not predictive of delusional ideation after accounting for the Beck depression scores (Table 3). Accordingly, cognitive distortion probably does not mediate the link between depression and delusion. It was of interest to see whether cognitive distortions are related to the distinct reasoning styles observed in the beads task. Contrary to our hypothesis, CEQ did not correlate with any of the measures in the beads task.

The final measure of emotion that was examined was state anxiety level. As expected, SAI was highly correlated with depression scores. It was also correlated with CEQ and several PDI scores. However, we found no relation between anxiety levels and performance on the beads task, supporting So and colleagues' study (2008) which found no impact of anxiety manipulation on the JTC. On the other hand, it might have been expected that state anxiety would be associated with the distress accompanying delusional ideas.

The results of our linear regression analyses indicate that the significant factors in predicting the amount of delusional thinking are Max2 and Beck. The high r value indicates that approximately one third of the variance in PDI scores can be accounted for by these reasoning and depression scores. All other variables are rendered statistically insignificant once these factors are entered into the regression. This

suggests that it is by contributing to depression and aberrant reasoning that state anxiety and cognitive distortions exert their effects on delusional ideation. The only other study to our knowledge that examined the relative contribution of reasoning and depression as it relates to delusions is Garety et al. (2005). The authors studied an actively delusional population and found that both the JTC bias and anxiety contributed independently to delusions. This is in contrast to the present study where depression, rather than anxiety, was a significant variable. It is possible that anxiety plays larger role in active clinical delusions than in non-clinical delusional ideations. It is also possible that anxiety is primarily a consequence of delusions rather than a risk factor. However, in both cases, these findings are in accordance with the relative null effect that emotional salience has on JTC (for a review, see Fine et al., 2007). Emotions seem to play a role in delusional thinking, independent of reasoning bias.

The reasoning element that was found to be most invoked in predicting delusional thoughts was not the classic number of 'draws to decision', that is, *the* jumping to conclusions variable. It was Max2, a variable reflecting the certainty with which one becomes sure of *new* conclusions. As this variable has never been studied before, comparison with literature is difficult. DTD was a predictor of delusional thinking, as shown by the significant correlation observed, but less so than Max2. More specifically, when the PDI score was broken down into its components, Max2 was found to be the only predictor of the conviction with which one holds delusional beliefs (Table 3). When the distress of and preoccupation with delusional thoughts were examined, depression was found to predominate as the most relevant predicting variable (Table 3).

These results suggest a multidimensional understanding of delusional thought where reasoning and emotions interplay significantly in the experience of delusional ideation.

In addition to replicating the jumping-to-conclusions phenomenon in non-clinical individuals with delusional ideation, we showed that this population is more likely to develop an unusually high degree of conviction about alternate, new beliefs. Although delusional ideation was associated with levels of depression and anxiety, the link between emotional factors and delusional ideation was not mediated by a distinct reasoning style (that is, not by a JTC or JTNC bias). Emotional and reasoning factors emerged independently in the regression models predicting delusional thinking. With further elaborations of the distinct reasoning style of mildly delusional individuals and delusional patients, more refined approaches to cognitive behavioural therapy may be developed.

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Bridging Chapter 2 to Chapter 3

The beads task, that has been used to demonstrate a data gathering deficit in delusional schizophrenia patients (Huq et al, 1988; Garety et al., 1999), has also been used in healthy participants with delusional-like ideations (Colbert & Peters, 2002; McKay et al., 2006; White & Mansell, 2009), showing that people with delusional experiences need less evidence to reach a conclusion than people without such experiences. Chapter 2 replicated these findings in healthy participant with delusional-like ideation, but also reported novel findings. When changing their mind about their initial conclusion, people with delusional-like ideation were overconfident about their new choice and tended to need little evidence to change their conclusion, suggesting a 'jump to new conclusion'. However, these results barely reached significance even though 80 participants completed the task.

Chapter 3 investigated whether an induction of paranoid feelings could temporarily strengthened these results, on the basis that this induction would exaggerate the reasoning bias already observed. The induction of paranoid feelings did promote a stronger relationship between delusional-like ideation and the amount of evidence needed to reach a conclusion. In addition, the jump to new conclusions was confirmed and reached significance in these conditions.

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Chapter 3

**Reasoning bias in healthy people with delusional-
like ideation after induction of paranoid feelings**

Abstract

Delusions have been correlated to a jump to conclusion style of thinking in patients. However, studies exploring the relationship between experiences similar to delusions in healthy participants and a hasty way of reaching conclusions had difficulties replicating this finding. A previous study showed that participants with delusional ideations display a neurocognitive bias similar to that of delusional patients after we induced paranoid feelings. In the present study, we postulated that a similar induction of paranoid feelings will exaggerate the reasoning bias sometimes found in healthy participants with delusional-like ideations. We use a classic and a modified version of the beads task in healthy participants. Thirty-seven participants took part in the study. To induce paranoid feelings, participants wore an electroencephalogram cap on their head during the whole experiment and were told that their brain electrical activity was recorded. The consent form stated that small currents could be emitted and that one purpose of the study was hidden. In addition, participants were recorded next to a one-way mirror. Higher scores of delusional-like ideations correlated with fewer draws to decision. In addition, higher conviction in these ideas correlated with a relative jump to new conclusion in the modified version of the beads task. These findings suggest that, when healthy people with delusional-like ideation are experiencing paranoid feelings, their cognitive strategies resemble those of deluded patients.

Introduction

Delusions, a hallmark of schizophrenia, have been thought to emerge in part because of abnormal reasoning processes (Garety et al., 1999). Studies assessing this reasoning bias showed that patients required less evidence to reach a decision than controls (Huq et al., 1988; for a review see Fine et al., 2007). The task used to evaluate this reasoning bias is the beads task, where two jars are presented to participants. One jar has a majority of beads of one color and a minority of beads of another color whereas the other jar has the reverse proportions. Beads are drawn one at a time from only one jar, showed to participants and placed back in the jar. Participants have to guess from which jar the beads were drawn (Phillips & Edwards, 1966). The jump to conclusion (JTC) bias is characterized by the very low number of beads deluded patients needed to choose a jar. In schizophrenia patients, most studies found a JTC bias (Garety et al., 2005; Langdon et al., 2008; Moritz & Woodward, 2005; Peters & Garety, 2006; Ross et al., In press; Startup et al., 2008; van Dael et al., 2006; Warman et al., 2007). Peters et al. (2008) showed that this fewer draws before decision was specifically related to delusions and not to schizophrenia or other psychiatric disorders, confirming previous findings (Moritz & Woodward, 2005; Peters & Garety, 2006). Interestingly, a smaller draw to decision (DTD) is also observed in 'at risk' for psychosis participants, suggesting that this bias is present before the occurrence of clinical delusions (Broome et al., 2007). This data gathering deficit might thus exist along a continuum of delusional experiences.

Experiences that resemble delusions have been observed in the general population (Peters et al., 1999; van Os et al., 2001; Verdoux & van Os, 2002). These delusional-like ideations of non-clinical people have also been associated with the JTC bias (White & Mansell, 2009). In a study with a large sample, Freeman et al. (2008) reported that 40 out of the 200 participants needed only 2 beads or less to choose a jar. Most interestingly, the JTC bias was predicted by the degree of conviction in paranoid ideas (ideas of reference and ideas of persecution), and by the number of perceptual anomalies (sensory intensity, distortion of the external world, hallucinations), in accordance with the results of Colbert and Peters (2002). This shows that delusional-like ideation of healthy participants is linked to a cognitive bias similar to that seen in deluded patients. However, the correlations between DTD and delusional-like ideation were not always observed (McKay et al., 2006; Warman, 2008, Lincoln et al., In Press), except for one study that show a correlation between the degree of conviction in delusional-like ideas and DTD (McKay et al., 2008). Thus, the replication of patients' results in healthy people with experiences similar to delusions remains difficult. One aim of the present study is therefore to bring further understanding of this discrepancy.

Contrary to patients, healthy people with delusional-like ideations might be quicker to reach a conclusion depending on the situations. A previous study (Prevost et al., submitted) showed that semantic processing in participants with delusional-like ideations was modulated by whether or not participants experienced paranoid feelings. When paranoid feelings were not induced in participants, no differences in semantic processing were observed between high and low scorers on delusional-like ideations

items (Chapter 4). However, when these feelings were induced in participants, those with delusional-like ideations showed a shallow processing of semantic information (Chapter 5), as found before in patients (Debruille et al., 2007). This suggests that, in these participants, situations inducing paranoid feelings can promote cognitive mechanisms similar to those observed in patients. The present study thus aimed at evaluating whether, after induction of paranoid feelings, delusional-like ideation in healthy people will be associated with a quick decisional process based on little information. We hypothesize that delusional-like ideation and the conviction associated to these beliefs will be correlated to few DTD.

Even though deluded patients jump to conclusion, it is not clear whether they stick to this conclusion or switch to another conclusion, if evidence is given to them in this direction. We evaluated the number of beads needed to change jars in a beads task adapted from Moritz and Woodward (2005). In our adapted version, the sequence of beads shown to participant follows the proportion of one jar for 20 beads and then follows the proportion of the other jar for 80 beads. Participants are thus compelled to change their choice of jar, as the total number of beads finally suggests that the jar of origin is not the one initially thought to be (see method for further details). To our knowledge, only one study evaluated this possible ‘jump to new conclusion’ in healthy participant and showed a trend for a negative correlation between conviction in delusional-like ideation and the number of beads before changing jar (Rodier et al., submitted). In the present study, we hypothesized that paranoid feelings increase the tendency to jump to new conclusions in participants with delusional-like ideation.

Method

Participants

Participants were recruited by advertisements placed in a local French newspaper. They were screened by phone to exclude potential participants with current psychiatric disorders, neurological diseases and drug abuse. All participants had completed secondary school. A total of 37 people, aged between 18 and 50 years (mean = 34.8 years old; S.D. = 9.8), took part in the study. They were financially compensated for their participation in the study and all gave written informed consent in accordance with the Douglas Institute Research Ethics Board's criteria.

Delusional-like ideation

Delusional-like ideation was assessed with the Peters et al. Delusion Inventory (PDI-21, Peters et al., 1999, 2004). This questionnaire has 21 items scored yes/no, the sum of which represents quantitatively delusional-like ideation of a participant (PDI_{tot}). For each item scored, degree of conviction for the belief (PDI-conviction), of distress caused by the belief (PDI-distress) and of preoccupation for the belief (PDI-preoccupation) are also evaluated.

Paranoid feelings induction

To induce paranoid feelings, the methodology used in our previous study was used (Prévost et al., Chapter 5). Participants wore an electroencephalogram cap containing 28 electrodes and were told that their brain electrical activity was recorded throughout the experiment. The consent form was modified and stated that small and harmless currents could be emitted that could temporarily modify their brain activity. It also

stated that a purpose of the study was hidden and would be revealed at the end of the experiment. In addition, participants were tested next to a one-way mirror. It has been shown that being next to a one way mirror enhanced the feeling of being watched, a hallmark of paranoia (Fenigstein and Vanable, 1992). To assess the effectiveness of the induction, participants filled a paranoid feelings questionnaire (Bodner and Mikulincer, 1998; Appendix 6) before and after the induction. To control for anxiety levels and ascertain that the induction did not induce fear rather than paranoid feelings, participants also filled the state and trait anxiety inventory (STAI, Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), before and after the induction.

At the end of the experiment, a debriefing session took place. Participants were asked to read a paragraph that stated that nothing was hidden, that no currents were emitted and that nothing and no one was behind the mirror.

Beads Task

Two jars, containing 85% of purple beads and 15% of orange beads for the jar A and the reverse proportion for jar B, were presented to participants. After reading the instructions, they were told that the examiner will choose one of the two jars and draw all beads only from this jar, one at a time. They were instructed to guess from which jar the beads were drawn. A practice session allowed participants to ask questions and the examiner to repeat the instructions if there was an obvious misunderstanding. The first task included a sequence of 100 beads (figure 1). In this task, participants had to give an estimate of their level of certainty that each bead was coming from jar A or B for the 100 beads. The first 20 beads of this sequence had a large majority of orange beads,

suggesting jar B. The last 80 beads however, had a large majority of purple beads, suggesting jar A. The second task included a sequence of 20 beads comprising a large majority of purple beads, suggesting jar A. Participants were told to choose the jar of origin only when they were as certain as possible. The task ended when they made a decision.

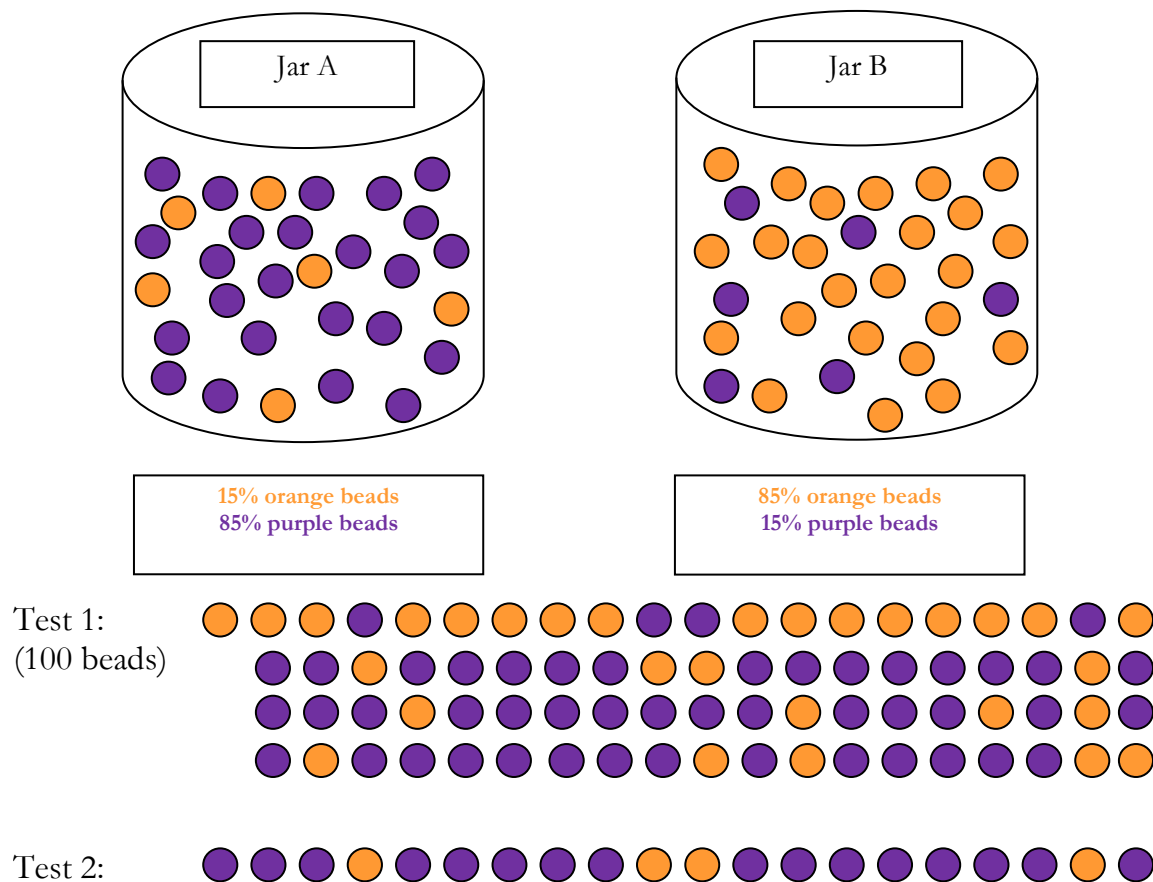


Figure 1: Sequence used for the beads task

Analyses

Paired sample t-tests were used to test the differences in anxiety levels and paranoid levels produced by the induction (before induction vs. after induction).

Pearson's correlations were one-tailed, given the a priori hypothesis. They were used to test the relationship between delusional-like ideations scores and beads task measures.

A general linear model was used to compare the data of the study without induction (Chapter 2) with the data of the present study. As it was predicted that the induction of paranoid feelings will strengthened the relationship between DTD and PDI measures, a univariate analysis of variance was chosen, with the PDI measures as the dependent variables and with DTD and group (without induction vs. with induction) as independent variables.

Results

Paranoid feelings and anxiety level

As shown in figure 2, paranoid feelings were enhanced by the induction ($t = -2.9$, $df = 36$, $p = 0.005$). Anxiety levels, however, did not significantly differ before and after the induction of paranoid feelings ($t = 0.7$, $df = 36$, $p = 0.458$).

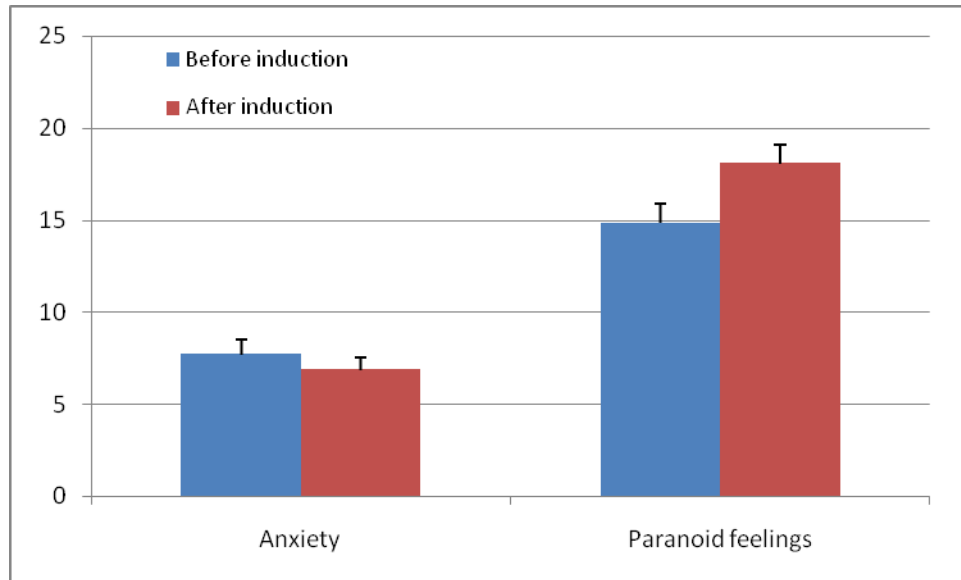


Figure 2: Mean anxiety levels and paranoid feelings levels, before and after the induction. Vertical bars represent standard errors.

Beads task

i) Task 1

Three participants started with the 'wrong' jar (Jar A) and did not change until the end. The degree of certainty for the jar chosen at the first bead of the sequence correlated with the conviction in delusional-like ideas ($r = 0.372$, $p = 0.014$), and only tended to correlated with the PDI-total ($r = 0.260$, $p = 0.066$). For the 17 participants who reached 100% certainty for jar B before the change of jar, that is, during the first 20 beads of the sequence, the number of beads to reach this 100% certainty correlated negatively with the PDI-preoccupation ($r = -0.462$, $p = 0.036$), and tended to correlate with PDI-distress ($r = -0.416$, $p = 0.054$) and with PDI-conviction ($r = -0.423$, $p = 0.051$). For the 22 participants who changed from jar B to jar A after the first 20 beads and reached 100% certainty about their new choice, the number of beads to reach certainty correlated

negatively with PDI-conviction ($r = -0.540$, $p = 0.006$). The level of certainty when changing from jar B to jar A correlate with PDI-distress ($r = 0.410$, $p = 0.029$) and tended to correlate with PDI-total ($r = 0.314$, $p = 0.077$).

ii) Task 2

This task was used to evaluate the draws to decision (DTD) and the jump to conclusion bias (JTC). DTD (mean = 8.9, S.D. = 4.7) was not only negatively correlated with the total number of items scored on the PDI ($r = -0.357$, $p = 0.015$), but also with the distress they caused (PDI-d: $r = -0.340$, $p = 0.020$), the preoccupation they caused (PDI-p: $r = -0.383$, $p = 0.010$) and the conviction in these beliefs (PDI-c: $r = -0.431$, $p = 0.004$, showed in figure 3).

Comparison with our previous study without paranoid feelings induction

The mean DTD in our previous study (9.2, S.D. = 7.3, $n = 80$) did not significantly differ from the one of the present study observed in task 2 (8.9, S.D. = 4.7, $n = 37$). Indeed, the univariate analysis of variance showed that the factor group (without induction versus with induction) was not predicting delusional-like ideation scores except for PDI-preoccupation ($F(1,117) = 4.2$, $p = 0.04$) that was higher in the group with induction than in the group without induction. DTD was predictive of delusional-like ideation scores as a main effect (for PDI-conviction: $F(18, 117) = 2.0$, $p = 0.019$; for PDI-distress: $F(18,117) = 1.8$, $p = 0.04$; for PDI-preoccupation: $F(18,117) = 2.3$, $p = 0.005$), except for PDI-total. In addition, the interaction between group and DTD was significant (for PDI-conviction: $F(12,117) = 2.4$, $p = 0.011$; for PDI-distress: $F(12,117) = 2.2$, $p = 0.02$; for PDI-preoccupation: $F(12,117) = 2.4$, $p = 0.009$), showing that the relationship between DTD

and delusional-like ideation scores was stronger after an induction of paranoid feelings than without induction (as illustrated by figure 3). This only tended to be significant for PDI-total ($F(12, 117) = 1.7, p = 0.09$).

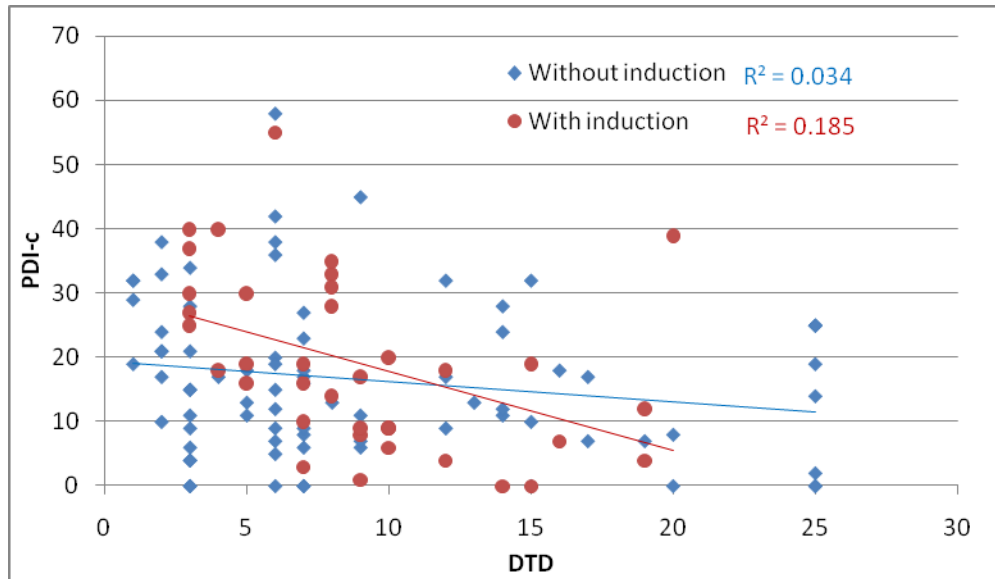


Figure 3: Correlations between draw to decision (DTD) and conviction in delusional-like ideations (PDI-c) in the present study (red) and the previous study without induction (blue).

Discussion

With an adapted version of Moritz and Woodward's task (2005), we observed that participants with high conviction in their delusional-like ideations are quicker to become certain of a change of jar than participants with less conviction in their delusional-like ideations, suggesting a jump to *new* conclusion. Using the classic beads task, we replicated literature findings, that is, participants with high delusional-like ideation scores needed less evidence than those with low scores to make a decision. In addition, the draw to decision was correlated with the conviction in these delusional-like

ideations. When comparing the present result where paranoid feelings were successfully induced (higher paranoid feelings after than before induction with no change in anxiety levels) with our previous study without induction, the association between conviction in delusional-like ideation and the draw to decision was enhanced by the induction. This suggests that, in healthy participants with delusional-like ideations, paranoid feelings can intensify cognitive biases similar to deluded patients.

Even though it has been previously found that high PDI scorers, compared to low scorers, requested fewer DTD (Colbert & Peters, 2002; White & Mansell, 2009), the relation between DTD and delusional-like ideation in healthy participants is far from established yet. One study did not find DTD differences between PDI scorers (Warman, 2008). In addition, correlations between beads DTD and PDI-conviction scores have been observed only once (McKay et al., 2006). Other studies either did not report correlations (Colbert & Peters, 2002; Warman, 2008; Freeman et al., 2008) or did not find significant results (Lincoln et al., In press; White & Mansell, 2009). Our previous study reported a significant correlation between PDI total and DTD but the correlation between PDI-conviction and DTD only tended to be significant (Rodier et al., submitted). In the present study, where paranoid feelings were induced, significant correlations between PDI total and DTD, and between PDI-conviction and DTD were observed, suggesting that the mental state of participants might play a major role in their processing of information. It confirms that healthy participants with delusional-like ideation function with reasoning biases similar to those observed in deluded patients when they feel paranoid.

However, no participants showed the extreme JTC bias that can be observed in patients (2 or less DTD). Only two studies observed this extreme JTC bias in healthy participants (Freeman et al., 2008; Lincoln et al., In press) that correlated with conviction in delusional-like ideations. As mentioned in Freeman et al. (2008), only 20% of their sample (n=200 students) needed 2 or less DTD to reach a conclusion. The paranoid feelings induction did not enhance the JTC in our participants. Further studies are needed to understand whether paranoid feelings slightly reduced the number of beads requested in high PDI scorers or whether it enhanced this DTD in low PDI scorers, or both. The comparison of the correlational analyses of our two studies suggests that it is both (figure 3). The opposite influence of paranoid feelings in low and high scorers is reminiscent of the different reactions between high and low scorers observed in our previous study with the semantic categorization task and the same induction of paranoid feelings in healthy participants. We found that low delusional-like scorers felt more analyzed after the induction whereas high delusional-like scorers felt that others were influencing their performance. It is thus possible that the cognitive strategies in reaction to the induction are not similarly modulated by the paranoid feelings in high and low scorers. Low scorers would tend to be more cautious and thus request more beads before choosing a jar whereas high scorers would tend to resemble patients more closely and to gather less evidence.

The effect of the induction on the modified version of the beads task was also visible. This modified task suggested that beads were being drawn from one jar at the beginning of the sequence but then suggested the other jar for the rest of the sequence. When

participants changed jar and were certain of their new choice, the number of beads needed to reach certainty was lower for higher conviction in delusional-like ideation, suggesting a relative 'jump to new conclusion'. This result confirms the trend observed in our previous study without paranoid feelings induction. Not only is delusional-like ideation associated with a relative jump to conclusion (fewer DTD) but also with a relative jump to new conclusion, especially with induction of paranoid feelings. This supports the idea that delusions are linked to a general deficit in data gathering. Echoing Maher's (1988, 2005) and Kapur's (2003) theory that delusions is the result of perceptual anomalies where information is more salient than it should be and thus triggers more weight in decision processing, delusional-like ideation might result from the same type of discrete anomaly. The relative jump to conclusions and to new conclusions bring evidence that the cognitive process is normal (choice of the correct jar) but the way delusional patients and delusional-like healthy participants process this information is biased, due to the abnormal importance each piece of evidence weights. It has been argued that the level of certainty in the choice of jar should thus correlate with delusions scores to support this theory (Fine et al., 2007), as some studies could not find such a correlation (Colbert & Peters, 2002; Peters et al., 2008). In the present study, level of certainty for the first bead correlated with conviction in delusional-like ideation, as was observed in other studies with delusional-like healthy participants (Warman et al., 2008; McKay et al., 2006) and with deluded patients (Huq et al., 1988; Peters & Garety, 2006). However, level of certainty when changing jar only tended to correlate with the delusional-like ideation.

The present study thus supports the presence of a data gathering deficit in delusional-like healthy participants, which can be reinforced by paranoid feelings. The mental state of participants with delusional-like ideation might explain why some studies could not find a relation between conviction in delusional-like ideation and DTD. This specific bias that makes participants inclined to gather less evidence before reaching a decision could thus be triggered in everyday life depending on the environmental situations and could participate in clinical delusions formation.

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Bridging Chapter 3 to Chapter 4

In chapters 2 and 3, delusional-like ideation was associated to a data gathering bias, just like delusions in psychiatric disorders (for a review see Fine et al., 2007). People with delusional-like ideation needed less evidence to reach a conclusion, but also needed less evidence to switch to another conclusion. This bias was reinforced when they experienced paranoid feelings. These results suggest that paranoid feelings can exaggerate the cognitive biases associated with delusional-like ideation and could thus participate in delusions formation.

In the next chapters, a cognitive bias thought to be involved in delusion maintenance was tested in healthy people with delusional-like ideation. Woodward and colleagues (2007, 2006) showed that clinical delusions and delusional-like ideation were associated with a bias against disconfirmatory evidence, suggesting that contradictory information might not be properly processed. In concordance with Woodward and colleagues, Debruille and colleagues (2007) observed, in deluded schizophrenia patients, a reduction of the amplitude of the N400, an event related potential that has consistently been associated with the processing of semantic information.

An event related potential (ERP) is the averaged electrical activity evoked by a stimulus at a given time, that can be recorded on the scalp of a participant (figure 1). Most ERPs are defined by their polarity, latency, scalp distribution and their sensitivity to experimental manipulations. The N400 is a negative potential that peaks around 400ms after the onset of a meaningful stimulus and is maximal at centro-parietal sites.

This ERP was first described by Kutas and Hillyard (1980) in a study using congruent and incongruent sentences. In this study, the amplitude of N400s evoked by incongruous final words was found to be greater than for congruous final words. Further studies showed that this N400 effect of semantic relatedness could also be observed with the single-word semantic priming paradigm (Neely, 1991). In these studies, N400 amplitudes were reduced for target words that were preceded by semantically related context words compared to those that were preceded by unrelated words (Bentin et al., 1985; Boddy, 1981; Rugg, 1985).

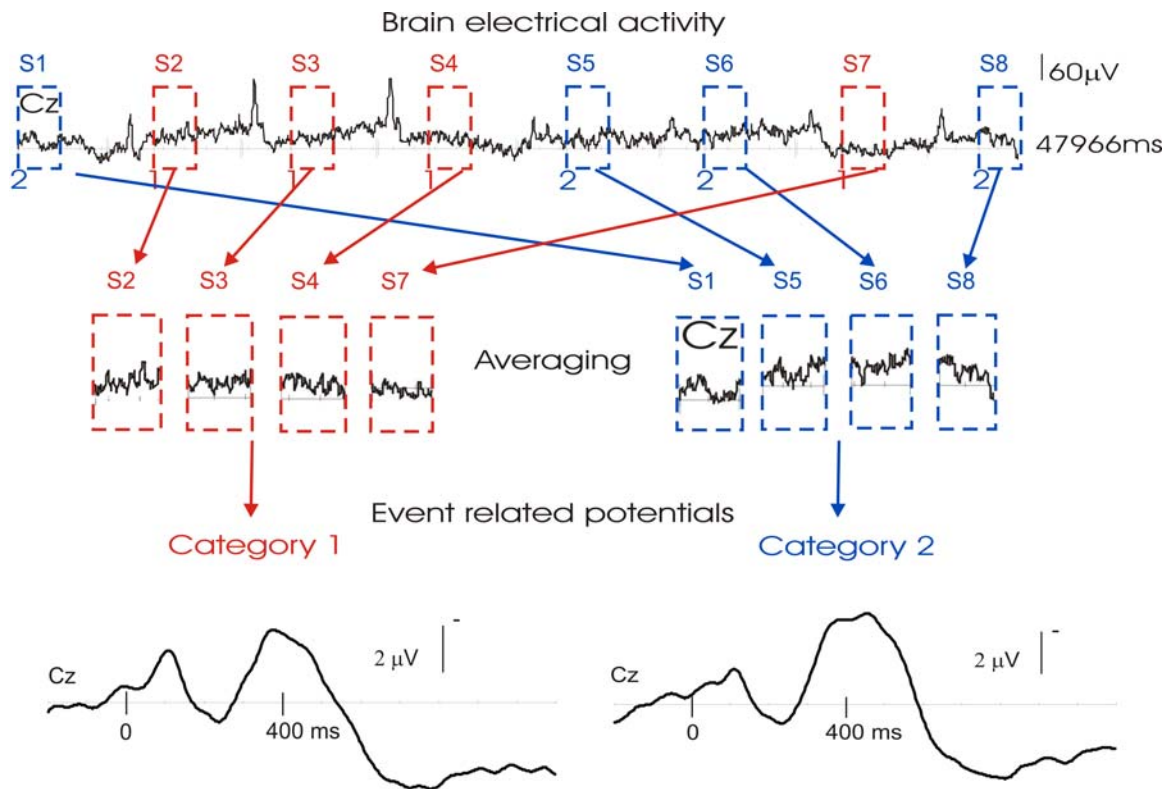


Figure 1: Schematic representation of the event-related potential technique

The long tradition of psychometric studies exploring this semantic priming effect systematically shows shorter reaction times to process a word ('cat') that is preceded by a semantically related word ('dog') compared to an unrelated word ('table'). This semantic priming has been observed in various tasks, such as in the lexical decision task, in which participants have to decide whether the target is a word or not, but also in explicit tasks where participants have to decide whether the target is related to the preceding word or not (for a review, see Neely, 1991). The shorter reaction times suggest that the processing of the target word is facilitated by the semantically related preceding word. The most accepted explanation for this facilitation effect is the automatic spreading of activation: the word 'dog' automatically activates (or pre-activates) concepts that are related to it, facilitating the processing of a following related word, like 'cat' (Collins & Loftus, 1975; Neely, 1977; Posner & Snyder, 1975). The sensitivity of the N400 to semantic relatedness has been shown repeatedly with all sorts of tasks (for a review, see Kutas & Federmeier, 2000) and makes this potential the best neurophysiologic marker to evaluate semantic processing. The reduction of the N400 amplitudes could thus index the facilitation effect of the context on a semantically related target word.

The task used in chapters 4 to 6 is a semantic categorization task with pairs of words, which is the same task as used previously with deluded patients (Debruille et al., 2007). The N400 amplitudes recorded for the target words of the semantic categorization task were analyzed in healthy participants. Chapter 4 aimed at evaluating

the relationship between N400 amplitudes and schizotypal traits that resemble schizophrenia symptoms, and especially delusional-like ideation.

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Chapter 4

**In the general population, N400 amplitude varies
with the disorganization and the interpersonal
factor of the schizotypal personality questionnaire**

Abstract

We examined whether correlations previously found between symptoms of schizophrenia patients and the amplitude of an event-related potential (ERP), the N400, could be also found between schizotypal experiences of healthy subjects and the N400. We chose a semantic categorization task previously used with patients. Schizotypal experiences were measured with the schizotypal personality questionnaire (SPQ). The effects of the other factors were controlled for when assessing the correlations between each SPQ factor and N400s. These correlations were assessed at each electrode site to see whether their distribution on the scalp follows that of the N400 effect. Disorganization and interpersonal scores were found to correlate with ERPs in the N400 time window, as previously reported for the comparable symptoms of patients. However, the scalp distribution of these correlations differed from that of the N400 effect.

Introduction

Research into the symptoms of schizophrenia focuses primarily on the three dimensions that are frequently used to describe schizophrenia, that is, reality distortion, disorganization and negative symptoms (Lenzenweger, 1999). Interestingly, experiences which resemble these symptoms can be observed in the general population (Raine, 1991; Reynolds et al., 2000; Verdoux & van Os, 2002). This finding has raised the idea that, rather than a dichotomy, there could be a continuum between schizophrenia and normality (Strauss, 1969; Claridge, 1997; Johns & van Os, 2001; Shevlin et al., 2007). Although the dichotomous view of psychopathology remains central to mental health care and research, there is a growing debate between these two approaches. One way to go forward is to test whether symptoms of schizophrenia patients and schizotypal personality traits of normals are associated with similar cognitive anomalies, since, as shown by Johns and van Os (2001), such similarities would reinforce the notion of a continuum. An increasing number of studies have looked at the relationship between schizotypal traits in healthy participants and cognitive functions. They observed in these participants similar cognitive anomalies as those found in schizophrenia patients (e.g., Bedwell et al., 2009; Johnston et al., 2008; Wilson et al., 2008).

Semantic processes are among the cognitive processes that have been widely studied in schizophrenia. The N400, an event-related potential (ERP) evoked by any potentially meaningful stimulus and thought to reflect semantic processing, has been related to reality distortion, disorganization and negative symptoms of schizophrenia

patients in various studies (e.g., Debruille et al., 2007; Andrews et al., 1993; Kostova et al., 2005, respectively). In the next paragraphs, these three relations will be reviewed.

The first relation, that between reality distortion and the N400, has been studied because of the ostensible tendency of patients to maintain their delusions in the face of disconfirmatory evidence. It has been hypothesized that this 'tendency' is related to a deficit in integrating the information that challenges their beliefs (Freeman, 2007; Moritz & Woodward, 2006). The N400 was thus used as an index of this integration since the amplitude of this ERP appears to be proportional to the amount of effort that is spontaneously deployed to integrate unexpected semantic information into cognitive representations (e.g., Holcomb, 1993). Stimuli that arguably trigger more integration effort, such as stimuli that do not match the context, elicit N400s of greater amplitudes than stimuli that are primed because they match preceding stimuli. Consistent with the N400 integration hypothesis and with their deficit in integrating disconfirmatory evidence, schizophrenia patients who were more delusional were found to have smaller N400s than patients who were less delusional (Debruille et al., 2007). The link between N400 and delusion severity in schizophrenia patients was confirmed by the results of Kiang and colleagues (2007). These authors reported that the severity of psychotic symptoms (i.e., delusions and hallucinations) correlates with a reduction of the N400 effect, that is, with a reduction of the difference between the amplitude of the N400 to mismatching stimuli and that to matching stimuli. Since the variations of one or of both of these amplitudes could be responsible for smaller N400 effects, one of the aims of the present study was to carefully differentiate the three N400 measures. In the rest of

this paper, 'N400 amplitude' will be used only to designate the raw amplitude of the N400 deflections, whereas the phrase 'N400 effect' will be exclusively devoted to N400 differences.

The second relation, that between disorganization and N400, has been studied partly because of the deficit found in schizophrenia patients in processing context efficiently and in keeping it in working memory during long stimulus onset asynchronies (SOAs) (Cohen & Servan-Schreiber, 1992; Hardy-Baylé et al., 2003; Hemsley, 2005). Accordingly, a word that is related to a following target word induces less priming in patients than in normal controls. One should thus observe a correlation in the direction opposite to that predicted for delusions. N400s elicited by primed target words should be larger in more- than in less-disorganized patients (see discussion section for another hypothesis leading to the same prediction). The results of previous works support that prediction. Correlations were found between thought disorder and larger N400 amplitudes for congruent targets in Kuperberg and colleagues (2006) and in Kostova and colleagues (2005, personal communication), which possibly explain the smaller N400 effects observed in Ditman and Kuperberg (2007). Interestingly, one study described greater N400s for the incongruent targets for higher thought disorder scores (Salisbury et al., 2000) while another mentioned greater amplitudes for the mean of congruent targets and incongruent targets (Andrews et al., 1993). Incidentally, it has to be noted that, in all the above mentioned studies, the word or the sentence used to prime the target stimulus was shown just once in the experiment. This can only increase the impact of the problematic maintenance of this context information in working memory

and further jeopardize the facilitation this context induces and account for the larger N400 amplitudes obtained for the targets.

However, correlations between N400s and the two symptoms mentioned above were not always observed (Ditman & Kuperberg, 2007; Kostova et al., 2005; Salisbury et al., 2000). For delusion, one study reported an opposite relationship, that is, greater N400 amplitudes with higher delusion scores (Kiang et al., 2008). For disorganization, the correlations with N400s sometimes failed to be found (Kiang et al., 2007, 2008) and one study described a relationship going in the reverse direction, that is, reduced N400 amplitudes for stimuli that do not match the context (non-exemplar category) for highly disorganized patients (Debruille et al., 2007). Nevertheless, these discrepancies may not be so surprising. Because delusions and disorganization can be positively correlated to each other (Lenzenweger & Dworkin, 1996; for comparable experiences in the general population see: Raine et al., 1994; Reynolds et al., 2000) their opposite influences on N400 amplitudes could cancel each other, or, one could even reverse the influence of the other. Therefore, in the present study, which aimed at evaluating the relation between schizotypal traits in healthy participants and the N400, it was decided to use partial correlations in order to assess the effect of one schizotypal trait on N400s while controlling for the effects of the two other traits.

Similarly, the third relation, that between the negative symptoms of schizophrenia and the N400 was not found in some studies (Ditman & Kuperberg, 2007; Kiang et al., 2008; Kuperberg et al., 2006; Salisbury et al., 2000). But two studies with schizophrenia patients found a tendency for a reduced N400 effect with more negative

symptoms (Kiang et al., 2007; Kostova et al., 2005). Moreover, when looking at similar schizotypal traits in healthy subjects, one study reported significant results. Kiang and Kutas (2005) observed a correlation between diminished N400 effects and higher scores for the interpersonal items of the schizotypal personality questionnaire, the SPQ (Raine, 1991), which reflect experiences that resemble negative symptoms in patients. As this interpersonal factor also includes paranoid ideation and social anxiety, the authors proposed that a mistrust bias might be responsible for this finding. They based their proposition on a study where mistrust was induced in university students (Schul et al., 2004). In this study, behavioral responses showed both an increased semantic priming effects for words having a meaning opposite to that of the prime (e.g., hollow-full) and a decreased effect for words that were synonyms (e.g., hollow-empty). The authors of this behavioral study proposed that “mistrust may be associated with increased activation of message-incongruent associations and decreased activation of message-congruent associations, by encouraging a person to focus more on the possibility that a message is invalid”. Kiang and Kutas (2005) thus related their smaller N400 effects to this decreased activation of message-congruent associations.

In addition to the interpersonal score, the SPQ can also be used to measure the disorganization trait and delusional-like ideation in healthy subjects. The idea that these experiences of healthy subjects resemble schizophrenia symptoms has been supported in several studies (Raine, 1991; Reynolds et al., 2000; Verdoux & van Os, 2002; for experiences which resemble delusions see Peters et al., 1999; van Os et al., 2000; for traits which resemble disorganization, see Coleman et al., 1996; Gooding et al., 2001; for

traits that resemble negative symptoms see Chapman et al., 1980; Cadenhead et al., 1996). Nevertheless, to stress the fact that there may be qualitative and quantitative differences with the symptoms of patients, a different terminology is used for healthy subjects. The phrase 'disorganization trait' is used to refer to experiences that resemble disorganization and the phrase 'delusional-like ideation' to refer to experiences evaluated by the SPQ that are observed in healthy subjects and that resemble delusions in patients.

Recent studies using schizotypal personality measures have demonstrated that ERPs may be used to study neurocognitive processes related to schizotypal traits in healthy individuals (Gassab et al., 2006; Kiang & Kutas, 2005; Wan et al., 2006; Wang et al., 2004). Although to a lesser extent than in the case of schizotypal personality disorders, the existence of measurable schizotypal traits in healthy populations may be seen as an opportunity for approaching the mechanisms of schizophrenia symptoms in a less confounded context. Indeed, whereas some patients' anomalies might also be the consequences of the long term disability induced by symptoms, this is less likely to be the case in healthy populations. Moreover, as with schizotypal personality disorders, studying healthy subjects allows interpretations free from the problems of patients' medication.

The aim of the present study was thus to explore the neurocognitive mechanisms underlying schizotypal personality traits in healthy individuals. More specifically, our goal was to see whether we could find in these subjects the relations observed in patients between N400 and the three schizophrenia symptoms, namely, the

smaller N400s with higher delusions scores, the greater N400s with more disorganization, and the smaller N400 effects in case of more severe negative symptoms. Although acknowledging that schizotypal personality traits of healthy subjects may be quantitatively and qualitatively different from schizophrenia symptoms, we aimed at testing whether these traits are accompanied by cognitive processes similar to those of patients, which would bring further support to the idea of a continuum between schizophrenia and normality (Peters et al., 1999; van Os et al., 2000).

In addition to the above-mentioned use of partial correlations to control for the effect of the other schizotypal factors when focusing on the relation of one of them with the N400, three features characterized the present study. First, we used the protocol of our previous study in patients (Debruille et al., 2007). This was done both to compare results obtained in patients to those in normals and to circumvent the following interpretation problem. In studies where each target word was preceded by a particular context word, the anomalous N400s to targets observed were seen as due to an abnormal priming of targets. This abnormality was thought to be related to a deficient processing of the context or to a problematic maintenance of the prime in working memory. However, if the processing of context words is impaired, the processing of targets also may be impaired and nothing can help to decide which of the two possibilities accounts for the anomalous target N400s. In the semantic categorization task of Debruille et al. (2007), the same category word was used as a context (i.e., first word of the trial) for all the trials for which participants had to make a decision. This was

aimed at facilitating the processing of the context so that it produced the same effects on the processing of the target word (i.e., on the second word of the trial) in patients as in normals. A previous study using this particular protocol reported an absence of significant differences between patients and normal controls in the ERPs evoked by such invariant context words (Debruille et al., 2009). Thus, if the disorganization trait is found to have an effect on the N400s to the targets of our study, it will be more likely to be due to a deficit in processing the targets themselves, which would, nevertheless, have to be confirmed by an absence of effects of schizotypal traits on each of the component of the ERPs elicited by the context word.

The second feature that characterizes the present study is to compute the correlations for each electrode site. For written words, the N400 effect reaches a maximum over midline centro-parietal electrodes and is slightly larger over right than left parietal sites (Holcomb, 1988; Kutas et al., 1988). Correlations involving the N400 effect can thus be expected to reach a maximum at these sites.

The third feature of this study derives from the fact that variations of the size of the N400 effects may have several causes. A smaller N400 effect can be due to larger N400 deflections for matching stimuli, to smaller N400 deflections for mismatching stimuli, or to both. As mentioned above, when discussing the larger N400 deflections found with disorganization and with the interpersonal factor in the matching conditions, such results have different functional significances. Therefore, correlations for each of the three schizotypal factors were measured three times, once with the N400s elicited

by matching stimuli, once with the N400s for mismatching stimuli and once for the N400 effects.

Methods

Participants

Forty-nine right-handed participants (35 women, 14 men) aged between 18 and 51 years were recruited by advertisements in an English and in a French newspaper. Participants who answered these ads were asked what their mother tongue was. Only English and French were accepted. The rest of the procedure was carried in the language of the participants. They had to have normal or corrected-to-normal vision and were screened by telephone and systematically excluded for any history of DSM-IV Axis I psychiatric illnesses, except for depressive episodes that resolved at least two years ago. The use of these a priori criteria led to include 2 participants who had suffered from depression. Both had recovered and were off medication for more than 6 years. Participants with a history of head injury with loss of consciousness longer than 10 minutes were excluded, as well as participants with neurological or medical conditions known to compromise brain function and participants abusing drugs. The procedure to recruit the participants included, first, a short questionnaire made of the 16 items of the 'odd belief and magical thinking' and 'ideas of reference' subscales of the schizotypal personality questionnaire (SPQ; Dumas et al., 2000; Dumas et al., 1999; Raine, 1991). They were used to pre-assess delusional-like ideation over the phone. In the first phase

of the recruitment, only those who scored 5 or more out of 16 (the maximal score) were asked to participate in the study (n=25), in order to have enough participants with high delusional-like ideation scores. No- or low-delusional-like ideation participants (n=24) were recruited in a second phase among people with delusional-like ideation scores smaller than five and whose demographic characteristics (age, gender and number of years of education) matched those of the high-delusional-like ideation score participants. At their arrival in the lab, participants gave written informed consent after the procedures were described according to the criteria of the Research Ethics Board of the Douglas Mental Health University Institute.

Before having their ERPs recorded, participants had to complete the SPQ. This questionnaire is based on the DSM-III-R criteria for schizotypal personality disorder and includes nine subscales that can be grouped into three clusters or factors: (1) interpersonal, (2) disorganization, and (3) cognitive-perceptual (Raine et al., 1994). The validity of the whole SPQ has been demonstrated (Raine, 1991). Its clusters have been defined by a factor analysis (Raine et al., 1994) and used in many previous studies (e.g. Dickey et al., 2005; Kiang & Kutas, 2005; Sommer et al., 2008). The interpersonal score is computed by adding the scores for the 'social anxiety', the 'no close friends', the 'constricted affect' and the 'paranoid ideation' subscale. The disorganization trait score is computed by adding the score for the 'odd speech' subscale to the score for the 'odd or eccentric behavior' subscale. Both subscales load on the same factor (disorganization) in the general population and in clinical population (Reynolds et al., 2000). The

‘cognitive and perceptual’ cluster could not be used to evaluate delusional-like ideation since it also includes hallucinations. It is thus the scores for the two subscales ‘Idea of references’ and ‘Odd beliefs and magical thinking’ that were used here, as previously done in a study performed to assess the neurocognitive mechanisms underlying delusional-like ideation in normals (e.g. Woodward et al., 2007). Here, these two scores were simply added. Note that paranoid ideation was not integrated into the delusional-like ideation score because this subscale does not include delusional-like items *per se* but rather, suspiciousness, which is already included in the interpersonal factor.

Pearson correlations between subjects’ characteristics are displayed in Table 1. Each SPQ factor correlated significantly with the two others. Additionally, age negatively correlated with the overall SPQ scores and with the interpersonal and disorganization factors but not with delusional-like ideation.

	Mean (Stdev)	Age	Years of study	SPQ	Inter- personal	Disorga- nization
Age	30.3 (10.4)					
Years of study	14.3 (1.7)	0.00				
SPQ	18.9 (14.1)	-0.31*	-0.13			
Interpersonal	7.2 (6.2)	-0.30*	-0.15	0.90***		
Disorganization	4.5 (3.7)	-0.34*	-0.17	0.85***	0.68***	
Delusion	5.1 (4.2)	-0.22	-0.04	0.85***	0.62***	0.62***

SPQ: Total score for the schizotypal personality questionnaire

*p < 0.05, **p < 0.01, ***p < 0.001

Table 1: Characteristics of the participants (1st column) and correlations (Pearson r coefficients) between these characteristics (following columns).

Task

Subjects were seated comfortably in a dimly lit room in front of a computer screen placed 1 m from their eyes. Black stimuli were presented on a white background at the center of this screen. Trials were made of two serially presented words. In two-third of the trials, the first word was the question word 'ANIMAL?' and, in one-third of the trials, the first word was the instruction 'INACTION'. These words were then followed by the target word. The stimulus onset asynchrony was 2 seconds and each word was displayed for 1 second. The target word was either an exemplar of the animal category (e.g., lion) or a non-exemplar of this category (e.g., hammer). Subjects had to decide whether or not the target word belongs to the animal category as rapidly and as accurately as possible by pressing one of two keys with their right index finger. The 'INACTION' word, introduced so that subjects have to pay attention to the first word, signaled to the participants that they should not respond to the target stimulus, which was also either an exemplar or a non-exemplar of the animal category. The non-exemplars stimuli comprised names of tools, piece of furniture, office and kitchen objects, building and parts of buildings, and transportations means. The target word was followed 2 to 2.5 seconds later by the word 'Blink', giving the subjects the opportunity to blink without disrupting the electroencephalogram (EEG) signal of the trial. All target words used were selected from among familiar words using the Content, Mousty and Radeau's database (1990) for the French words and the Kucera and Francis (1967) counts for the English words. In the French version, in both the exemplar and the non-exemplar categories, there were forty-seven words with a frequency comprised

between 0 and 1000 out of 100 millions occurrences, nine words with a frequency comprised between 1000 and 3000 and four words with a frequency higher than 3000. In the English version, in both categories, there were forty-seven words with a frequency comprised between 0 and 9 out of one million; ten words with a frequency comprised between 10 and 17 and three words with a frequency comprised between 35 and 117. The average length of words in each category did not differ from one another. In the French version the mean number of letters was 6.5 ± 1.7 in the exemplar category and 6.7 ± 1.5 in the non-exemplar category. In the English version the mean number of letters was 5.5 ± 1.8 in the exemplar category and 5.75 ± 1.7 in the non-exemplar category. In the action condition, there were 60 trials with exemplar target words and 60 trials with non-exemplar target words. For the 'INACTION' condition there were 30 trials for each of the two stimulus categories. So, for both conditions, the probability of occurrence of an animal target word was 50%. Each target word was presented only once, thus the probability of occurrence of a particular target word was 1 out of 180.

Data acquisition

Behavioral responses were recorded for each trial. The EEG was recorded with tin electrodes from the ECI cap (Electro-Cap International), which were placed according to the modified expanded 10-20 system (American EEG Society, 1991) with a right ear lobe initial reference. Twenty-eight electrodes were used. Sites were grouped into three

subsets. The sagittal subset included Fz, FCz, Cz, and Pz; the parasagittal subset, FP1/2, F3/4, FC3/4, C3/4, CP3/4, P3/4, O1 and O2; and the lateral subset, F7/8, FT7/8, T3/4, TP7/8, T5 and T6. Eye movements and blinks were monitored with F7 and F8 for horizontal movements and with FP2 and an additional electrode placed on the right cheekbone for vertical movements. The impedance was kept below 5K Ω . The gain of the Contact Precision Instruments amplifiers used was set at 20 000. The half amplitude cut-offs of high and low pass frequency filters were set at 0.01 and 100 Hz, respectively. In addition, a 60 Hz electronic notch filter was used. EEG signals were digitized at a 256 Hz sampling frequency and stored along with the stimulus and response codes. The EEG was re-referenced off-line to the mean of the left and right earlobes signals.

Measures

EEG epochs corresponding to trials with incorrect responses or with reaction times shorter than 200ms or longer than 2000ms were rejected. We also rejected trials with excessive eye movements, amplifier saturations or analog-to-digital clippings lasting more than 100ms. Our baseline was set between –200 and 0 ms. Averages were calculated over the time period between target word onset and 1000 ms later. The minimum numbers of artifact-free trials averaged by subject was 28 and 30 for the exemplar and the non-exemplar categories, respectively. The mean number of trials averaged was 49 (SD 8) in both the exemplar category and the non-exemplar category. The N400 amplitude was measured by computing the mean voltage of the ERPs in a

350-550 ms time window, relatively to the baseline. This time window was centered on the negative peak observed on the grand average of the non-exemplar – exemplar ERP subtractions. For each subject, a mean voltage was computed at each electrode for the N400 in the exemplar category, for the N400 in the non-exemplar category and for the N400 difference (non-exemplar minus exemplar amplitudes).

Analyses

Mean reaction times (RTs) and accuracies (As) were obtained in the action condition, that is, for all trials except those with INACTION as the prime word. Two subjects were excluded from all analyses because their error rate was greater than 10%. RTs and As were analyzed with separate one-way repeated-measure ANOVAs (i.e., t-tests) with category (exemplar versus non-exemplar) as the within-subject factor. Assuming a linear decomposition, partial correlations were run to control for the effect of the two other schizotypal factors. These correlations were run between each of the three factors and RTs on the one hand, and each of the three factors and As, on the other hand. This was done in an exploratory way, to generate a priori hypotheses for future studies.

For mean voltages of ERPs in the N400 time window, a two-ways repeated measure omnibus ANOVA was run with category (exemplar vs. non-exemplar) and electrode site as within-subjects factors. The three subsets of electrodes were analyzed separately when an interaction between the category factor and the electrode was

observed in the omnibus ANOVA. For the parasagittal and lateral subsets of electrodes, the hemi-scalp (right versus left) was added as a third within-subject factor. We used the Greenhouse and Geisser (1959) procedure to compensate for heterogeneous variances for the factor having more than two levels, that is, the electrode factor. In each case, the original degrees of freedom are reported together with the *Epsilon* (E) correction factor and the corrected probability level.

The mean voltage values of the N400s in the exemplar category, the N400s in the non-exemplar category and the N400 effect (non-exemplar minus exemplar differences) were correlated (two-tailed) to the delusional-like ideation, the interpersonal and the disorganization factor scores at each electrode, to assess the scalp distribution of the effects. Partial correlations between ERP measures at each electrode and each SPQ subscale scores were then computed. This allowed controlling for the two remaining SPQ factors scores, which was necessary since significant correlations were found between these factors (see Table 1) and since their comparable symptoms have been found to have opposite effects on ERPs in the N400 time window in studies with schizophrenia patients (e.g., Andrews et al., 1993; Kuperberg et al., 2006). Partial correlations were possible since correlations could be assumed to be linear. For the correlation between disorganization trait and interpersonal, the Pearson's r was 0.68 (see table 1). The use of a 6 degrees polynomial function to find the best fit only improves the r up to 0.71. The initial straight line was thus an adequate solution. For the correlation between the disorganization trait and delusional-like ideation, the Pearson's r was 0.62. The use of the same type of complex function only improves the r up to 0.64.

Finally, for the correlation between delusional-like ideation and the interpersonal trait, for which the Pearson's r was 0.62, the use of a complex polynomial function only improves the r up to 0.64. Pearson, and thus, linear correlations were therefore a good model to represent the association between factors.

Results

Behavioral data

Mean reaction times were shorter in the exemplar ($843 \text{ ms} \pm 122$) than in the non-exemplar ($923 \text{ ms} \pm 160$) category ($F_{1,45} = 55.4, p < 0.001$). Accuracies (i.e., error rates) did not differ significantly between the exemplar ($2.8\% \pm 3.5$) and the non-exemplar ($2.3\% \pm 3.1$) categories. No correlation with delusional-like ideation, disorganization trait or interpersonal scores was found, either with reaction times or with error rates, even when running partial correlations and thus when studying the effect of one factor while controlling for the two others.

ERP data

ERPs in the N400 time-window were more negative in the non-exemplar than in the exemplar category as showed by the omnibus ANOVA ($F_{1,45} = 53.6, p < 0.001$). Since the category factor interacted with electrode ($F_{27,1215} = 6.5, E = 0.169, p < 0.001$), we conducted ANOVAs for each subset of electrodes and observed that ERP amplitudes in the non-exemplar category was greater than in the exemplar category for the three

subsets (sagittal: $F_{1,46} = 45.2$, $p < 0.001$, parasagittal: $F_{1,45} = 51.5$, $p < 0.001$ and lateral: $F_{1,46} = 46.5$, $p < 0.001$), as observed on Figure 1. ERPs were more negative over the left than over the right hemi-scalp at the parasagittal ($F_{1,45} = 25.2$; $p < 0.001$) and lateral ($F_{1,46} = 13.1$, $p < 0.001$) subsets (Figure 2). In contrast, a category x hemi-scalp interaction at the parasagittal subset ($F_{1,45} = 4.2$, $p = 0.045$) revealed that the difference between the exemplar and the non-exemplar categories was larger over the right than over the left side of the scalp (Figure 3 & 4). The post-hoc analyses performed showed that this difference was significant for each hemi-scalp at the parasagittal subset (left: $F_{1,45} = 44.9$, $p < 0.001$; right: $F_{1,45} = 53.8$, $p < 0.001$).

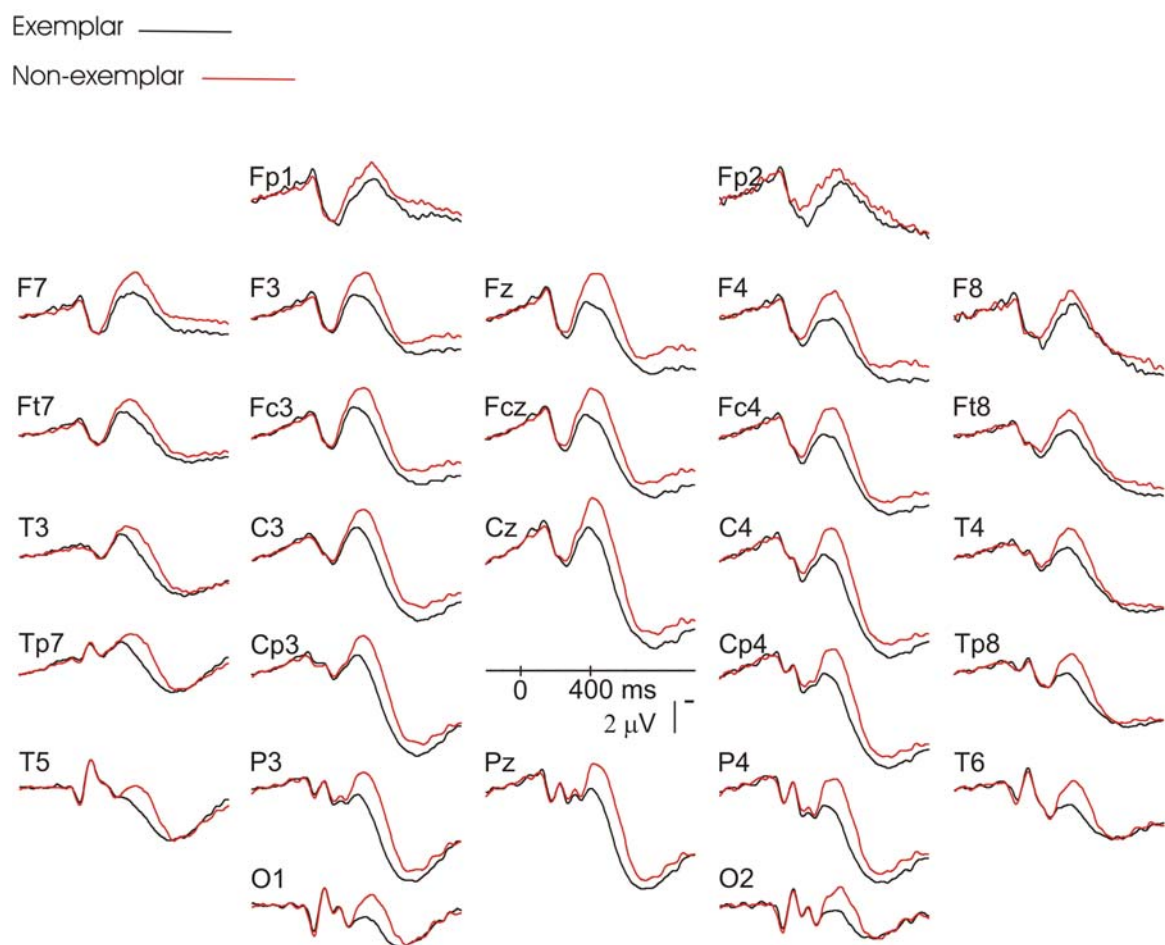


Figure 1: Grand average ERPs for the exemplar and the non-exemplar categories (n=47)

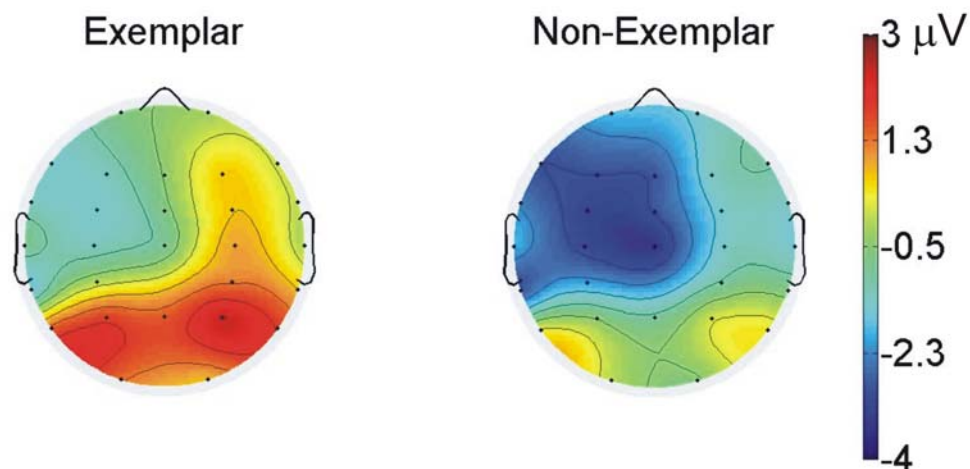


Figure 2: Spline interpolated voltage maps of the N400 amplitude for the exemplar and the non-exemplar categories in the 350-550 ms time-window

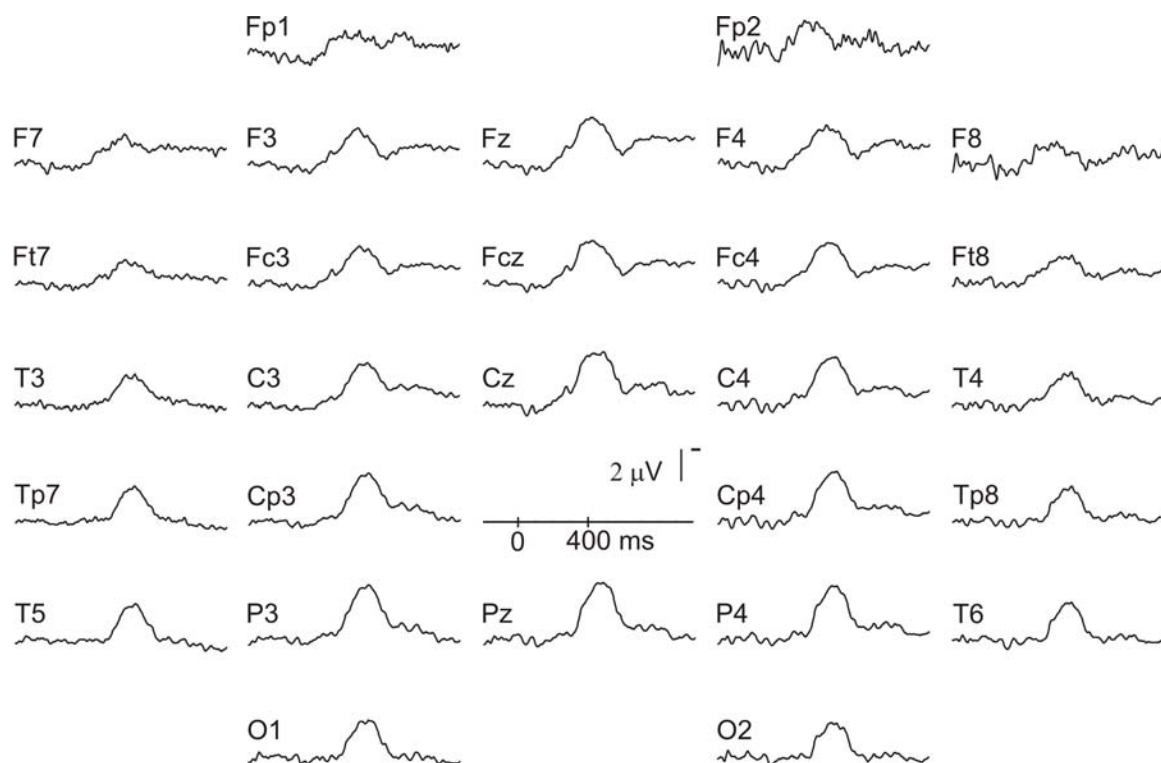


Figure 3: Grand average ERPs of the N400 effect (non-exemplar minus exemplar ERPs) (n=47).

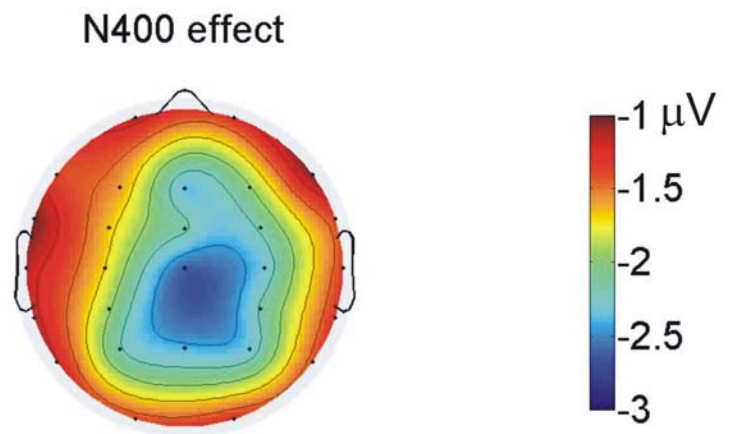


Figure 4: Spline interpolated voltage maps of the N400 effect (non-exemplar minus exemplar ERPs) in the 350-550 ms time-window.

The Pearson correlations between each SPQ factor and ERP amplitudes in the N400 time-window were assessed for each of the 28 electrodes. Partial correlations were then systematically computed to control for the two other SPQ factors. As displayed in Figure 5, no significant bivariate correlation between delusional-like ideation and ERP amplitudes was found over centro-parietal electrodes. Some bivariate correlations were observed at frontal electrode sites that were no longer significant when we controlled for the interpersonal and the disorganization scores.

The disorganization scores negatively correlated with ERP voltages in the N400 time window over all the frontal and central electrodes in the exemplar and non-exemplar categories. The higher the disorganization scores, the more negative the ERPs were in the N400 time-window at these sites in both categories. These correlations remained significant after adjustment for delusional-like ideation and interpersonal scores, as shown by Figure 5. However, the N400 *effect* did not correlate with the disorganization factor, which suggests that the increase in negativity induced by the disorganization trait was similar in the exemplar and the non-exemplar category.

Regarding the interpersonal factor, no correlation was found with the ERP amplitude in the exemplar and non-exemplar categories after adjustment for delusional-like ideation and disorganization scores (Figure 5). In contrast, there were positive correlations between the N400 effect and interpersonal scores, which remained significant over the left central electrodes when delusional-like ideation and disorganization scores were controlled for. Smaller N400 differences were associated with higher interpersonal scores.

As age correlated with disorganization and interpersonal factors, each partial correlation was also run controlling for age in addition to the others factors. Correlations were also run without the two participants with a history of depression. This did not change the correlations found or their scalp distribution.

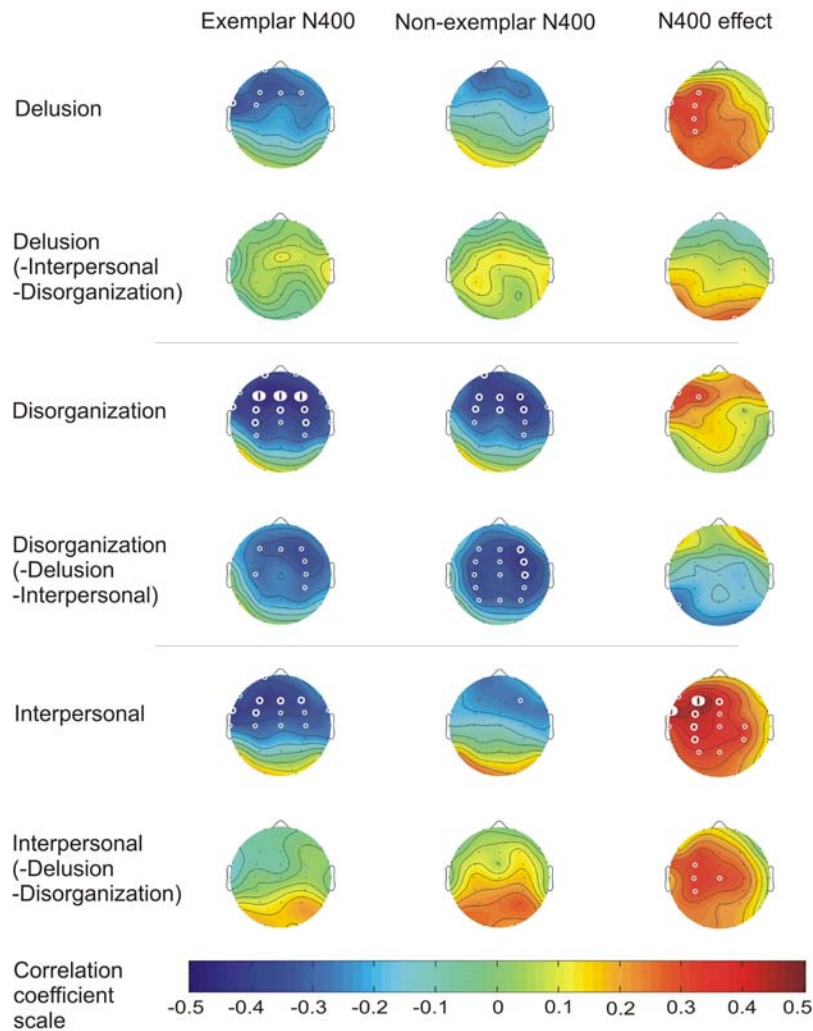


Figure 5: Spline interpolated maps of the correlation coefficients between mean ERP voltages in the 350-550 ms time window and schizotypal features. Bivariate correlations for each factor are followed by partial correlations that controlled for the two other factors' scores. The blue colors used for negative correlation coefficients mean that greater N400 amplitudes correlate to higher factor scores, as greater N400s (for exemplars, non-exemplars and effect) are associated with more negative values. Significant correlations at one electrode site are tagged by a small ring for $p < .05$, by an intermediate ring for $p < .01$ and by a large ring for $p < .001$. No correction of the alpha level was necessary here despite the large number of statistical tests done because of the a priori hypothesis (i.e., that strongest correlation would be observed at centro-parietal sites, that is, at the sites where the N400 effect with written words is usually maximal). A Bonferroni correction taking into account all the tests done ($3 \text{ traits} \times 28 \text{ electrodes} = 84$) would set the alpha level at 0.0005. With a less conservative correction, considering familywise errors, the alpha would be set at 0.0017 (for 28 electrodes).

Discussion

We investigated in healthy subjects the relationship between delusion-like ideation, disorganization trait and interpersonal factors, and the N400 potential elicited during a semantic categorization task. As sometimes observed in patients (Debruille et al., 2007; Lenzenweger & Dworkin, 1996), and often in healthy populations (Raine et al., 1994; Reynolds et al., 2000), the scores for each factor were significantly correlated with the scores for the two other factors. Individuals who had higher delusion-like ideation scores also tended to have higher disorganization scores and greater scores for the interpersonal factor (see Table 1). The effect of each schizotypal factor was thus studied while controlling for the effects of the two remaining factors. The N400 protocol used was designed to circumvent the effect of the deficit of the processing of prior context (Debruille et al., 2009). The source of the variations of N400 effects was assessed by measuring correlations in both the exemplar and the non-exemplar categories. Finally, the correlations were computed at each electrode sites, to test whether the relationship under investigation follows the scalp distribution of the N400 effect obtained in the experiment between exemplar and non-exemplar targets. The results obtained demonstrated the relevance of this method. Correlations between these ERPs and disorganization and interpersonal factors were observed but their scalp topography did not follow that of the N400 effect. The few correlations found between ERPs in the N400 time window and delusion-like ideation became insignificant when controlling for the two other factors (Figure 5).

The N400 protocol used herein led to a negative deflection in the N400 time window for both categories. This deflection was widespread over the scalp. The N400 in the non-exemplar category was significantly greater than the N400 in the exemplar category and this ERP difference had a centro-parietal maximum greater over the right than over the left hemiscalp (Figure 4). These results suggest that our protocol, where a single category is shown as a first word, elicits the classical N400 effect found for written words (Holcomb, 1988; Kutas & Federmeier, 2000).

Significant correlations between N400 amplitudes and disorganization scores were found over centro-parietal electrode sites. This replicates the results of previous studies done with patients (Andrews et al., 1993; Kostova et al., 2005; Kuperberg et al., 2006; Salisbury et al., 2000). The more disorganized subjects, the larger their N400 deflections. In the present study, this was significant not only in the exemplar but also in the non-exemplar category. The correlations remained significant after controlling for the two other factors. Interestingly, no correlation with the N400 effect was observed, as in Kiang and Kutas' study (2005) with healthy subjects. In both studies, the disorganization trait may have enhanced N400 amplitudes similarly in the exemplar and non-exemplar categories, leaving the N400 effect unchanged. The fact that this was obtained here in a task created to circumvent the effect of the deficit in the processing of the *prior* context suggests that larger target N400s could be caused by an anomalous semantic processing of target stimuli themselves. Such an anomalous processing could have also existed in previous studies, in addition to the deficiency in the processing of the context that was suggested. Most interestingly, while part of the correlations were

observed at N400 sites, that is, at centro-parietal sites, the strongest correlations were found at right fronto-central sites. These results should be considered with caution since, in contrast with centro-parietal locations, they do not correspond to a priori hypotheses. Nevertheless, they suggest that the amplitude of an ERP component other than the N400 could also depend on the severity of the disorganization trait. Future research should be devoted to assess the functional significance of this component. In any case, the N400 effect is known to be generated by multiple brain regions (Halgren et al., 2002), having multiple contributing electrophysiological sub-components (Franklin et al., 2007). Disorganization may thus affect a sub-component of the N400 that is not maximal over centro-parietal electrodes.

As for the correlations observed at centro-parietal sites, given that a semantic categorization task was used, they are most likely due to a modulation of the classical N400 by the disorganization factor. This association of greater N400s with higher disorganization scores may have different functional significances depending on the hypothesis of reference. Regarding the hypothesis that N400 amplitudes index the automatic spreading activation within the lexicon (Deacon et al., 2000; Kutas & Hillyard, 1984), our results are consistent with studies using schizophrenia patients (Andrews et al., 1993; Salisbury et al., 2000) which suggest that schizophrenia, and more specifically thought disorders, may be related to an overspread activation in the network of word representations (Maher et al., 1987; Manschreck et al., 1988; Spitzer et al., 1993). This idea that words induce a broader activation in more- than in less-disorganized individuals implies that targets also induce broader activation. Therefore, according to

the hypothesis that N400 is generated by the activation, all targets should elicit larger N400 deflections, and N400 effects may not change, as observed here. A similar interpretation could be made at the level of the network coding for meanings, following the hypothesis that N400 indexes activation in semantic memory (see Kutas & Federmeier, 2000; Lau et al., 2008). Alternatively, according to the hypothesis that the amplitude of the N400 is proportional to the efforts deployed by the brain to integrate the meaning of the stimulus in the context (Holcomb, 1933), our results indicate that healthy people with more disorganization scores deploy greater efforts to try to integrate target stimuli than people without disorganization. This may be a consequence of an initial overspread of activation since it arguably increases difficulty. However, the absence of effects of disorganization scores on error rates and reaction times does not provide further support to these lexical and semantic access views of N400s, because these processes are likely to be involved in the categorization task. Alternatively, according to a fourth hypothesis, the N400s index a late inhibition of inappropriate representations (Debrulle, 1998; Debrulle et al., 2008; for a review, see Debrulle, 2007). In the case of the present experiment, these inappropriate representations could be those related to animals that were activated by the question word 'ANIMAL?' and that are inappropriate for non-exemplars targets. Due to their overspread of activation, subjects with higher disorganization scores would have activated more of these representations and thus would have more inhibition to perform, hence the greater N400 amplitudes. This hypothesis may also be used to interpret the greater N400s obtained in the exemplar condition. The first word 'ANIMAL' may activate knowledge

corresponding to animals other than the target. This inappropriate activation may be more important in cases of more marked disorganization.

Another finding of the present study is that, in the N400 time-window, the subtractions of the voltages of the exemplar category from those of the non-exemplar category positively correlated with higher scores for the interpersonal factor of the SPQ. The higher the score, the smaller the N400 effect, since this effect has a negative voltage. These results are consistent with those of a previous study (Kiang & Kutas, 2005), which reported a correlation between ERP amplitude in the N400 time-window and interpersonal scores in normals. Our study replicates this finding but also shows that it persists when controlling for the two remaining schizotypal factors. Moreover, it suggests that these correlations are maximal over left centro-parietal electrodes (see Figure 5) whereas the typical sites where the N400 effect is maximal for written word stimuli are usually at the right centro-parietal part of the scalp (Holcomb, 1988; Kutas et al., 1988). However, these results should be considered with caution since they do not correspond to a priori hypotheses. Nevertheless, they suggest that the correlations may be due to the modulations of an ERP other than the N400, the functional significance of which would have to be investigated. Alternatively, the interpersonal factor might preferentially affect a sub-component of the N400 that is not maximal over centro-parietal electrodes. This left centro-parietal preferential location is difficult to compare with findings in the literature. The correlations reported in other studies pertained to only one scalp location. In Kiang and Kutas (2005), it was the midline parietal electrode (Pz). In their more recent study in schizophrenia patients, Kiang et al. (2007) found that

smaller N400 effects at the central electrode, Cz, tend to correlate with the severity of negative symptoms, and thus with symptoms that resemble those measured by the SPQ interpersonal factor. Meanwhile, Kostova et al. (2005) found the same relationship between negative symptoms of patients and the N400 effect at Pz, but this was only a trend ($p = 0.08$). However, no measures of the correlations between the different clinical factors were made. It thus remains unclear whether it would have been necessary to control for other factors in their subjects' samples too, and whether the correlation with ERPs would persist with these controls.

The maps of the bivariate correlations obtained for the disorganization trait and those obtained for the interpersonal score are interesting to compare to the maps of partial correlations (Figure 5). This comparison reveals that controlling for the two other schizotypal factors may have dramatic effects. At some sites, this control induced a switch in the direction of the correlations. By emphasizing the importance of the control, these findings may help to reconcile some of the discrepancies present in the N400 studies of schizophrenia. These discrepancies could be due to varying patterns of symptom correlations across the population samples studied.

Regarding delusion-like ideation, the atypically localized correlations found between the severity of this factor and the amplitude of the ERPs in the N400 time-window (Fig. 5) disappeared when we controlled for the effect of the two other factors, unlike the correlations found in patients (Debruille et al., 2007), which resisted this control. Therefore, it seems that delusion-like ideation may not be correlated to N400 in normals and that healthy subjects with delusion-like ideation do not have abnormal

semantic processes. The present study thus suggests that delusion-like ideation observed in healthy subjects might not be similar to delusional beliefs of patients as they are not underlain by the same neurocognitive mechanisms. These results are at odds with the findings of Debruille et al. (2007) and Kiang et al. (2007) in schizophrenia patients and could be used to support a distinction between normal population and schizophrenia patients in contrast with the idea of a continuum between the two (Garety et al., 2007; Shevlin et al., 2007; Verdoux & van Os, 2002). However, the results of Prevost et al. (Chapter 5) suggest that smaller N400s can be found in healthy subjects with high scores on delusion-like ideation items of the SPQ, when boosting paranoid feelings, which probably diminishes some of the differences between schizophrenia patients and healthy subjects.

In summary, the results of the present study suggest that the semantic processes accompanying a particular schizotypal personality trait should be studied while controlling for the other traits. As with other brain imaging techniques, various localizations have to be examined to test whether the correlations actually pertain to the neurocognitive component under focus. Moreover, our study supports the view of a continuum between schizophrenia and normality at least for disorganization and interpersonal factors to the extent that they were found, in healthy subjects, to be accompanied by semantic processes biases similar to those observed in schizophrenia patients.

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Bridging Chapter 4 to Chapter 5

Chapter 4 investigated the processing of semantic information, indexed by the N400 event related potential, in healthy participants with delusional-like ideation. No significant correlations emerged between this trait and N400 amplitudes, suggesting that delusional-like ideation does not influence semantic processing, unlike clinical delusions of schizophrenia patients.

However, participants might not address the laboratory environment in the same way that deluded patients do. The abnormal processing of information observed in deluded patients previously observed could be a reflection of patients' mental state, which tend to be more paranoid. In chapter 5, the same task was repeated in a new group of healthy participants and modifications were introduced in the protocol to induce paranoid feelings.

In such conditions, all participants reported greater paranoid feelings after than before the induction, but no changes in their anxiety levels. Delusional-like ideation in healthy participants was correlated with reduced N400 amplitudes, somewhat similar to what has been observed with deluded schizophrenia patients. Cognitive bias of people with delusional-like ideation can thus be promoted by situations triggering paranoid feelings.

Chapter 5

**Paranoid induction reduces N400s of healthy
subjects with delusional-like ideation**

Abstract

A previous study suggests that the amplitude of the N400 event-related potentials (ERPs) of healthy subjects does not vary with their delusional-like ideations. This contrasts with the smaller N400s observed in More- than in Less-deluded schizophrenia patients. Here, we hypothesize that these smaller N400s were related to the paranoid feelings patients had during the ERP recording. We thus induced this type of feelings in healthy subjects by adapting the informed consent form. Delusional-like ideation was assessed with the schizotypal personality questionnaire. 34 healthy subjects completed a semantic categorization task. Paranoid feelings were significantly enhanced by the induction. In these conditions, greater delusional-like ideation scores were associated with smaller N400s. Controlling for the two other schizotypal factors strengthened these results. In addition, the amplitudes of the late positive component were positively correlated with the delusional-like ideations scores. These findings have potential implications for theories on the persistence of delusions.

Introduction

Delusions are defined as ‘false beliefs (...) that is firmly sustained (...) despite what constitutes incontrovertible and obvious proof or evidence to the contrary’ (DSM-IV-TR). Although they are mostly observed in psychotic patients, experiences that resemble delusions and that we will refer to as ‘delusional-like ideations’ have been shown to have a sizeable frequency in the general normal population (Peters et al., 2004; Peters et al., 1999; van OS et al., 2000). In keeping with the continuum view between normality and pathology (Colbert & Peters, 2002; Shevlin et al., 2007), schizotypal traits in healthy subjects can be associated with cognitive mechanisms similar to those observed in patients with schizophrenia symptoms.

Several theories have been proposed to explain the formation and persistence of delusions (for review, see Freeman, 2007). One of them accounts for the maintenance of delusions despite contradictory evidence. It consists of a deficit in the processing of information that disconfirms beliefs and their corresponding expectancies (Moritz & Woodward, 2006; Woodward et al., 2007; Woodward et al., 2006). Studies suggest that this type of processing can be objectively measured by computing the amplitude of the N400 event-related potential (ERP). The N400 is a negative potential that is maximum around 400 milliseconds after the occurrence of any potentially meaningful stimulus (for a review, see Kutas & Federmeier, 2000; Kutas & van Petten, 1994; Lau et al., 2008). Its amplitude is inversely proportional to the extent to which the eliciting stimulus fits semantic expectancies (Kutas & Hillyard, 1984). In studies using pairs of words, the amplitude of the N400 elicited by the second word is thus modulated by the

expectancies induced by the first word (Bentin et al., 1985). For instance, when the first word is 'animal' and the second word is the name of an object, the N400 amplitude is large. When the second word matches the expectations and is an animal's name, the N400 amplitude is small. It is thus suggested that when semantic processes are more difficult, N400 amplitudes are large (Holcomb, 1993).

In Debrulle et al. (2007) schizophrenia patients who were more delusional displayed smaller N400 amplitude than less delusional patients, confirming the idea of different semantic processes in these patients. Another study done with schizophrenia patients by Kiang and colleagues (2007) reported that psychotic symptoms (delusions and hallucinations) were correlated with a diminution of the N400. However, in this latter study, the authors focused on the N400 effect, that is, on the subtraction of the N400s to the matching stimuli from the N400s to the mismatching stimuli. It was thus not possible to see whether the modulation of the N400 effect was due to smaller N400s in the mismatching condition, to larger N400s in the matching condition, or to both. Another problem is the absence of control for the effects of other symptoms whereas these symptoms are often correlated with each other and may have opposite effects on ERPs of the N400 time-window. These effects could thus cancel each other, which could explain why no effect of delusions on N400 ERPs was found in some other studies (Ditman & Kuperberg, 2007; Kostova et al., 2005; Mathalon et al., 2002).

Nevertheless, in a third study in which healthy subjects took part (Prévost et al., Chapter 4) and where these controls were performed, no N400 amplitude reduction was associated to delusional-like ideations whereas the semantic task was the same as

that used with patients in Debruille and colleagues' study (2007). There was thus no evidence supporting the presence, in healthy subjects, of the cognitive difference found in patients. However, even though the experimental conditions were identical, schizophrenia patients and healthy subjects did not go through the experiment in the same mental state. In contrast to healthy subjects with delusional-like ideations, schizophrenia patients often asked questions that reflected paranoid feelings. Much more often than healthy subjects, they wanted us to guarantee that the electrodes placed on their scalp were just for recording purposes. They wanted to be sure that nothing was done to inject currents into their brain or to modify the way it functions. Brain recording environments may thus induce or enhance paranoia in patients but not, or less so, in healthy subjects.

Accordingly, for the environment to have the same effect in healthy participants, one would have to find a way to make them feel somewhat paranoid. This could not be as difficult as it may seem at first. Being watched, realizing that people just stopped talking when we enter a room, hearing people laughing behind us, or hearing about a terrorist attack 'naturally' trigger paranoid feelings in everyday life. Fenigstein and Venable (1992) reported that when subjects are placed next to a one-way mirror, they *feel* that they are being watched, a hallmark of paranoia. This self-reported feeling was correlated with the scores on a paranoia scale. Here, we used these findings and had our subjects sit next to such mirror. In addition, we also attempted to reproduce schizophrenia patients' suspicion that examiners could modulate their brain functioning. We mentioned to participants that small and harmless electric currents might be

emitted during the recording to change the way their brain works (as in transcranial magnetic stimulation studies, see Taylor et al., 2000).

Paranoid inductions could change semantic processes by favouring the intuitive, emotional and fast system over the rational, logical and slow system. These two systems, reminiscent of those described by Shneider and Shiffrin (1977), Epstein and Pacini (1999) or Stanovich and West (2000), are thought, by Speechley and Ngan (2008), to work in parallel and to lead to the same output in most circumstances. When conflicts occur between their outputs, the rational one usually overrides the emotional one. Nevertheless, as proposed recently by Speechley and Ngan (2008), in contexts that are too emotional, the output of the intuitive system would be too strongly activated and could not be overridden, hence delusions. The experimental situation in patients and the paranoid induction in healthy subjects with delusional-like ideations may lead to such a boost of the emotional system. Another possibility, which does not exclude this one, is that, during such feelings, semantic processes are shallow. Interestingly, 'shallowness' could be related to smaller N400s since tasks that are less semantic (e.g., physical, or lexical) processes have been found to induce smaller N400s amplitudes than explicitly semantic tasks (Chwilla et al., 1995; Kounios & Holcomb, 1994). Other potentially interesting findings are the smaller N400s obtained for stimuli for which subjects pay less attention (McCarthy & Nobre 1993).

The aim of the present study was thus to test whether healthy subjects with high scores for delusional-like ideations would have smaller N400s than subjects with low scores, after a paranoid induction. To test this hypothesis, we used the same task as in

our previous study in healthy subjects (Prévost et al., Chapter 4). The same method as in this previous study was followed. That is, we first assessed whether schizotypal traits correlate with each other. Given that this was the case in our subject sample, and given that these schizotypal factors (i.e., disorganization and interpersonal) may have opposite effects on ERPs in the N400 time-window, their effects were controlled for when studying the effect of delusional-like ideations. On the other hand, N400s to animal exemplars and non-exemplars were assessed together with the N400 effects to find the causes of variations of N400 effects. Finally, the correlations between the scores for a schizotypal factor and the N400 amplitudes were computed at each electrode site to see whether these correlations followed the scalp topography of the N400 effect.

Method

Participants

Thirty eight right-handed participants (20 women, 18 men) aged between 19 and 51 years were recruited by newspaper advertisements. They each had normal or corrected-to-normal vision and spoke French as their first language. They were screened by telephone and excluded for any history of DSM-IV Axis I psychiatric illnesses, except for depressive episodes that resolved at least two years ago. Subjects with a history of head injury with loss of consciousness longer than 10 minutes were also excluded, as

well as subjects with a neurological or medical condition compromising brain functioning. All participants abusing drugs were excluded. All gave written informed consent prior to participation after procedures were described according to the Douglas Institute Research Ethics Board's criteria.

Participants had to fill the French version of the schizotypal personality questionnaire (SPQ, Raine, 1991; Dumas et al., 1999; Dumas et al., 2000) before signing the consent form. The SPQ, which includes nine subscales, was used to assess delusional-like ideations as well as two other schizotypal factors, or clusters, that are disorganization and interpersonal factors, the latter being comparable to negative symptoms in schizophrenia patients. The SPQ is based on the DSM-III-R criteria for schizotypal personality disorder. Its validity has been demonstrated (Raine, 1991) and its three clusters, which have been defined by a factor analysis (Raine et al., 1994), have been used in many previous studies (e.g., Dickey et al., 2005; Kiang & Kutas, 2005; Sommer et al., 2008). The score for delusional-like ideation was computed by adding the score for the 'odd beliefs or magical thinking' subscale to that obtained for the 'ideas of reference' subscale. The score for the 'paranoid ideation' subscale was not entered into the delusional-like ideations computation as it was part of the interpersonal factor. The score for the disorganization cluster was computed by adding the score for the 'odd behavior' subscale to that for the 'odd speech' subscale. The score for interpersonal cluster was computed by adding the scores for the subscales 'social anxiety', 'no close friends', 'constricted affect' and 'paranoid ideation'. In our sample, the mean delusional-like ideation scores was 4.6 (SD = 3.3), the mean disorganization scores was 4.9 (SD =

4.5) and the mean interpersonal scores was 7.6 (SD = 8.2). Although the three comparable schizophrenia symptoms have been found relatively independent in patients (Lenzenweger, 1999; Lenzenweger & Dworkin, 1996), schizotypal factors were highly correlated in previous studies (Raine et al., 1994; Reynolds et al., 2000). Accordingly, in the present study, delusional-like ideations scores correlated with disorganization ($r = .58, p < 0.001$) and with interpersonal scores ($r = .55, p < 0.001$). Disorganization scores correlated with interpersonal scores ($r = .56, p < 0.001$).

The median of the delusional-like ideations scores was used to split subjects into two groups. Four subjects, who had an error rate exceeding 10% in the N400 task, were excluded from the analyses. Subjects with the median score were assigned to the group with lower delusional-like ideation scores (LD). This group ($n = 18$; 9 females) was characterized by a mean delusional-like ideation score of 2 (SD = 1.5), a mean age of 30.4 (SD = 10.8) and a mean number of years of study of 12.3 (SD = 1.9). The group with more delusional-like ideations (MD) ($n = 16$, 7 females) was characterized by a mean delusional-like ideations score of 7.6 (SD = 2.2), a mean age of 32.9 (SD = 8.5) and a mean number of years of study of 13.2 (SD = 2.7). For the 34 subjects, the mean age was 31.6 (SD = 9.7) and the mean number of years of study was 12.7 (SD = 2.3). None of the differences between the two groups for the mean age, the mean number of years of study or the sex ratio was significant.

Paranoid induction

In order to increase paranoid feelings, the consent form signed by each subject specified that the cap that records the electrical activity of the brain contained some plates that may emit small and harmless electric currents aimed at temporarily modifying their cerebral activity, as in transcranial magnetic stimulation (TMS) studies, or in transcranial direct current stimulation (TDS) studies. It was also said that one goal of the experiment was hidden and would be revealed only after the recording session. To further boost paranoid feelings subjects were recorded next to a one-way mirror and the technician made noise behind that mirror before the recording. The purpose was to induce the idea that a person they had not met was observing them behind that mirror and may be recording them in a video. Subjects had to fill two questionnaires before reading the consent form and then, during the recording session. The first was the questionnaire created by Bodner and Mikulincer (1998) to assess paranoid feelings of participants during experimental situations, to which we added an item (i.e., 'I feel that others are changing my functioning'). The second was the state part of the state and trait anxiety inventory (STAI, Spielberger et al., 1983), which was used to control for the possible change in anxiety levels. At the end of the session, subjects were told that there was no current emitted, nothing behind the one-way mirror and that there was no hidden goal.

Task

Subjects were seated comfortably in a dimly lit room in front of a computer screen placed 1 m from their eyes. Black stimuli were presented on a white background at the center of the screen. Trials were made of two serially presented words. The first word was either the priming word 'ANIMAL?', in two-thirds of the trials, or the instruction word 'INACTION', in one-third of the trials. These words were then followed by the target word, which was either the name of an animal or the name of an artifact. The instruction-target stimulus onset asynchrony was 2 seconds and each word was displayed during 1 second. The target items were either exemplars (e.g., lion) or non-exemplars (e.g., hammer) of the category 'ANIMAL?'. Subjects had to categorize targets into animal exemplars or non-exemplars as rapidly and as accurately as possible by pressing one of two keys with their right index finger. The 'INACTION' word signaled to the subject that they should not respond to the target stimulus. The target word was followed, 2 to 2.5 seconds later, by the word 'Blink', giving the subjects the opportunity to blink without disrupting the electroencephalogram (EEG) signal. All target words used were selected from among familiar words using the Content and coll.'s database (Content et al., 1990) for French words. In both the animal (exemplar) and the artifact (non-exemplar) categories, there were forty-seven words with a frequency comprised between 0 and 1000 out of 100 millions occurrences, nine words with a frequency comprised between 1000 and 3000 and four words with a frequency higher than 3000. The mean number of letters was 6.5 +/- 1.7 in the exemplar category and 6.7 +/- 1.5 in

the non-exemplar category. Each target word was presented only once. In the action condition, there were 60 trials with exemplar target words and 60 trials with non-exemplar target words. For the 'INACTION' condition there were 30 trials for each of the two stimulus categories.

Data acquisition

Accuracy and reaction time were collected for each trial. The EEG was recorded with tin electrodes mounted on an elastic cap (from Electro-Cap International). These electrodes were placed according to the modified expanded 10-20 system (American EEG Society, 1991) with a right ear lobe initial reference. The EEG was re-referenced off-line to the mean of the left and right earlobes. Twenty-eight electrodes were used. Sites were grouped into three subsets. The sagittal subset included Fz, FCz, Cz, and Pz; the parasagittal subset, FP1/2, F3/4, FC3/4, C3/4, CP3/4, P3/4, O1 and O2; and the lateral subset, F7/8, FT7/8, T3/4, TP7/8, T5 and T6. Eye movements and blinks were monitored with F7 and F8 for horizontal movements and with FP2 and an additional electrode placed on the right cheek for vertical movements. The impedance was kept below 5K Ω . EEG signals were amplified with Contact Precision Instruments amplifiers. Their gain was set at 20 000. The half amplitude cut-offs of high and low pass frequency filters were set at 0.01 and 100 Hz, respectively. In addition, a 60 Hz electronic notch filter was used. EEG signals were digitized at a 256 Hz sampling frequency and stored along with the stimulus and response codes.

Measures

The EEG epochs corresponding to trials with incorrect responses or with reaction times shorter than 200 ms or longer than 2000 ms were rejected. We also rejected trials with excessive movements, that is, with movements corresponding to amplitudes exceeding ± 100 microvolts and trials with amplifier saturation or analog-to-digital clipping lasting longer than 100 ms. Our baseline was set at -200 to 0 ms. Averages were calculated over the time period comprised between the onset of the target word and 1000 ms later. Our measures were made by computing the mean voltage of the ERPs in selected time-windows relative to the $-200 - 0$ ms baseline. A $350 - 550$ ms time window, centered on the latency of the peak observed in the non-exemplar minus exemplar subtractions, was used to measure the mean N400 amplitude relatively to baseline. This time-window had the advantage of including the peaks of the N400s of the exemplar and of the non-exemplar categories, the maxima of which occurred at different times. Mean voltage amplitudes were also computed in the $550 - 750$ ms time-window that immediately followed the N400. This was made in order to test the differences observed on the grand-averages in this time windows, which is that of the late positivity complex (LPC). An additional $50 - 150$ ms time window centered on the peak of the N1 at Cz was used to compare the amount of attentional resources allocated to the early processing of target words and to test the differences detected by visual inspection in the early parts of the grand averages.

Analyses

Two mixed-model repeated measure ANOVAs were used to compare the two groups before and after the paranoia induction (within-subjects factor). The first ANOVA was used for their paranoid feelings and the second, for their anxiety levels (STAI). One sample t-test and one independent samples t-test were used to analyze variations of paranoid feelings scores. Mean reaction times and accuracies obtained in the action condition were analyzed with similar ANOVAs having category (exemplar versus non-exemplar) as a within-subjects factor and group (MD versus LD) as the between-subjects factor. As delusional-like ideations scores were correlated to interpersonal scores and disorganization scores, and since these factors have been found to have opposite effects on ERPs in the N400 time window (Kiang & Kutas, 2005), as the schizophrenia symptoms which resemble these schizotypal traits have (Andrews et al., 1993; Kuperberg et al., 2006), disorganization and interpersonal scores were introduced as covariates in these analyses. ERP measures were analyzed with the same ANOVAs adding the electrode site as another within-subject factor. For the parasagittal and lateral subsets of electrodes, there was a third within-subject factor: the hemi-scalp (right versus left). Each time interactions involving the group factor were found, post-hoc ANCOVAs were performed to identify the source of the interaction. For the parasagittal subset, the prefrontal values (FP1/2) of one subject were excluded from the analyses as they were greater than ten standard deviations. The Greenhouse and Geisser procedure (Greenhouse & Geisser, 1959) was used to correct for possible violations of the sphericity assumption

for the factor having more than two levels, that is, the electrode factor. In each case, the original degrees of freedom are reported together with the *Epsilon* (E) correction factor.

Some ERP effects, such as the effect of repetition, may have one scalp distribution in the N400 time window and another in the LPC time-window (e.g., Guillem et al., 2001). In contrast, other authors found similar scalp distribution for the N400 and the LPC, suggesting that the two potentials have the same generators (e.g., Groppe et al., 2008; Makeig et al., 2004). In order to see whether the effect of delusional-like ideation modulates the same generators in these two time windows, we tested whether its distribution in the N400 time window differed from its distribution in the LPC time window. To achieve this goal, we performed supplementary ANCOVAs with another within-subjects factor, the time window (350-550ms vs. 550-750ms).

To compare the N400 amplitudes of the participants of the present study who had a paranoid induction to those of participants who did not have the induction, data from the previous study (Prévost et al., Chapter 4) were introduced and supplementary ANCOVAs were run with an additional between-subjects factor, the experimental group (Induction vs. No-induction).

Finally, bivariate correlations between the mean N400 amplitudes at each of the 28 electrode sites of the scalp and the scores for delusional-like ideation, interpersonal and disorganization subscales were also computed. As mentioned before, since delusional-like ideation scores were correlated with interpersonal and disorganization factors in our sample, and since they have been found to have opposite effects on ERPs in the N400 time window (Andrews et al., 1993; Kiang & Kutas, 2005; Kuperberg et al.,

2006), partial correlations were added to control for these two factors when evaluating the relation between delusional-like ideation and N400 amplitude. We also performed analyses following the same principle for the disorganization and the interpersonal factors. Partial correlations were possible since correlations could be assumed to be linear. As mentioned in the introduction, several studies have found significant Pearson correlations between N400s and each schizophrenia syndrome.

Results

Behavioral data

Paranoid feelings were successfully increased by the induction. The total scores for the questionnaire of Bodner and Mikulincer (1998) were higher after this induction than before for all subjects ($F_{1,32} = 19.3, p < 0.001$). No interaction between delusional-like ideation and paranoid induction (before and after the induction) was observed, revealing that the increases in paranoid scores produced by the induction were similar in both groups. Both at baseline and after induction ($F_{1,32} = 3.7, p = 0.063$), subjects with more delusional-like ideations (MDs) tended to have greater paranoid scores than subjects with less delusional-like ideations (LDs) (Before induction, 8.6 ± 6.9 for MDs and 3.8 ± 4.9 for LDs; After induction, 12.9 ± 10.3 for MDs and 9.3 ± 5.9 for LDs). One item, 'I feel that my behavior is being analyzed', was enhanced by the induction in LDs ($t = 3.8, p = 0.001$) but not in MDs whereas the item 'I feel that others influence my performance' was enhanced by the induction in MDs ($t = 2.6, p = 0.022$) but not in LDs. MDs displayed

higher level of anxiety than LDs, as measured by the state part of the STAI ($F_{1,32} = 5.8$, $p = 0.022$). However, the induction had no effect on anxiety levels in either group.

Mean reaction times were shorter for exemplars (909 ms $\pm$ 157.4) than for non-exemplars (1011 ms $\pm$ 189.6) categories ($F_{1,32} = 50.1$, $p < 0.001$). Accuracies (i.e. error rates) did not differ significantly between the exemplar (4.7% $\pm$ 4.1) and the non-exemplar (3.9% $\pm$ 3.7) categories. MD subjects responded approximately 115 ms faster (899 ms $\pm$ 161.8) than LD subjects (1015 ms $\pm$ 167.2) ($F_{1,32} = 4.4$, $p = 0.045$), a difference that tended to be strengthened by controlling for disorganization and interpersonal factors ($F_{1,30} = 6.0$, $p = 0.020$). MD subjects were found to make fewer errors (3.7% $\pm$ 3.6) than LD subjects (4.9% $\pm$ 4.1). However, this difference was significant only when disorganization and the interpersonal factor were controlled for ($F_{1,30} = 4.5$, $p = 0.042$).

ERP data

N100 time window

Group effects were observed only when disorganization and the interpersonal factor were added as covariates. For the sagittal subset of electrodes only, we observed a group x category interaction ($F_{1,30} = 4.75$, $p = 0.037$). The posthoc revealed that LD subjects had greater N100 amplitudes than MD subjects only in the exemplar category for this subset of electrodes ($F_{1,30} = 7.18$, $p = 0.012$). For the parasagittal subset, a main group effect was observed ($F_{1,29} = 4.40$, $p = 0.045$), meaning that LD subjects had greater N100 amplitude than MD subjects in both categories. No group effect was observed at the lateral subset. No other interactions involving the group factor were found.

Comparison of N100 amplitudes with those found in the previous study without induction

To see to what extent the attentional resources allocated to the task differ according to the induction, we compared N100 amplitudes at O1 and O2 across studies. No significant difference or interaction emerged.

N400 time window

N400 amplitudes were larger for non-exemplar than for exemplar target words in the two groups of subjects at the sagittal ($F_{1,32} = 26.8, p < 0.001$), parasagittal ($F_{1,31} = 32.5, p < 0.001$) and lateral ($F_{1,32} = 37.2, p < 0.001$) subset of electrodes. There was a main effect of group. MD subjects had smaller N400s than LD subjects at the sagittal ($F_{1,32} = 5.4, p = 0.027$), parasagittal ($F_{1,31} = 5.4, p = 0.027$) and lateral ($F_{1,32} = 6.8, p = 0.014$) subsets in both categories. Category x group x electrodes interactions were observed at the sagittal ($F_{3,96} = 9.2, E = 0.601, p < 0.002$), parasagittal ($F_{6,186} = 4.3, E = 0.354, p = 0.015$) and lateral ($F_{4,128} = 37.2, E = 0.560, p = 0.017$) subset. The post-hoc ANOVAs indicated that the N400 amplitudes were smaller for the MD than the LD group in both the non-exemplar (sagittal: $F_{1,32} = 4.2, p = 0.049$; parasagittal: $F_{1,31} = 4.3, p = 0.045$; lateral: $F_{1,32} = 4.7, p = 0.037$) and the exemplar category (sagittal: $F_{1,32} = 5.7, p = 0.023$; parasagittal: $F_{1,31} = 6.2, p = 0.018$; lateral: $F_{1,32} = 7.6, p = 0.009$). No significant interaction between group and electrodes were found at this level.

The main effect of group on each subset of electrodes was confirmed by the analyses where the interpersonal and the disorganization factors were added as covariates (sagittal: $F_{1,30} = 14.6$, $p < 0.002$; parasagittal: $F_{1,29} = 11.7$, $p = 0.002$; lateral: $F_{1,30} = 8.9$, $p = 0.006$). As displayed Figure 1 and 2, ERPs of MD subjects were less negative in the N400 time window than those of LD subjects. A group x category interaction showed that differences between MD and LD subjects were not equivalent in the two experimental categories (sagittal: $F_{1,30} = 7.1$, $p = 0.012$; parasagittal: $F_{1,29} = 7.3$, $p = 0.011$; lateral: $F_{1,30} = 5.2$, $p = 0.030$). However, the post hoc ANCOVA showed that the group differences were significant in both the exemplar (sagittal: $F_{1,30} = 24.9$, $p < 0.001$; parasagittal: $F_{1,29} = 19.3$, $p < 0.001$; lateral: $F_{1,30} = 13.8$, $p < 0.002$) and the non-exemplar categories (sagittal: $F_{1,30} = 6.9$, $p = 0.013$; parasagittal: $F_{1,29} = 6.4$, $p = 0.017$; lateral: $F_{1,30} = 4.1$, $p = 0.050$).

As the N400 effects evoked in each group peaked at different latencies, that is, at 456 ms in MDs and at 518 ms in LDs, we visually measured this latency in each subject at Cz after digitally smoothing the ERP waveforms. The t-test showed that the difference between the two groups was not significant ($t = 1.24$, $df = 32$, $p = 0.2$).

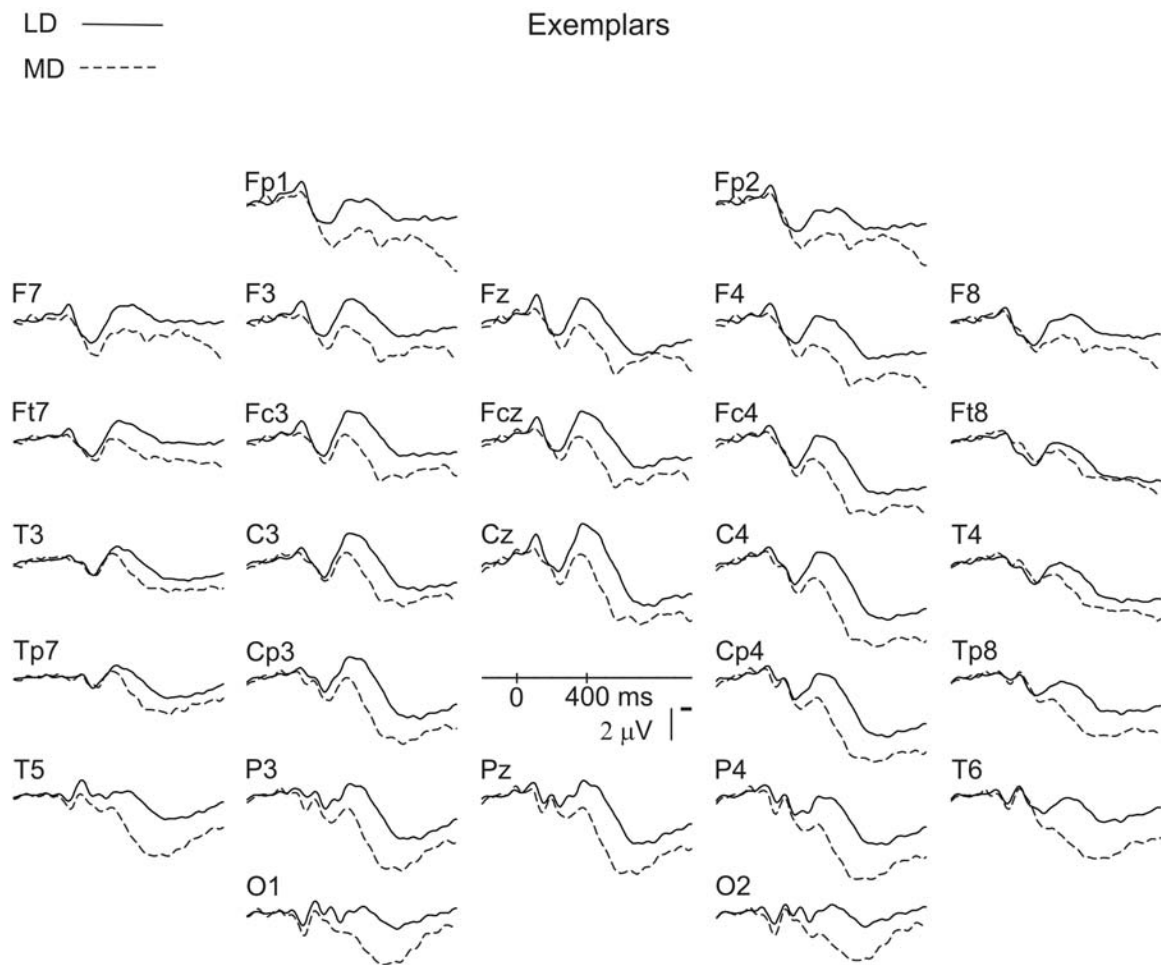


Figure 1: Grand average ERPs in the exemplar category for subjects with more delusional-like ideations (MD; n = 16) and for subjects with less delusional-like ideations (LD; n = 18).

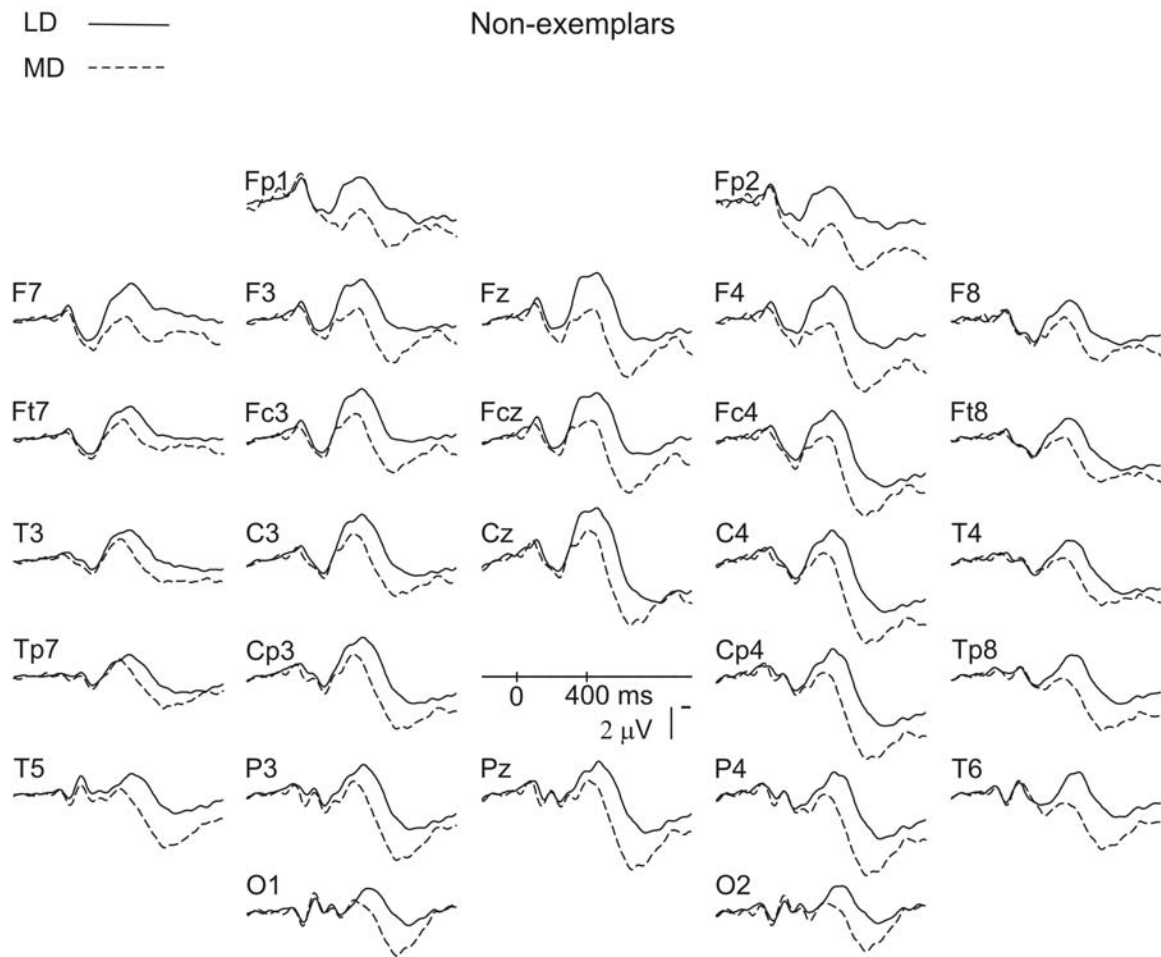


Figure 2: Grand average ERPs in the non-exemplar category for subjects with more delusional-like ideations (MD; n = 16) and for subjects with less delusional-like ideations (LD; n = 18).

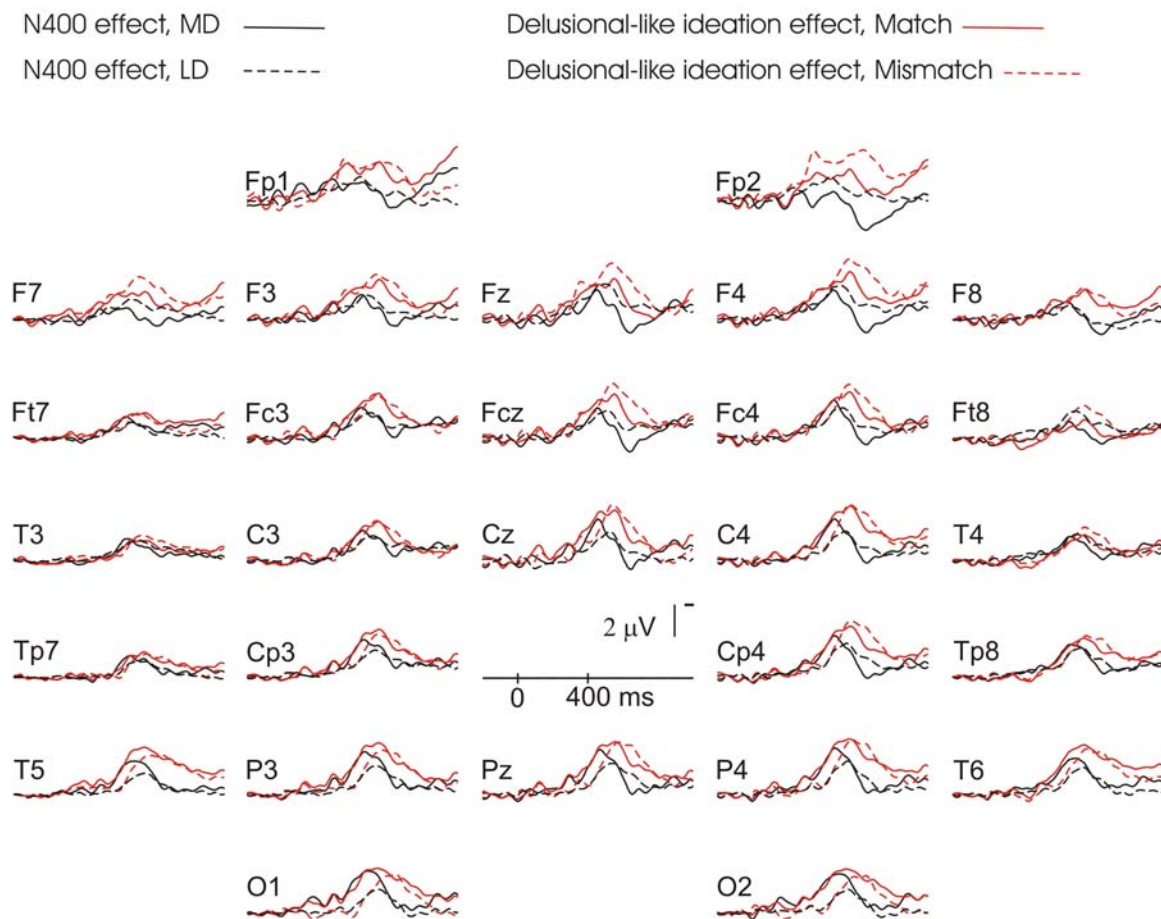


Figure 3: Subtractions of the ERPs of the exemplar category from the ERPs of the non-exemplar category in subjects with more (MD) and less (LD) delusional-like ideations (black lines) and subtractions of the ERPs of the MDs from the ERPs of the LDs in both categories (red lines).

Comparison of N400 amplitudes with those found in the previous study without induction.

In order to further study the effect of the paranoid induction on ERPs, the N400 amplitudes of the two groups of the present study were compared to those of subjects with More- and Less-delusional-like ideation of our previous study (Prévost et al, in press) since the two latter groups had no paranoid induction. The forty subjects (28 females) of the previous study had a mean age of 30.0 (SD = 9.9), a mean number of years of education of 14.0 (SD = 1.5) and a mean delusional-like ideation score of 4.7 (SD = 3.4). Repeated measures ANCOVAs controlling for the disorganization, the interpersonal factor, and for the other variables that significantly differ between the participants of the two studies, that is, the sex ratio and the mean number of years of study revealed, first, a main effect of delusional-like ideation significant at the sagittal ($F_{1,66} = 4.3, p = 0.043$), parasagittal ($F_{1,65} = 7.9, p = 0.006$) and lateral ($F_{1,66} = 8.2, p = 0.006$) subset of electrodes. This effect interacted with induction (no induction vs. induction) at the sagittal ($F_{1,66} = 7.4, p = 0.008$) and the parasagittal ($F_{1,65} = 5.1, p = 0.028$) subsets of electrodes, meaning that MD subjects had smaller N400 amplitudes than LD subjects only after the paranoid induction. At the lateral subset, this interaction was not significant ($F_{1,66} = 2.2$).

LPC time window

The match effect was significant at the parasagittal ($F_{1.31} = 7.9, p = 0.009$) and lateral ($F_{1.32} = 11.3, p < 0.003$) subsets of electrodes with more positive ERPs in the exemplar than in the non-exemplar category. MD subjects displayed more positive ERPs than LD subjects at the sagittal ($F_{1.32} = 4.1, p = 0.052$), parasagittal ($F_{1.31} = 5.2, p = 0.029$) and lateral ($F_{1.32} = 6.6, p = 0.015$) subsets of electrodes. This group effect was confirmed by the analyses where the interpersonal and disorganization factors were included as covariates (sagittal: $F_{1.30} = 21.3, p < 0.001$; parasagittal: $F_{1.29} = 16.6, p < 0.001$; parasagittal: $F_{1.30} = 11.5, p < 0.003$). In contrast to the results obtained in the N400 time window, group and category did not interact in the LPC time window.

Comparison of LPC amplitudes with those found in the previous study without induction.

Similarly to the analyses done for the N400, the LPC amplitudes of the two groups of the present study were compared to those of the two groups of our previous study (Prévost et al, Chapter 4) controlling for the disorganization, the interpersonal factor, and for the demographic characteristics that differed, that is, the sex ratio and the mean number of years of study. The ANCOVAs revealed an interaction between the two between-subjects factors, that is, induction (no induction vs. induction) and delusional-like ideation (LD vs. MD) at the sagittal ($F_{1.66} = 8.9, p = 0.004$) and the parasagittal ($F_{1.65} = 6.4, p = 0.014$) subsets of electrodes, meaning that MD subjects had larger LPC amplitudes than LD subjects only after a paranoid induction. At the lateral subset, this interaction was not significant ($F_{1.66} = 2.7, ns$).

The effect of delusional-like ideation obtained in the present study in the N400 time window was compared to that in the LPC time window to test whether it had a different distribution on the scalp and thus whether the two effects could have different brain generators. A significant triple interaction between window, category and group was found in the sagittal ($F_{1,30} = 9.8, p = 0.004$), the parasagittal ($F_{1,29} = 13.2, p < 0.002$) and the lateral ($F_{1,30} = 11.4, p = 0.002$) subsets. This interaction did not involve the electrode or the hemiscalp factor. Moreover, post-hoc analyses done separately in the exemplar and the non-exemplar categories showed no significant window x group x electrodes or hemiscalp interaction. The effect of delusional-like ideation on ERPs in the N400 time window thus had a scalp topography that was similar to that of the effect of delusional-like ideation in the LPC time window.

Bivariate and partial correlations

As shown by Figure 4a, delusional-like ideation positively correlated with the ERPs of the exemplar category in the N400 time window especially when correlations were controlled for interpersonal and disorganization factors. The strongest correlations had a centro-parietal distribution. Knowing that greater N400 amplitudes have more negative values, these positive correlations mean that higher delusional-like ideation scores were associated with smaller N400 amplitudes. Positive centro-parietal correlations were also significant for the non-exemplar category when disorganization and interpersonal factors were taken into account. In contrast, delusional-like ideation negatively correlated with the N400 effect (non-exemplar minus exemplar ERPs) when

controlling for interpersonal and disorganization factors, meaning that higher scores on delusional-like ideation items were related to larger N400 effects.

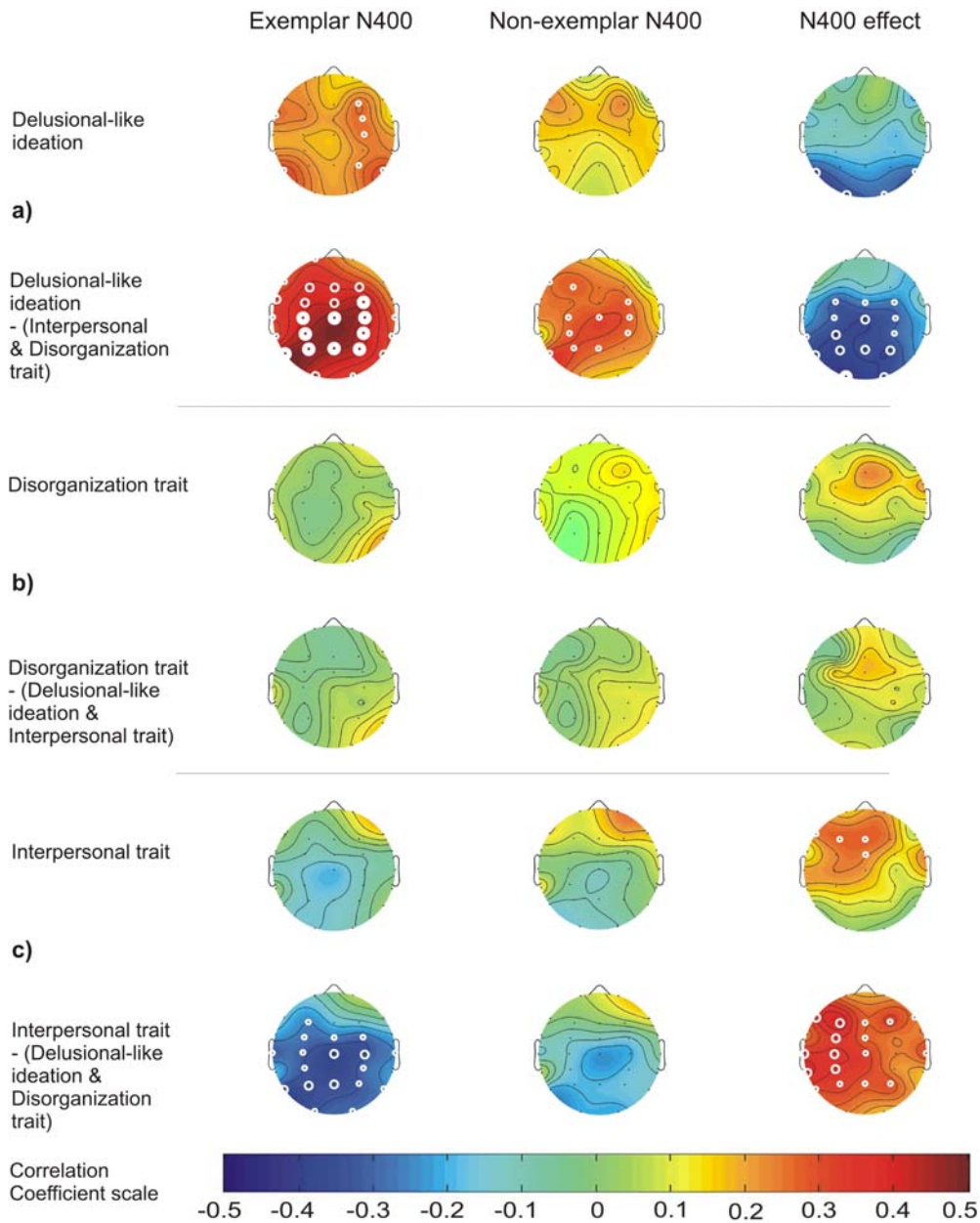


Figure 4: Spline interpolated maps of the correlation coefficients between mean ERP voltages in the 350-550 ms time window and schizotypal traits. Bivariate correlations of each factor are followed by partial correlations controlling for the other two factors scores. Significant correlations are tagged by a small circle for $p < .05$, by an intermediate circle for $p < .01$ and by a large circle for $p < .001$. No correction of the alpha level was necessary here despite the large number of statistical tests done because of the a priori hypothesis (i.e., that strongest correlation would be observed at centro-parietal sites, that is, at the sites where the classical N400 is usually maximal). A Bonferroni correction would set the alpha level at 0.0005 (3 traits $\times$ 28 electrodes).

Disorganization scores did not correlated with the N400 amplitudes in the exemplar and the non-exemplar categories or with the N400 effects, even when controlling for delusional-like ideation and interpersonal factors (Figure 4b). The interpersonal factor correlated negatively with the deflections in the N400 time window to the exemplar target words when the two other factors were controlled (Figure 4c). This means that higher interpersonal scores were associated with greater N400 amplitudes in the exemplar category. These latter correlations were widely distributed except for frontal electrodes. No correlation was found between interpersonal factor and the N400 amplitude of non-exemplar words. Correlations were positive for the N400 effect when controlling for the two other factors, showing that the N400 effect was diminished for higher interpersonal scores, especially over the left hemiscalp.

Discussion

The aim of this study was to test the hypothesis that healthy subjects with delusional-like ideation display reduced N400 amplitude after the induction of paranoid feelings. To achieve this goal, we use the semantic categorization task used in our previous study with patients (Debruille et al., 2007) and in our previous study in a healthy population (Prévost et al., Chapter 4). Like in these former studies, ERPs were more negative in the N400 time window for the non-exemplar (mismatching targets) than for the exemplar (matching targets) category. As hypothesized, subjects with higher delusional-like ideation scores (MD) showed smaller N400s than subjects with low delusional-like ideation scores (LD). This difference held for both categories.

Additionally, the late positive complex (LPC) amplitude was greater in MD than in LD subjects.

The induction led to a significant increase of the paranoid feelings' scores. The increase in paranoid feelings scores was partly due to different items in LD subjects than in MD subjects. LD subjects felt that their behaviour was being analyzed more strongly after the induction when MD subjects did not feel more analyzed after the induction. However, MD subjects felt that others were influencing their performance more strongly after the induction when LD did not. The induction did not increase the same feelings in both groups. It enhanced precisely paranoid feelings in MD subjects but might have enhanced some feelings of self-consciousness in LD subjects. Surprisingly, the scores to the state part of the state and trait anxiety inventory (STAI, Spielberger et al., 1983) remained unchanged by this induction in both MD and LD subjects. This contrasted with our predictions that an increase would be observed, at least in MD subjects, who were more anxious than LDs even before the induction. One possibility for the absence of increase could be that the content of the induction corresponded to the suspicions of MDs and, as such, did not further enhance their anxiety levels. In any case, the stability of the anxiety levels in both groups implies that ERPs differences observed in the present study are likely to be due to the effect of the paranoid induction itself. The fact that healthy subjects with higher delusional-like ideation scores displayed reduced N400 amplitudes compared to subjects with less or no delusional-like ideation, like in More- relative to Less-delusional schizophrenia patients (Debruille et al., 2007; Kiang et al., 2007), suggests that the induction of paranoid feelings has promoted a

similar cognitive strategy to that displayed by patients. To assess the effect of the induction, the N400 amplitudes of the previous study (Prévost et al., in press) were compared to those of the present study. Analyses revealed significant differences in N400 amplitudes across studies. MD subjects had smaller N400 amplitudes after paranoid induction than in the study without induction but LD subjects had no significant variations of N400 amplitudes between the two studies.

The fact that larger N400 effects were observed for higher delusional-like ideation scores (Figure 4a) should be taken with caution. A superficial analysis of the results suggests that this could be due to a greater decrease of the N400 in the exemplar than in the non-exemplar category. This analysis is contradicted by Figure 3, which reveals that the amplitude of the effect of delusional-like ideation in the non-exemplar category was similar to that observed in the exemplar category. This similarity suggests an absence of differences in the N400 effect. The contradiction is most likely to be due to the 50 ms delay observed in the ascending slope of the effect of delusional-like ideation on ERPs in the non-exemplar (dashed lines) relative to the exemplar category (continuous lines). If it had been possible to adapt the time-window of measure of the non-exemplar category to this delay, the effect of delusional-like ideation in this condition would have appeared as large as that observed in the exemplar category and there would have been no correlation between delusional-like ideation and the N400 effect.

The ERP differences observed between the two groups in the N400 time window appeared to continue during the following time-window, that is, the LPC time window.

As the N400 and the LPC potentials partially overlap each other, one might wonder whether the differences observed in the N400 time window are due to LPC differences. Nevertheless, the difference between MD and LD subjects peaked at about 500 ms, thus between the latency of the peak of the N400 effect and the latency of the peak of the LPC (Figure 3), as in Debruille et al. (2007) This indicates that delusional-like ideation led to both a decrease of N400 and an increase of LPC amplitudes. The absence of differences of scalp topographies between the delusional-like ideation effect in the N400 time window and the delusional-like ideation effect in the LPC time window does not contradict this idea. The two components have been found to have similar scalp topographies and their decomposition seems to lead to a common independent component (Groppe et al., 2008; Makeig et al., 2004).

As illustrated in Figure 4c, the interpersonal factor also had an important impact on the ERPs in the N400 time window. Comparing Figure 4a to Figure 4c shows that this impact was in a direction opposite to that of the effect of delusional-like ideation. It is thus not surprising that the effect of delusional-like ideation appeared to be stronger when the interpersonal and disorganization covariates were introduced in the analyses. On the other hand, it is to note that more severe delusional-like ideation can be associated with higher disorganization scores and higher interpersonal scores, as is the case in the present study, in Debruille and colleagues (2007) and in Prévost and colleagues (Chapter 4). Accordingly, opposite effects on the ERPs of the N400 time window may explain some of the discrepancies existing in the literature if there were differences between the patterns of correlations and the clinical dimensions across

population samples (Condray et al., 1999; Niznikiewicz et al., 1997). Interestingly, when comparing the present study with our previous study (Prevost et al., Chapter 4), the paranoid induction appears to increase the partial correlations between the interpersonal factor and the ERPs in the N400 time windows. It also seems to widen the distribution of these correlations, with more left and medial centro-parietal electrodes involved than in our previous study in healthy subjects. The paranoid induction may thus have enhanced the impact of suspiciousness on ERPs, an idea which is in line with Kiang and Kutas' proposition (2005) that it is the suspiciousness dimension of the interpersonal factor that is responsible for the correlation between interpersonal scores and the amplitude of ERPs in the N400 time window.

On the other hand, the disorganization factor did not correlate with the N400 in the present study, in contradiction with studies with schizophrenia patients where greater N400 amplitudes correlated with higher thought disorder scores (Andrews et al., 1993; Kostova et al., 2005) and in contradiction with our previous study where these correlations were found in healthy subjects (Prévost et al., Chapter 4). One possibility is that the paranoid induction used in the present study decreased disorganization, in line with the original thinking of Bleuler (1911, 1950) who viewed delusion as a compensatory reaction against disorganization. The induction could have provided a hint for that compensatory mechanism. In addition, it could have prevented subjects from being relaxed by the slow pace of the experiment due to the long SOAs (i.e, 2 seconds) and its simplicity. By doing so, it could have foiled free associations which, for disorganized subjects, are distant and far from associations that are useful for the task.

The paranoid induction could thus trigger a more restricted mode of processing where fewer inappropriate associations occur. In these circumstances, disorganization would have had much less consequences on information processing, hence an absence of correlations. But it has to be noted that this reasoning leads to predict an impact of disorganization in the protocol used by Kiang and Kutas (2005). Indeed, the pace of their experiment was even slower than that of the present one and they used healthy subjects without paranoid induction. However, Kiang and Kutas (2005) reported an absence of impact of disorganization on N400 effects. Their results can be explained only if disorganization increased the N400 amplitudes of the exemplar and the non-exemplar category similarly. No impact on N400 effect should then be seen, as observed in Prévost and colleagues (Chapter 4).

Another result seems to be at odd with previous results. In the present study, the amplitudes of the N400s for exemplars were smaller in MD than in LD subjects, whereas, in Debruille and colleagues (2007), the N400s for exemplars of More-delusional patients were not significantly smaller than that of Less-delusional patients. However, the N400 deflections of patients in Debruille and colleagues (2007) were already very small in the exemplar category and could not be decreased as much as in the non-exemplar category.

Whether they were obtained in schizophrenia patients or in healthy participants with delusional-like ideation under paranoid feelings, the functional significance of the smaller N400s obtained in participants with more or less delusional-like ideations has to be discussed. As mentioned in the introduction, there is a general agreement on the

idea that N400 indexes semantic processes. However, there are at least three different views as to the precise nature of these processes. Within the first, that of access in semantic memory (for a review, see Kutas & Federmeier, 2000), the smaller N400s obtained in MD subjects suggest that they access a smaller amount of semantic representations than LD subjects. In other terms, the target word activates a more limited range of semantic features or associates of the target concept. Dealing with such a smaller range may be simpler for the system, an interpretation that is consistent with the shorter RTs and the fewer errors observed in MD than in LD subjects.

Others view N400 as an index of the efforts deployed by the brain to integrate the meaning of the eliciting item within its context (Holcomb, 1993; van Berkum et al., 1999). Accordingly, the induction would lead to a weakening of the integration efforts of MD subjects. The shorter RTs of the subjects with delusional-like ideation also give support to this possibility of a shallower integration. Moreover, this possibility is in accordance with the jumping to conclusions style of reasoning, a style which has been proposed as a cognitive account of delusion formation (Broome et al., 2007; Garety & Freeman, 1999). Nevertheless, this account is inconsistent with the fact that MDs did not make more errors than LDs. On the contrary, they were a little bit more accurate than LDs.

Still within the N400 integration hypothesis, our results could be interpreted as suggesting that MD subjects are more skilled at the task than LD subjects. Their smaller N400s, shorter RTs, and greater accuracies could reflect a greater ease at performing the semantic integration. Following this idea leads to conclude that the paranoid

induction had a positive effect on subjects with delusional-like ideation. However, evidence against this interpretation is provided by Coch and Holcomb (2003) in their study with first-grade children. They observed that More-skilled readers produce greater N400 potentials than Less-skilled readers. Accordingly, smaller N400s do not index greater eases at semantic processing.

A yet different account of the present results is provided by the idea that N400 indexes the inhibition of inappropriate semantic representations (for a review, see Debruille, 2007). In the present study, the prime word 'animal' would have activated the knowledge corresponding to various animals in the expectation that the target will be the name of an animal. The occurrence of the name of an object would trigger the inhibition of this knowledge whereas the occurrence of the name of an animal would trigger the inhibition of the knowledge that does not correspond to that specific animal. Within the view that N400s indexes this type of inhibition, the smaller N400s of MD subjects suggest that the induction led to a decrease of the amount of knowledge that was inhibited. In other terms, some of the expectations contradicted by the target remained in an activated state. These results can thus be used to support the view that the persistence of delusion despite disconfirming evidence may be due to a lack of inhibition of inappropriate knowledge by disconfirming evidence (Debruille et al., 2007; Moritz & Woodward, 2006). Such a partial inhibition is compatible with the shorter RTs and the jumping to conclusion style, but not with the smaller error rates. On the other hand, it may be tempting to link this weak inhibition with the two processing systems used by Speechley and Ngan (2008) to account for the delusions, that is, the slow and

rational system and the fast and intuitive system. The partial inhibition could be the neurocognitive mechanism by which the output of the first fails to suppress the output of the second system.

Authors also diverge as to the functional significance of the LPC. Using words as stimuli, Kutas and colleagues (1977) showed that an ERP similar to the LPC, since it peaked around 600ms at midline parietal sites, behaved like the well-known oddball P3b component (Squires et al., 1975). Its amplitude appears to be maximal for stimuli of the rare category. Therefore, the LPC could include a component that belongs to the P3b family and the latency of which would be delayed by the use of stimuli (i.e., words) that are more complex than the simple tones used in the classical oddball protocol. Analyzing LPC differences obtained in the present experiment as P3b-differences leads to two possibilities. First, MD subjects paid greater attention to our word stimuli than LDs. However, this possibility is inconsistent with their smaller N400s, since N400 amplitudes are known to be greater when more attention is allocated to the semantic processing of the stimulus (Chwilla et al., 1995). It is also inconsistent with the smaller N100s MDs had. Indeed, the amplitude of these early ERPs is well-established index of the amount of attentional resources allocated to the processing of a stimulus (Mangun & Hillyard, 1990). The second possibility derives from the idea that the P3b indexes the amount of information introduced in working memory, or the working memory update (Donchin & Coles, 1988). Accordingly, after a paranoid induction, subjects with delusional-like ideation would include more information in working memory than subjects with less delusional-like ideation. This view goes with the idea that smaller N400s index lesser

semantic inhibition since this idea implies that a greater amount of knowledge remains in an activated stage and can thus enter the next stage of information processing, that is, the working memory stage. In the present experiment, the nature of this information would be as previously mentioned. The prime word 'animal' would have activated the knowledge corresponding to various animals in the expectation that the target will be the name of an animal. The occurrence of the name of an object would normally trigger the inhibition of this knowledge. Meanwhile, the occurrence of the name of an animal would trigger the inhibition of the knowledge that does not correspond to that specific animal. In case of a partial inhibition, some of this inappropriate knowledge would enter working memory. This view is consistent with the findings of two recent studies showing that the amplitude of the LPC elicited by words is proportional to the amount of information conveyed by these words (Burkhardt, 2007; Kounios et al., 2009).

Taken together, the faster reaction times, the reduced N400 amplitudes and the greater LPCs in MD subjects suggest that delusional-like thinking in normal individuals who are having paranoid feelings is accompanied by robust changes in cognitive strategies. These ERP results are similar to those found in delusional schizophrenia patients, which strengthens the idea of a continuum from personality traits in healthy people to psychiatric disorders in patients. On the other hand, the weakness of semantic processes found could be responsible for the persistence of inaccurate ideas and beliefs, including delusional-like ones, by preventing a full processing of contradicting information.

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Bridging Chapter 5 to Chapter 6

The two previous chapters evaluated the relationship between schizotypal traits of healthy people and the semantic information processing indexed by the N400 event-related potential. Chapter 5 was a modified version of chapter 4 where paranoid feelings were induced in participants. Only when participants experienced paranoid feelings, delusional-like ideation was correlated to reduced N400 amplitudes, suggesting a shallower processing of semantic information or a facilitation effect of the context on the processing of this information.

The present chapter analyzed the sub-components of the N400 potential to help understand which aspects of the semantic processing are influenced by the three schizotypal traits evaluated previously, that are disorganization, the interpersonal factor and delusional-like ideation. Some of these sub-components were sensitive to the context or some were independent of it. Delusional-like ideation was found to influence the processing of semantic information even when paranoid feelings were not induced, as shown by its influence on a centro-parietal component of the N400. However, this influence was not related to the facilitation effect of the context on the target words. When paranoid feelings were induced, delusional-like ideation influenced a centro-parietal component of the N400 as well, but that was sensitive to the context effect on the target word. Paranoid feelings thus promoted the influence of delusional-like ideation on the facilitation effect of the context.

Chapter 6

**Schizotypal traits of healthy participants correlate
with specific independent components of the N400
potential**

Abstract

Schizotypal traits have been shown to modulate semantic processing, as indexed by the N400 event-related potential. Namely, delusional-like ideation was correlated with smaller N400 amplitudes, disorganization with enhanced N400 amplitudes and the interpersonal factor with reduced N400 effects. The present study investigates whether each trait impacts different independent components of the N400 potential or the same components using the data of two previous semantic categorization studies, which differed only in environmental conditions. Namely, in the second study, paranoid feelings were induced in participants so that their cognitive functioning resembles that of schizophrenia patients. The data of both studies were separately submitted to an Independent Component Analysis (ICA). Six independent components were chosen in each study based on their distribution, the percentage of variance they accounted for and their overlapping activity in the N400 time window. This was done for the exemplars of the semantic category chosen, non-exemplars and the difference between the two. Partial correlations and linear modelling were used to study how schizotypal traits affect the activity of each component of the N400. In both studies, delusional-like ideation was related to centro-parietal components whereas disorganization was related to frontal components and the interpersonal factor to frontal and central components, which could not be entirely observed with the ERPs mean amplitudes.

Introduction

Recent studies have shown that healthy people with traits that resemble schizophrenia symptoms demonstrate cognitive anomalies similar to those observed in schizophrenia patients (e.g., Bedwell et al., 2009; Johnston et al., 2008; Wilson et al., 2008). More specifically, anomalies of the processing of semantic information have been found in healthy subjects with traits similar to disorganization, delusions, and negative symptoms (Prévost et al., Chapters 4 and 5; Johnston et al., 2008), echoing earlier results obtained with patients (e.g., Debruille et al., 2007; Salisbury et al., 2000; Kiang et al., 2007; Rossell et al., 1998). However, the correlations between these schizotypal traits and the event-related potential (ERP) reflecting semantic processing, that is, the N400, were intriguing with regards to their scalp localizations. While priming the semantic processing of written words usually impacts centro-parietal sites (Holcomb, 1988; Kutas et al., 1988), the correlations were maximal at right fronto-central sites for disorganization and at left central sites for interpersonal factors, suggesting that these traits could relate to particular components of the N400.

Two semantic categorisation experiments were previously built to assess the scalp distribution of these N400 modulations in a systematic way (Prévost et al., Chapter 4; Prévost et al., Chapter 5). In one of these experiments paranoid feelings were induced in participants to favour cognitive strategies similar to those of schizophrenia patients. Both studies were otherwise identical regarding participants' characteristics and the semantic categorization task used. After induction of paranoid feelings, correlations between N400 amplitudes and disorganization became non-existent while correlations

between N400s and delusional-like ideations appeared over centro-parietal electrodes. The correlations with the interpersonal factor moved from left central to left fronto-central sites. To determine whether schizotypal traits impact similar sub-components of the N400 potential in the two studies and whether these components are maximally activated over frontal regions and centro-parietal regions, we now analyze the data of these two previous experiments using independent component analysis (ICA) and linear modelling.

Late ERPs, such as the N400, are thought to be summations of the activities of different sub-components over the scalp (Halgren et al., 2002; van Petten & Luka, 2006; Luck, 2005). A way to extract these sub-components is to apply ICA (Comon, 1992; Bell & Sejnowski, 1995) on the ERP data. This type of analysis rests on the hypothesis that the sub-components should be statistically independent from one another, and are thus referred to as Independent Components (ICs). Previous studies have shown how ICs could differentiate specific brain processes which partially overlap in time and in space (Debener et al., 2005; Ceponiene et al., 2005). In the present study, ICA was applied to the ERP data of the two previous studies to isolate the ICs involved in the correlations observed between schizotypal traits and ERPs in the N400 time window. Indeed, these correlations were overlapping on the scalp, suggesting that schizotypal traits could influence similar components of the N400. On the other hand, some correlations were localized over parietal sites whereas others were more frontal, suggesting that different ICs might be at stake.

Very few studies have investigated the ICs composing the N400, the negative potential that reaches its maximum around 400 milliseconds and is sensitive to semantic manipulations (Kutas & Hillyard, 1980; Kutas & Iragui, 1998). Mehta and colleagues (2009) recently observed that the ICs contributing the most to semantic processing of auditory meaningful stimuli (and thus to the N400 potential) was a right parieto-occipital component. Another study with auditory stimuli showed that multiple components index the semantic processing of a word in a time window similar to that of the N400 (Ceponiene et al., 2005). Another study showed three types of components explaining the N400 potential: a parieto-occipital cluster, a right frontal cluster and a left frontal cluster of components (Debruille & Renoult, 2009). This suggests that each sub-component of the N400 might reflect a specific aspect of semantic processing. Factors, such as the experimental conditions, patients' symptoms or personality traits, might affect only some of these aspects of semantic processing and thus only one or a few ICs, hence the relevance of ICA.

In the present study, we predicted that each schizotypal trait would impact different independent components, whose maximal activity would match the localization of the correlations previously observed with mean voltage amplitudes. Most importantly, the present work aimed at exploring whether ICs that are related to schizotypal traits are sensitive to the facilitation effect induced by the semantic relatedness between the context stimulus and the target stimulus. Our semantic categorization task is made of two types of target words: names of animals and names of artefacts. Most of the target words are preceded by the word 'ANIMAL?' and

participants have to decide if a target word is an animal or not. In this task, the treatment of an animal target word is facilitated (shorter reaction times and smaller N400s) by the context word 'ANIMAL?'. Consequently, some ICs could be influenced by the context facilitation effect, as the N400 amplitudes were in both studies, but others could be insensitive to that effect. As both delusions and disorganization have been proposed to result from anomalous context utilisation in patients (Hemsley, 1993; 2005), it is expected that both delusional-like ideation and disorganization will influence the facilitation effect, as suggested by N400 studies in patients (Debruille et al., 2007; Ditman & Kuperberg, 2007; Kostova et al., 2005; Kuperberg et al., 2006).

Methods

Participants

Participants, aged between 18 and 50 years old, had normal or corrected to normal vision, were right-handed and had no history of psychiatric illness, except for depression that resolved at least two years before the experiment took place. Criteria of exclusion included a history of head injury with loss of consciousness longer than 10 minutes, neurological or medical conditions known to compromise brain function and drug abuse. The study without paranoid induction had 47 participants and the study with induction had 38 participants.

Before having their ERPs recorded, participants had to complete the SPQ. This questionnaire is based on the DSM-III-R criteria for schizotypal personality disorder and includes nine subscales that can be grouped into three clusters or factors: (1)

interpersonal, (2) disorganization, and (3) cognitive-perceptual (Raine et al., 1994). The validity of the whole SPQ has been demonstrated (Raine, 1991). Its clusters have been defined by a factor analysis (Raine et al., 1994) and used in many previous studies (e.g. Dickey et al., 2005; Kiang & Kutas, 2005; Sommer et al., 2008). The interpersonal score is computed by adding the scores for the 'social anxiety', the 'no close friends', the 'constricted affect' and the 'paranoid ideation' subscale. The disorganization trait score is computed by adding the score for the 'odd speech' subscale to the score for the 'odd or eccentric behavior' subscale. The 'cognitive and perceptual' cluster could not be used to evaluate delusional-like ideation since it also includes hallucinations. It is thus the scores for the two subscales 'Idea of references' and 'Odd beliefs and magical thinking' that were used here, as previously done in a study performed to assess the neurocognitive mechanisms underlying delusional-like ideation in normals (e.g. Woodward et al., 2007). Here, these two scores were simply added. Note that paranoid ideation was not integrated into the delusional-like ideation score because this subscale does not include delusional items *per se* but rather, suspiciousness, which is already included in the interpersonal factor.

The induction of paranoid feelings in the study with induction was made with the addition of two sentences in the consent form. One stated that small and harmless currents could be emitted that could temporarily change brain functioning. The second sentence stated that a purpose of the study was hidden and would be revealed after the experiment took place. In addition, participants were recorded next to a one-way mirror. The induction was efficient as participants had enhanced paranoid feelings after

this manipulation, measured with Bodner and Mikulincer's questionnaire (1998) to which one item was added ('I feel that others are changing my functioning'). To control for a possible induction of fear instead of paranoid feelings, anxiety levels were assessed before and after the induction. The induction did not affect participants' anxiety. At the end of the experiment, participants were told that no currents were emitted, that nothing was hidden and that nobody or nothing was behind the mirror.

Task

Subjects were seated comfortably in a dimly lit room in front of a computer screen placed 1 m from their eyes. Black stimuli were presented on a white background at the center of this screen. In two-thirds of the trials, the first word was the question word 'ANIMAL?' and, in one-third of the trials, the first word was the instruction 'INACTION'. These words were then followed by the target word. The stimulus onset asynchrony was 2 seconds and each word was displayed for 1 second. The target word was either an exemplar of the animal category (e.g., lion) or a non-exemplar of this category (e.g., hammer). When the first word was 'ANIMAL?', subjects had to decide whether or not the target word belongs to the animal category as rapidly and as accurately as possible by pressing one of two keys with their right index finger. The word 'INACTION', introduced to avoid a habituation effect, signaled to the participants that they should not respond to the target stimulus, which was also either an exemplar or a non-exemplar of the animal category. The non-exemplars stimuli comprised names of tools, piece of furniture, office and kitchen objects, building and parts of buildings, and transportations means. The target word was followed 2 to 2.5 seconds later by the

word 'Blink', giving the subjects the opportunity to blink without disrupting the electroencephalogram (EEG) signal of the trial. In the action condition, there were 60 trials with exemplar target words and 60 trials with non-exemplar target words. For the 'INACTION' condition there were 30 trials for each of the two stimulus categories. Each target word was presented only once, thus the probability of occurrence of a particular target word was 1 out of 180. The mean frequency of usage and the mean number of letters of the exemplars were matched to those of the non-exemplars (Prévost et al, Chapter 4 and 5).

Data Acquisition

The EEG was recorded with tin electrodes mounted in an ECI cap (Electro-Cap International) from 30 active points, all initially referenced to the right ear lobe. Twenty-eight of these points were placed according to the extended International 10-20 System (American EEG Society, 1991). The remaining two active electrodes were placed below each eye in order to allow the monitoring of vertical eye movements by comparing their EEG signals to those derived from Fp1 and Fp2. The monitoring of horizontal eye movements was performed by comparing F8 to F7 signals. The impedance was kept below 5K Ω . The gain of the Contact Precision Instruments amplifiers used was set at 20 000. The half amplitude cut-offs of high and low pass frequency filters were set at 0.01 and 100 Hz, respectively. In addition, a 60 Hz electronic notch filter was used. EEG signals were digitized at a 256 Hz sampling frequency and stored along with the stimulus

and response codes. The EEG was re-referenced off-line to the mean of the left and right earlobes signals.

Measures

Our baseline was set between –200 and 0 ms. Averages were calculated for EEG epochs with correct responses only that were given between 200 and 2000 ms after stimulus onset. The N400 amplitude was measured by computing the mean voltage of the ERPs in a 350-550 ms time window, relatively to the baseline. This time window was centered on the latency of the negative peak observed on the grand average of the non-exemplar – exemplar ERP subtractions, which was 450 ms. For each subject, a mean voltage was computed at each electrode for the N400s of the exemplars, for the N400 of the non-exemplars and for the N400 difference (non-exemplar minus exemplar amplitudes).

Analyses

Independent Component Analysis

ICA was run with EEGLAB 6.01b (Delorme & Makeig, 2004), a freely available open source toolbox (<http://www.sccn.ucsd.edu/eeglab>) running under Matlab 7.7 (Mathworks, Natick, MA). Individual subjects ERPs of 1 second (–200 to 800 ms) from our 30 active electrodes were concatenated separately for each condition (exemplars, non-exemplars) in each task, yielding two different matrices of 30 x 9766 points (38 subjects x 257 time points) for the study with induction and 30 x 12079 (47 subjects x

257 time points) for the study without induction that were submitted to ICA. Decompositions of ERPs from each study were performed separately. We applied infomax ICA (Bell & Sejnowski, 1995) with the EEGLAB function runica (Delorme & Makeig, 2004), which produced 30 independent components.

Six independent components (IC) were selected based on their distribution on the scalp, the percentage of variance they accounted for in 350-550ms time window, and their overlapping activity in the N400 time window for exemplars, non-exemplars and the differences (N400 effect, i.e., non-exemplars minus exemplars). The 6 electrodes (F3, F4, CZ, PZ, P3 and P4) were chosen for comparison purposes and according to the localization of the maximal correlations previously observed in Prevost et al. (in press) and in Prevost et al. (submitted). Table 1 displays the variance of the N400 amplitude accounted for by each IC in both studies.

Without induction	IC2	IC3	IC5	IC7	IC9	IC12	All ICs
Exemplars	27	0	-8	9	13	11	56
Non-exemplars	-17	36	36	-9	36	-4	69
Difference	23	23	41	16	1	30	84
With induction	IC1i	IC2i	IC3i	IC4i	IC6i	IC7i	All ICs
Exemplars	9	20	20	50	48	-38	62
Non-exemplars	40	-10	1	7	-17	40	52
Difference	28	6	20	60	38	-10	93

Table1: Percent of variance accounted for by various independent components (ICs). Negative values indicate that if this IC activity were to be removed, the signal would be enhanced (see documentation on <http://www.sccn.ucsd.edu/eeqlab>). Note that the ICs of the study with induction and those of the study without induction are from different decompositions.

Categories effect

One-way ANOVAs were applied to mean voltage amplitudes at selected sites (6 electrodes) and to IC mean activity (6 ICs for each study) with the same within-subject factor (exemplar vs. non-exemplar) using Statistical Package for the Social Sciences version 13.0 (SPSS Inc., 2004, Chicago, IL).

Schizotypal traits influence

The three schizotypal traits were positively correlated in our studies ($r > .55$, $p < .001$). Partial correlations were therefore computed between traits scores and the mean activity of selected ICs (or the mean voltage amplitudes for selected electrodes), using SPSS. Every correlation was thus controlled for the two other schizotypal trait scores, thereby isolating the unique contribution of each trait. Although efficient at handling correlations among predictors, this procedure typically has limited statistical power (Neter et al., 1996). We therefore supplemented it with a linear modelling (multiple regressions) approach: a linear model was used to predict mean activity/amplitude from the scores of the three traits, as well as from their pairwise interactions. The relative importance of each schizotypal trait in predicting activity/amplitude (i.e. the probability that this trait is actually important) was computed using the Bayesian Information Criterion (BIC) with the R package *glmulti* (Burnham & Anderson 2002; Calcagno & de Mazancourt, in press).

Study without induction

Results

Mean voltage amplitudes were greater (more negative) for non-exemplars than for exemplars for all selected electrodes, as can be seen in figure 1 (Cz: $F(1,46) = 42.2$, $p < 0.001$; Pz: $F(1,46) = 61.9$, $p < 0.001$; P3: $F(1,46) = 53.5$, $p < 0.001$; P4: $F(1,46) = 76.6$, $p < 0.001$; F3: $F(1,46) = 24.2$, $p < 0.001$; F4: $F(1,46) = 34.1$, $p < 0.001$).

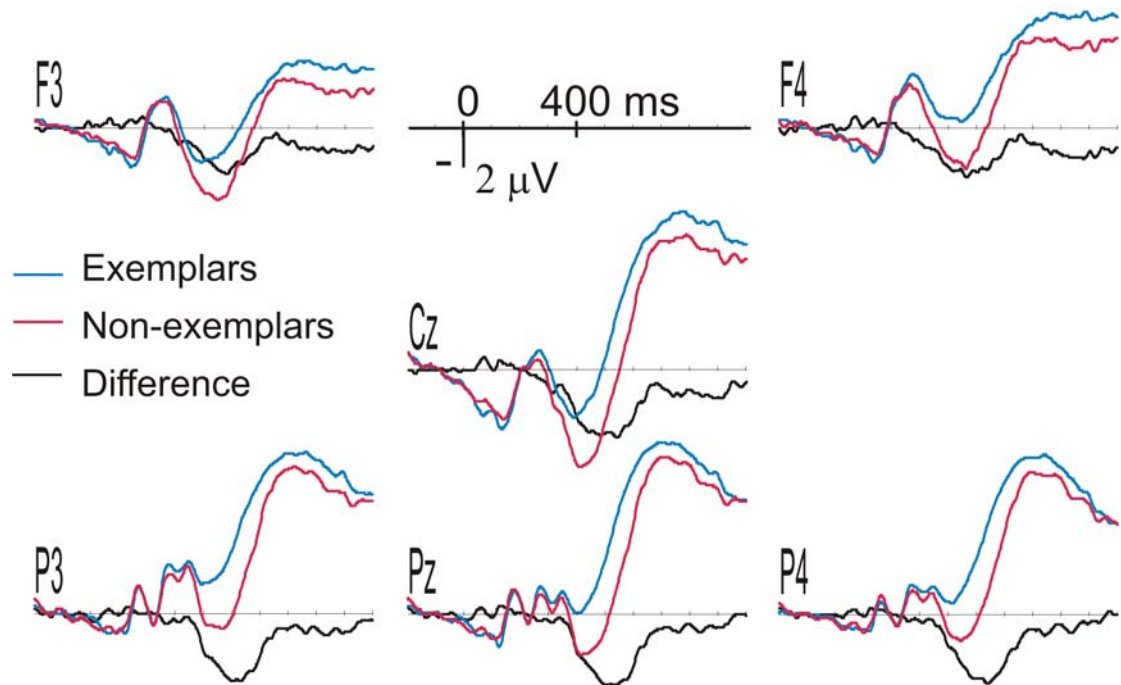


Figure 1: In the study without induction, mean voltage amplitudes for exemplars, non-exemplars and for the differences (non-exemplars minus exemplars).

Results from the partial correlations between N400 mean voltage amplitudes and schizotypal traits are given in Figure 2A (adapted from Prévost et al., Chapter 4).

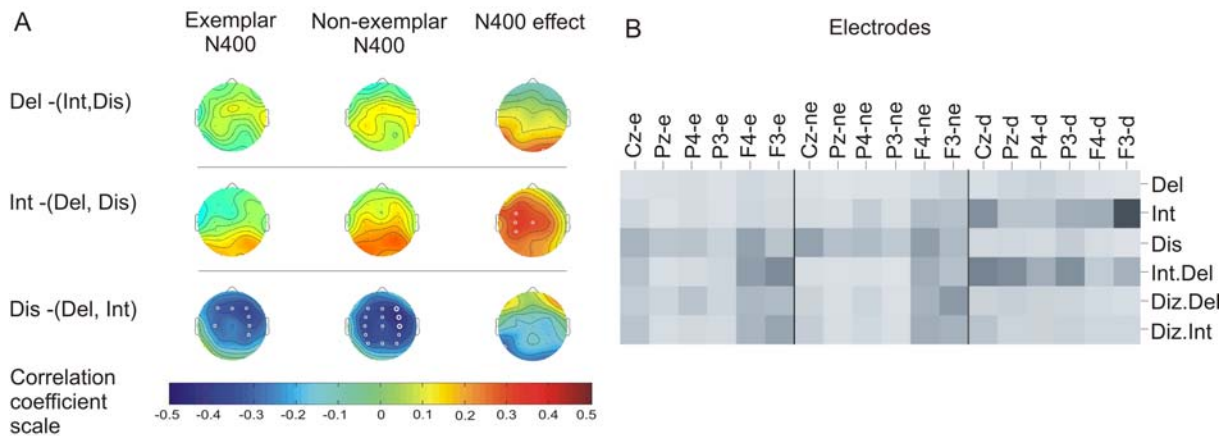


Figure 2: In the study without induction: A/ Scalp map of the partial correlation coefficients between N400 amplitudes in the 350-550 ms time window and schizotypal traits; white circles represent $p < 0.05$ (adapted from Prévost et al., Chapter 4). B/ Representation of the linear model. The darkness of each box is proportional to the relative importance of each of the three schizotypal traits, or of the interaction of two of these traits, in predicting mean voltage amplitudes of ERPs in the same N400 time window for the 6 selected electrodes in the exemplar condition (e), non-exemplar condition (ne) and difference (d). In other words, the level of grey of each box ranges from 0 (white) to 1 (black), indicating the probability that one trait or the interaction of two traits belongs to the best models predicting mean N400 amplitude, as defined by the Bayesian Information Criterion. Del: delusional-like ideation; Int: interpersonal trait; Dis: disorganization trait.

Results from the linear model are presented in Figure 2B. Delusional-like ideation did not influence N400 amplitudes, except in interaction with the interpersonal factor on frontal electrodes for exemplar and non-exemplar conditions and on centro-parietal electrodes for the N400 effect. The interpersonal factor was involved in the best model fitting the N400 amplitudes over frontal electrodes voltage for non-exemplars and for the differences, and over Cz for the difference only. Disorganization influenced the mean voltage at F4 and F3 in both conditions and at Cz for non-exemplars only.

With independent components, an exemplar category effect was observed for IC3 ($F(1,46) = 5.8$; $p < 0.05$), IC5 ($F(1,46) = 14.3$; $p < 0.001$), and IC12 ($F(1,46) = 24.7$; $p < 0.001$). It was just a trend for IC7 ($F(1,46) = 3.3$; $p < 0.075$), and was not significant for IC2 ($F(1,46) = 2.1$; $p = 0.157$) and IC9 ($F(1,46) = 0.0$; $p = 0.958$).

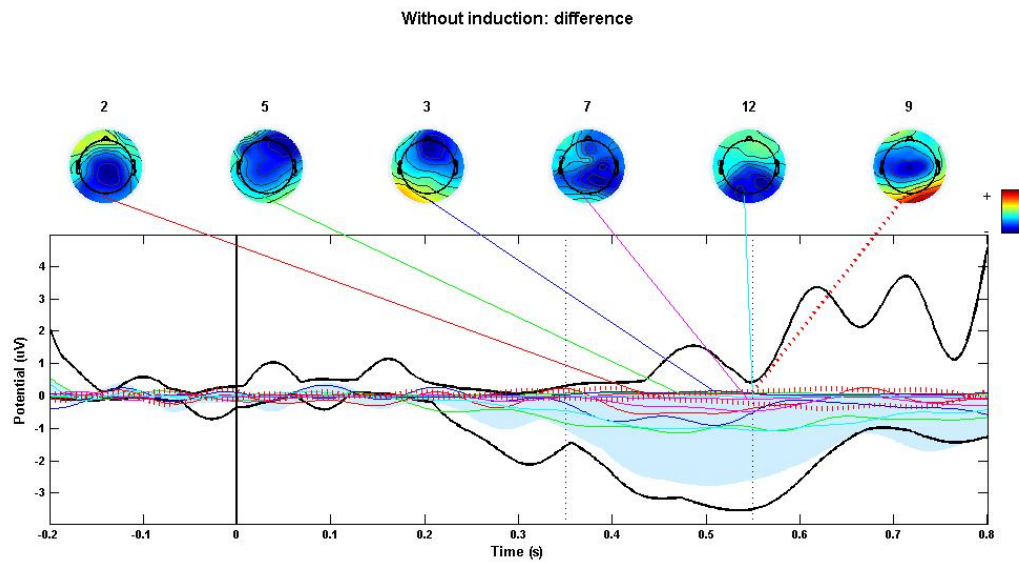


Figure 3: Scalp distribution and activity of the ICs for the difference (non-exemplar minus exemplar). The vertical black lines at time 0 indicates target words onset. The thick black lines show the envelope, that is the most positive and negative values of the ERPs over all channels and at each time point. The blue traces show the envelopes of the contribution of the independent components (ICs) represented. Each IC scalp map is connected to its data envelope by a color line that points to the moment of peak contribution to the ERP (see Delorme & Makeig, 2004).

		IC2	IC3	IC5	IC7	IC9	IC12
Exemplar	Del	-0.18	0.26[†] (-0.03, 0.51)	0.06	-0.14	-0.11	0.07
	Int	0.09	-0.27[†] (-0.52, 0.02)	0.02	0.20	-0.23	0.07
	Diz	0.07	-0.27[†] (-0.52, 0.02)	-0.08	-0.08	0.11	-0.11
Non-Exemplar	Del	-0.05	0.29* (0.00, 0.54)	-0.03	-0.09	-0.05	-0.04
	Int	0.24	-0.15	-0.08	0.12	-0.01	0.12
	Diz	-0.14	-0.39** (-0.61, -0.11)	0.08	0.01	-0.01	-0.06
Differences	Del	0.30* (0.01, 0.54)	0.09	-0.10	0.03	0.07	-0.18
	Int	0.27[†] (-0.06, 0.55)	0.14	-0.09	-0.07	0.25	0.06
	Diz	-0.39** (-0.61, -0.11)	-0.23	0.16	0.12	-0.13	0.09

Table 2: Partial correlations coefficients found in the study without induction, by controlling for the two other schizotypal traits (the confidence interval given between the parentheses is for $P < 0.1$). Del: Delusional-like ideation, Int: Interpersonal factor, Dis: disorganization trait. Indicated in bold are the results for [†] $P < 0.1$, * $P < 0.05$ and ** $P < 0.01$

The participation of each schizotypal trait in the models is presented in figure 4. IC7 and IC12 were not noticeably related to any schizotypal traits, consistent with partial correlations (table 2).

The activity of IC3, a right fronto-central component, was best explained by the interpersonal factor for non-exemplars and for differences, but there is a clear interactive effect with disorganization for exemplars, non-exemplars and differences. As showed by the partial correlations, enhanced IC3 activity correlated with higher disorganization scores. IC9 activity was also modulated by the interpersonal factor, for the differences.

The activity of IC5, a right frontal component, was most influenced by the interpersonal factor alone, or in interaction with delusional-like ideation for exemplars and non-exemplars. Disorganization also contributed to IC5 activity for the exemplars, and in interaction with delusional-like ideation, for the non-exemplars. Consistent with partial correlations, no effect was detectable when looking at the difference though.

Only IC2, a centro-parietal component, tended to be influenced by delusional-like ideation. However, this influence was subtle and found only for IC2 activity for non-exemplars minus exemplars.

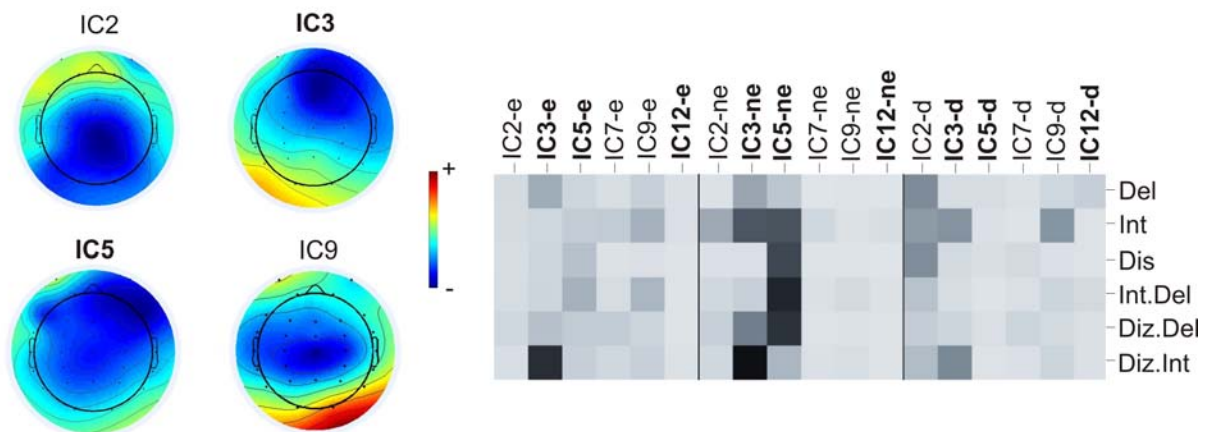


Figure 4: Results of ICA and linear model analyses in the study without induction. Left panel: scalp map of the activity of the four ICs influenced by schizotypal traits. Right panel: representation of the linear model, where the darkness of each box is proportional to the relative importance each of the three schizotypal traits, or of the interaction of two of these traits, in predicting ICs activity in the N400 time window in the exemplar condition (e), non-exemplar condition (ne) and difference (d). In other words, the level of grey of each box ranges from 0 (white) to 1 (black), indicating the probability that one trait or the interaction of two traits belongs to the best models predicting mean ICs activity, as defined by the Bayesian Information Criterion. Del: delusional-like ideation; Int: interpersonal trait; Dis: disorganization trait. ICs whose activity is significantly different between exemplars and non-exemplars are in bold.

Discussion

Voltage amplitudes of the N400 for the exemplar category were more negative than for non-exemplar category for all electrodes, reflecting the facilitation effect of the context on the exemplar target words. Delusional-like ideation had little impact on N400 amplitudes. The interpersonal factor was associated to a reduced N400 effect over the central electrode, whereas disorganization was mostly linked to enhanced amplitudes to non-exemplars, and less importantly to enhanced amplitudes to exemplars. For further details, a full discussion is available in Prevost et al. (Chapter 4).

Out of the six independent components, two frontal (IC3 and IC5) and one parieto-occipital (IC12) were modulated by the stimulus category. The other components activities for exemplars were not significantly different from that for non-exemplars and thus not sensitive to the facilitation effect. The distribution of these components sensitive to the facilitation effect is very similar to that of the clusters of components found in the only study that explored the sub-components of the N400 (Debruille & Renoult, 2009). The present study thus confirms the implication of at least two types of components in the facilitation effect.

Delusional-like ideation influenced the activity of a centro-parietal component (IC2) for the difference between non-exemplars and exemplars, but mostly impacted a right frontal component (IC5) in interaction with the interpersonal factor or with disorganization, for both exemplars and non-exemplars (figure 3). However, the activity of the centro-parietal component for exemplars was not significantly different from that

for non-exemplars whereas the activity of the right frontal component was. The relation between delusional-like ideation and the N400 was not visible in mean voltage amplitudes (figure 2) but can be observed after independent components extraction, suggesting that independent component analysis might be more sensitive to detect factor influences on semantic processing.

Disorganization was part of the best models explaining the activity of the right frontal component (IC5) both for exemplars and non-exemplars (figure 3), which was not seen in partial correlations. The impact of disorganization on another right frontal component (IC3), already shown by the partial correlations, was also observed in the linear model but only in interaction with the interpersonal factor. Both frontal components activities were significantly modulated by the exemplar categories. As expected, disorganization influenced the components that had a frontal distribution, consistent with the results observed for the mean electrodes voltage amplitudes. These results show that the influence of disorganization on semantic processes is more frontal than centro-parietal. The functional significance of this distinction remains unclear. It has been postulated that disorganization was related to a greater spreading of activation in the semantic networks (Maher et al., 1987; Manschreck et al., 1988; Spitzer et al., 1993) shown with short SOAs experiments. If the N400 reflects the activation of the semantic representation of a meaningful stimulus (Kutas & Federmeier, 2000; Lau et al., 2008), this overspread of activation can be observed in larger N400 amplitudes for a word, independently of its context. The more negative ERPs in the N400 time window in schizophrenia patients with current thought disorder (Andrews et al., 1993; Salisbury et

al., 2000) could support this proposal. In the present study with healthy participants, larger N400s correlated with high disorganization scores, also supporting this idea. The spreading of activation could be the process generating the central component (IC2) that was partially influenced by disorganization. This component was not sensitive to the context and could thus reflect the processing of the target words independently of its context. On the other hand, the effect of disorganization on the frontal component could reflect its influence on the category effect rather than the facilitation effect. Indeed, if overspread activation affected the context effect, the amplitude of the N400 should be reduced because it would ease the context effect on the targets for both exemplars and non-exemplars, opposite to what we observed here. Previous studies have showed that artefacts words elicited larger N400 amplitude than animal words (Proverbio et al., 2007; Debruille & Renoult, 2009). This category effect is likely to participate in the present semantic processing observed.

The interpersonal factor mostly influenced the two right frontal components (IC3 and IC5, figure 2) in the exemplar and non-exemplar conditions, but also had some effect on a central component (IC9). Only one of those components was also influenced by the interaction with disorganization (IC3). The interpersonal factor thus seemed to affect the facilitation effect, and possibly the category effect, as both frontal components have activities that contrasted exemplars from non-exemplars, which was unexpected. The interpersonal factor of healthy people has been linked once with ERPs in the N400 time window (Kiang & Kutas, 2005). Our study suggests that the impact of the interpersonal factor is related both to a central component and to frontal

components of the N400 potential, a result similar to the effect of disorganization. The central component, however, was not sensitive to categories. The interpersonal factor thus influenced both the semantic processing of the target word independently of the context but also the aspect of the word processing in relation to its context or to its category membership. One study in schizophrenia patients reported that negative symptoms correlated with smaller N400 difference between category membership target words (Mathalon et al., 2009). The interpersonal factor being similar to negative symptoms of schizophrenia, it is possible that this trait influence the category effect more than the facilitation effect in our study.

In conclusion, disorganization, delusional-like ideation and the interpersonal factor were linked to the same components to some degree. As expected, frontal correlations between disorganization and ERPs amplitudes were underlain by an influence of this schizotypal trait on frontal independent components. Interestingly, the interpersonal factor influenced a central component, as expected, but also a frontal one, which was not observed with ERPs amplitudes. Similarly, delusional-like ideation showed a participation in the variation of activity of both a frontal and a centro-parietal component. These results suggest that mean voltage amplitudes correlations were not sufficient to estimate schizotypal traits influence on semantic processing.

Study with induction

Results

As displayed in figure 5, more negative voltages in the non-exemplar than in the exemplar conditions were observed for all electrodes (Cz: $F(1,37) = 23.1$, $p < 0.001$; Pz: $F(1,37) = 27.3$, $p < 0.001$; P3: $F(1,37) = 30.7$, $p < 0.001$; P4: $F(1,37) = 32.2$, $p < 0.001$; F3: $F(1,37) = 17.3$, $p < 0.001$; F4: $F(1,37) = 31.7$, $p < 0.001$).

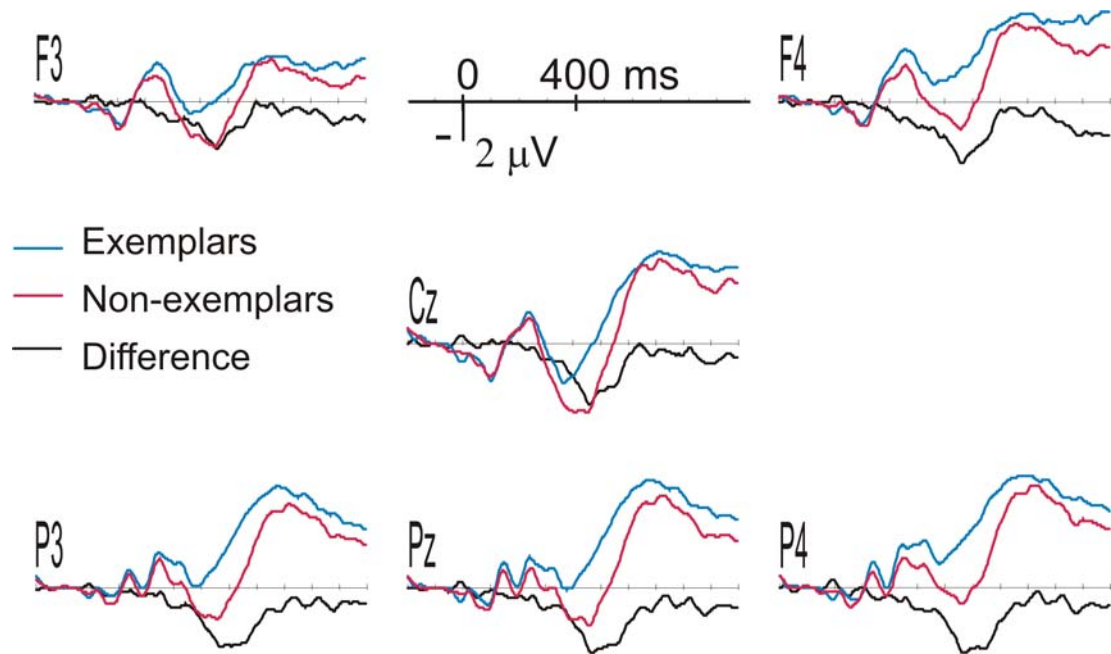


Figure 5: In the study with induction, mean voltage amplitudes for exemplars, non-exemplars and for the differences (non-exemplars minus exemplars).

The linear model (figure 6B) followed the partial correlations results (figure 6A) for delusional-like ideation influence. The interpersonal factor influenced mean voltage amplitudes over left frontal electrodes for the N400 effect only. In interaction with delusional-like ideation and with disorganization, it predicted the N400 effect amplitude over Pz and P3 and over Cz, P3 and F4 respectively. It also affected N400 amplitudes over centro-parietal electrodes for exemplars, when in interaction with delusional-like ideation. Finally, disorganization had little implication in the models fitting the mean amplitudes, except when in interaction with delusional-like ideation or with the interpersonal factor.

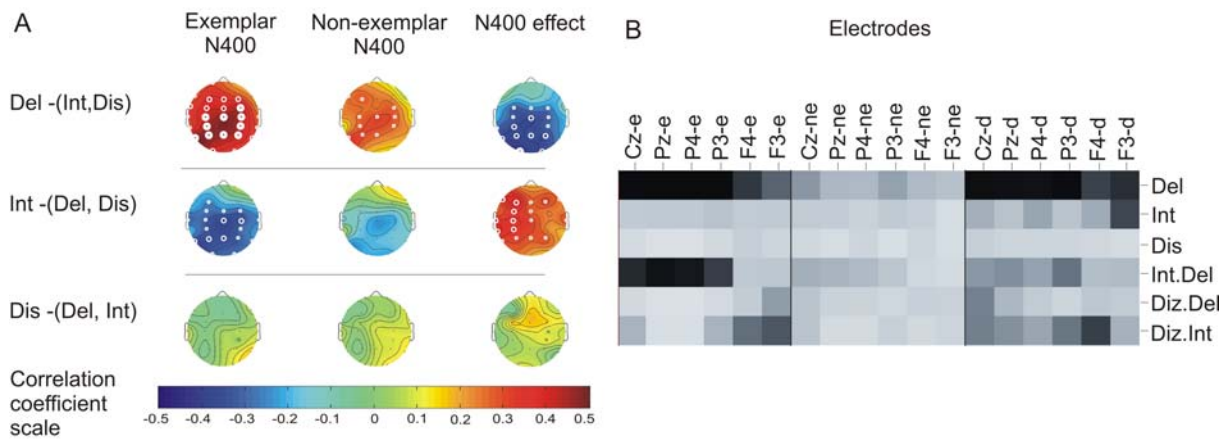


Figure 6: In the study with induction: A/ Scalp map of the correlation coefficients between N400 amplitudes in the 350-550 ms time window and schizotypal traits; white circles represent $p < 0.05$ (adapted from Prévost et al., Chapter 5). B/ Representation of the linear model, where the darkness of each box is proportional to the relative importance of each of the three schizotypal traits, or of the interaction of two of these traits, in predicting mean voltage amplitudes of ERPs in the same N400 time window for the 6 selected electrodes in the exemplar condition (e), non-exemplar condition (ne) and difference (d). In other words, the level of grey of each box ranges from 0 (white) to 1 (black), indicating the probability that one trait or the interaction of two traits belongs to the best models predicting mean N400 amplitude, as defined by the Bayesian Information Criterion. Del: delusional-like ideation; Int: interpersonal trait; Dis: disorganization trait.

ICs activities are displayed figure 7. An exemplar category effect was observed on IC4i ($F(1,37) = 4.1$; $p < 0.05$) and IC6i ($F(1,37) = 5.8$; $p < 0.05$). A trend for a category effect was observed in IC1i ($F(1,37) = 3.6$; $p < 0.067$) and was not significant in IC2i ($F(1,37) = 0.0$; $p = 0.839$), IC3i ($F(1,37) = 1.0$; $p = 0.314$) and IC7i ($F(1,37) = 1.1$; $p = 0.300$).

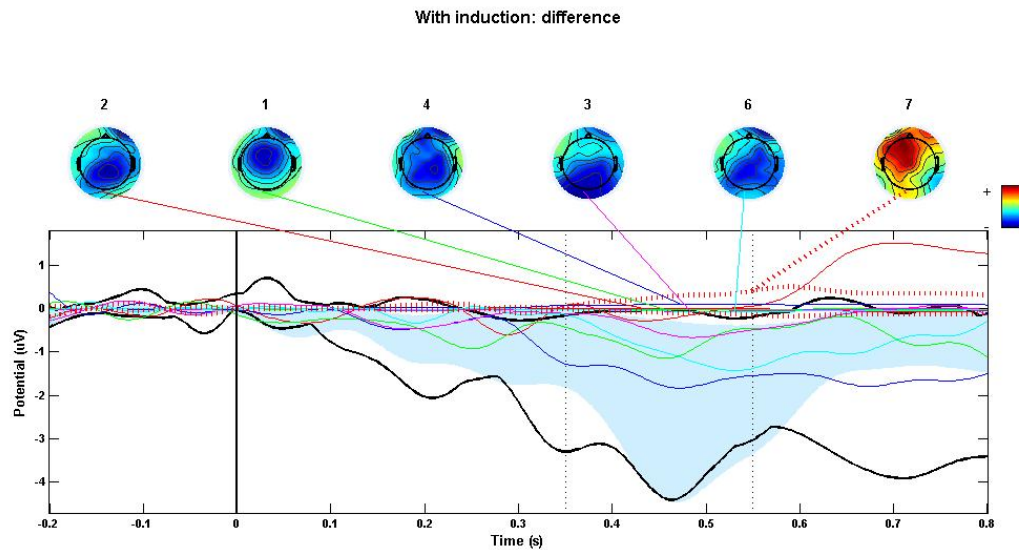


Figure 7: Scalp distribution and activity of the ICs for the difference (non-exemplar minus exemplar). The vertical black lines at time 0 indicates target words onset. The thick black lines show the envelope, that is the most positive and negative values of the ERPs over all channels and at each time point. The blue traces show the envelopes of the contribution of the independent components (ICs) represented. Each IC scalp map is connected to its data envelope by a color line that points to the moment of peak contribution to the ERP (see Delorme & Makeig, 2004).

		IC1i	IC2i	IC3i	IC4i	IC6i	IC7i
Exemplar	Del	0.07	-0.04	0.19	0.25	-0.35* (-0.61,-0.03)	-0.25
	Int	-0.08	-0.29[†] (-0.56, 0.04)	-0.18	0.20	0.13	0.21
	Diz	-0.16	0.13	0.05	-0.29[†] (-0.56, 0.04)	0.18	0.13
Non-Exemplar	Del	0.15	0.09	-0.01	0.14	-0.42* (-0.65,-0.11)	-0.21
	Int	-0.01	-0.10	-0.22	-0.20	0.23	0.13
	Diz	-0.03	-0.11	0.17	0.06	0.18	0.24
Differences	Del	0.06	0.10	-0.23	-0.20	0.14	0.19
	Int	0.12	0.28	0.02	-0.29[†] (-0.56, 0.04)	0.00	-0.20
	Diz	0.23	-0.22	0.09	0.32[†] (-0.58, 0.01)	-0.09	0.04

Table 3: Partial correlations coefficients found in the study with induction, by controlling for the two other schizotypal traits (the confidence interval given between the parentheses is for $P < 0.1$). Del: Delusional-like ideation, Int: Interpersonal factor, Dis: disorganization trait. Indicated in bold are the results for $^{\dagger}P < 0.1$ and $*P < 0.05$.

Figure 8 summarizes the relationship between traits and ICs activity. IC3i was not noticeably related to any schizotypal traits. The activity of IC6i, a centro-parietal component, was best accounted for by delusional-like ideation for exemplar and non-exemplar categories. The activity of IC7i, a left fronto-central component, was best explained by the interpersonal factor alone for exemplar and non-exemplar categories, or in interaction with disorganization and delusional-like ideation. The activity of IC4i, a right centro-parietal component, could noticeably be fitted by delusional-like ideation for exemplar category and by the interpersonal factor for the differences. The activity of IC2i, a parieto-central component, could partially be accounted for by the interpersonal factor for the differences. The activity of IC1i was influenced only by the interaction between disorganization and delusional-like ideation, for the differences.

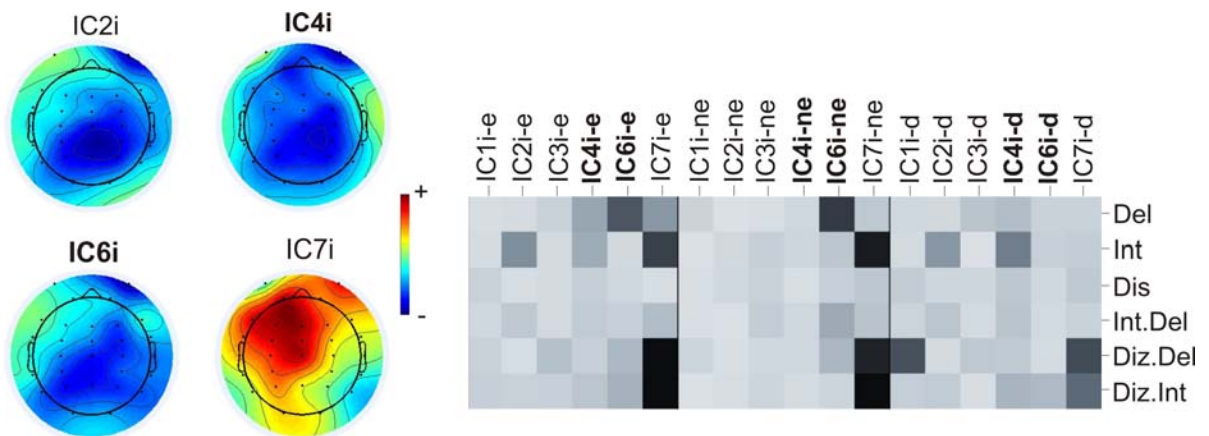


Figure 8: In the study with induction, Left panel: scalp map of the activity of the four ICs the most influenced by schizotypal traits. Right panel: representation of the linear model, where the darkness of each box is proportional to the relative importance of the three schizotypal traits, or the interaction of two of these traits, in predicting ICs activity in the N400 time window in the exemplar condition (e), non-exemplar condition (ne) and difference (d). In other words, the level of grey of each box ranges from 0 (white) to 1 (black), indicating the probability that one trait or the interaction of two traits belongs to the best models predicting mean ICs activity, as defined by the Bayesian Information Criterion. Del: delusional-like ideation; Int: interpersonal trait; Dis: disorganization trait. ICs whose activity is significantly different between exemplars and non-exemplars are in bold.

Discussion

ERP amplitudes were significantly larger in non-exemplars than in exemplars on all electrodes, replicating the findings of the study without induction. Delusional-like ideation strongly influenced the mean voltage amplitudes over all electrode sites for exemplars and for the N400 effect, and partially for non-exemplars. Disorganization had almost no impact on N400 amplitudes, but showed some involvement when considered in interaction with delusional-like ideation or with the interpersonal factor. The interpersonal factor was correlated with the mean voltage amplitude in the N400 time window for exemplars and their difference with non-exemplars. However, the linear model suggests that its influence was in interaction with delusional-like ideation for exemplars and, when alone, only for left frontal electrodes for the difference.

Concerning the independent components involved in the semantic processes evaluated in the N400 time-window, two centro-parietal components (IC4i and IC6i) had a different activity between exemplars and non-exemplars, confirming previous results (Debruille & Renoult, 2009; Mehta et al., 2009). The other components showed no sensitivity to categories. Contrary to the study without induction, no frontal component participated in the effect of the context on the target word. It has been suggested that frontal regions are related to controlled process of semantic information, especially for long stimulus onset asynchrony, as in the current study (Lau et al., 2008). The paranoid induction could thus have dampened this aspect of the semantic processing, if one agrees that the frontal activity observed on the scalp reflects frontal brain regions activity, which is highly hypothetical.

Delusional-like ideation was correlated to a centro-parietal component (IC6i), which is in concordance with the distribution of the correlations observed for N400 voltages. Delusional-like ideation thus influenced the semantic facilitation effect when participants had enhanced paranoid feelings. The smaller N400 amplitudes for exemplars and the larger N400 effect both correlated with delusional-like ideation scores, suggesting, at the very least, less neuronal resources needed to categorize exemplars. However, contrary to Hemsley's view (1993, 2005) that deluded patients are not using the context properly to process events, semantic processing seems to be facilitated in people with delusional-like ideation. Even though semantic information is influenced both by delusions in schizophrenia patients and by delusional-like ideation in healthy people, this influence seems to have opposite consequences. People with delusional-like ideation might have a stronger semantic priming effect, as suggested by their larger N400 effect, which allows them to process more efficiently expected information, such as exemplars in the current study. This result is reminiscent of the confirming bias that has been found in people with high level of preoccupation for their delusional-like ideation (Freeman et al., 2005).

Disorganization tended to be related to a centro-parietal component (IC4i) but this was not confirmed by the linear model. However, when in interaction with the interpersonal factor or with delusional-like ideation, it was involved in the best models fitting a right frontal component (IC7i) for exemplars, non-exemplars and their difference. This effect could be explained by the impact of the interpersonal factor alone that is found on the activity of this frontal component. The induction of paranoid

feelings could therefore have cancelled partially the impact of disorganization on the frontal components, as previously suggested with the N400 amplitudes analyses.

The interpersonal factor was highly involved in the best models fitting the left frontal component (IC7i) for exemplars and non-exemplars. This is consistent with the results observed with the N400 amplitudes and for which the strongest correlations were observed over left fronto-central electrodes for the difference. The activity of this frontal component was not different between exemplars and non-exemplars, suggesting that the interpersonal factor did not influence the facilitation effect but rather a more general aspect of semantic processing. As this frontal activity was noticeable until 800ms, it is possible that this schizotypal trait has a broad influence on late semantic processing. Interestingly, the interpersonal factor also influenced two centro-parietal components (IC2i and IC4i), echoing the distribution of the components activity modulated by this trait in the study without induction. The paranoid induction seems to have strengthened the influence of the interpersonal factor on the frontal components of the N400s, but not on the facilitation effect the context can have on the processing of the exemplar target words.

General conclusion

As expected, the distribution of the independent components influenced by a schizotypal trait reflected the distribution of the correlations between this schizotypal trait and ERPs amplitudes. Delusional-like ideation was related to centro-parietal components whereas disorganization was related to frontal components. Most interestingly, the influence of some traits was visible on ICs whereas it was not on ERP amplitudes. The interpersonal factor influenced both central and frontal components, in both studies, and delusional-like ideation influenced a centro-parietal component in the study without induction, which was not expected given ERPs correlations with these traits. These results confirm that ICA is a useful tool to specify the influence of variables on event-related potentials. Interestingly, when schizotypal traits affected the mean voltage of the N400, it tended to be for all electrodes, with little discrimination. In contrast, schizotypal traits tended to affect the activity of only one or two ICs, revealing a more specific and confined influence on the different mechanisms involved during the semantic categorization task.

The main difference between the two studies was the induction of paranoid feelings in participants (the 'with induction' study). In the study without induction, both frontal and centro-parietal components were sensitive to the context, whereas with the induction, only centro-parietal components were modulated by the facilitation effect. These results suggest two important characteristics. First, the effect of the context on a meaningful word can be processed by different components, and thus possibly by different brain sources, in concordance with recent studies (Rossell et al., 2003; Ruff et

al., 2008, for review, see Lau et al., 2008). Literature from category effects also supports the involvement of multiple brain sources in semantic processing (Kiefer, 2001; Sitnikova et al., 2006). Second, depending on the environmental conditions and thus, on the mental state associated to them, this processing could be shifted from one source to another. When paranoid feelings were induced, no frontal component participated in the facilitation effect, contrary to the study without induction of such feelings. Therefore, the involvement of a frontal source seems non-essential in the facilitation effect, as suggested by Lau and colleagues (2008). The influence of the interpersonal factor in both studies lends further support to this suggestion. The interpersonal factor was related to a frontal component with a right distribution that was sensitive to the context without paranoid induction, but also to a central component insensitive to the context. However, with paranoid induction, the component influenced by this trait had a left frontal distribution and was not sensitive to the facilitation effect on one hand, and another one had a central distribution and was sensitive to the context on the other hand.

As shown by the analyses with ERP amplitudes, the induction of paranoid feelings cancelled the effect of disorganization on the semantic processing. Without induction, disorganization influenced both the processing of the word in its context and independently of its context. With induction, none of this influence remained. This effect of paranoid induction is in total opposition with its effect on the relationship between delusional-like ideation and semantic processing. Delusional-like ideation was linked to components with similar centro-parietal distributions, although without

induction, the component was not sensible to the facilitation effect. This result suggests that delusional-like ideation has a permanent influence on semantic processing that become more specifically linked to the context effect when paranoid feelings are induced. The effect of the context on meaningful information could thus be enhanced by this schizotypal trait in specific conditions triggering paranoid feelings. Otherwise, delusional-like ideation can still influence the processing of meaningful stimuli, but independently of the context in which they appear.

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Conclusion

The present thesis aimed at investigating the presence of a continuum between clinical delusions of patients and delusional-like ideation of healthy people. To do so, the cognitive biases observed in patients with delusions were assessed in healthy participants with a wide range of delusional-like ideation scores, using the schizotypal personality questionnaire (SPQ, Raine, 1991) and the Peters et al. delusion inventory (PDI, Peters et al., 1999; 2004).

Chapters 2 and 3 evaluated the data gathering bias or jump to conclusions style of thinking, which is thought to participate in the formation of delusions. Indeed, patients with delusions almost consistently required less evidence to reach a conclusion than patients without delusions or healthy controls. This jump to conclusion style of thinking could explain how patients end up with false beliefs. As shown previously in healthy participants, this data gathering was replicated here. Most interestingly, people with delusional-like ideations also jumped to new conclusions and did not maintain their first conclusion. This new bias is reinforced when participants are experiencing paranoid feelings. These results suggest that healthy people with delusional-like ideations might jump to conclusions back and forth, a mechanism reinforced if they are feeling paranoid, until they find a conclusion to which they will stick. The maintenance of this belief is likely to rest on other mechanisms and require further study.

Chapters 4 to 6 evaluate how beliefs could persist, and thus how delusions are maintained. Healthy people with delusional-like ideations underwent a semantic

categorization task and their brain electrical activity was recorded. The amplitude of the N400, the event related potential indexing semantic processing, was reduced in participants with delusional-like ideations scores when participants experienced paranoid feelings. Otherwise, the relationship between semantic processing and delusional-like ideation was very subtle and visible only on sub-components of the N400 potential. These results could suggest that people with delusional-like ideation have a greater facilitation effect of the context on their processing of meaningful information. Their beliefs might be maintained by a misuse of contextual information, which would 'over-prime' meaningful events that are expected. This result supports the confirming bias found in healthy participants (Freeman et al., 2005) that correlated with delusional-like ideation. However, this finding is in opposition with findings in patients showing that delusion scores correlated with a reduction of the facilitation effect (Kiang et al., 2007) and with a reduction of the amplitude of the N400 for unexpected or mismatching information (Debruille et al., 2007). Healthy people with delusional ideation thus might deploy less effort to integrate the meaning of a word in its context.

In conclusion, the present work supports the continuum view between normality and psychosis, as the jump to conclusions style and the semantic information processing were both found to underlie the personality trait of healthy people that resembles delusions. This work supports the idea that both personality trait (delusional-like ideations) and state (paranoid feelings) are crucial factors that modulate the way people process events in everyday life. The interaction of personality and mental state triggered by specific situations could lead to psychosis. Future studies are necessary to evaluate

whether healthy people with delusional-like ideations who will develop clinical delusions are those who jump to new conclusions, to confirm the role of this bias in delusion formation. In addition, the new finding of a different processing of semantic information associated with delusional-like ideations needs to be replicated, as well as the results of a more difficult processing of this information in deluded patients.

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Appendix 1

Brain and Cognitive Sciences

SPQ

MALE

FEMALE

(CHECK ONE)

DATE OF BIRTH (MM/DD/YY) ___/___/___

Please answer each item by checking Y (Yes) or N (No). Answer **all** items even if unsure of your answer. When you have finished, check over each one to make sure you have answered them.

1. Do you sometimes feel that things you see on the TV or read in the newspaper have a special meaning for you? Y N
2. I sometimes avoid going to places where there will be many people because I will get anxious. Y N
3. Have you had experiences with the supernatural? Y N
4. Have you often mistaken objects or shadows for people, or noises for voices? Y N
5. Other people see me as slightly eccentric (odd). Y N
6. I have little interest in getting to know other people. Y N
7. People sometimes find it hard to understand what I am saying. Y N
8. People sometimes find me aloof and distant. Y N
9. I am sure I am being talked about behind my back. Y N
10. I am aware that people notice me when I go out for a meal or to see a film. Y N
11. I get very nervous when I have to make polite conversation. Y N
12. Do you believe in telepathy (mind-reading)? Y N
13. Have you ever had the sense that some person or force is around you, even though you cannot see anyone? Y N
14. People sometimes comment on my unusual mannerisms and habits. Y N
15. I prefer to keep to myself. Y N
16. I sometimes jump quickly from one topic to another when speaking. Y N
17. I am poor at expressing my true feelings by the way I talk and look. Y N
18. Do you often feel that other people have got it in for you? Y N
19. Do some people drop hints about you or say things with a double meaning? Y N

20. Do you ever get nervous when someone is walking behind you? Y N
21. Are you sometimes sure that other people can tell what you are thinking? Y N
22. When you look at a person, or yourself in a mirror, have you ever seen the face change right before your eyes? Y N
23. Sometimes other people think that I am a little strange. Y N
24. I am mostly quiet when with other people. Y N
25. I sometimes forget what I am trying to say. Y N
26. I rarely laugh and smile. Y N
27. Do you sometimes get concerned that friends or co-workers are not really loyal or trustworthy? Y N
28. Have you ever noticed a common event or object that seemed to be a special sign for you? Y N
29. I get anxious when meeting people for the first time. Y N
30. Do you believe in clairvoyancy (psychic forces, fortune telling)? Y N
31. I often hear a voice speaking my thoughts aloud. Y N
32. Some people think that I am a very bizarre person. Y N
33. I find it hard to be emotionally close to other people. Y N
34. I often ramble on too much when speaking. Y N
35. My "non-verbal" communication (smiling and nodding during a Y N conversation) is poor. Y N
36. I feel I have to be on my guard even with friends. Y N
37. Do you sometimes see special meanings in advertisements, shop windows, or in the way things are arranged around you? Y N
38. Do you often feel nervous when you are in a group of unfamiliar people? Y N
39. Can other people feel your feelings when they are not there? Y N
40. Have you ever seen things invisible to other people? Y N
41. Do you feel that there is no-one you are really close to outside of your immediate family, or people you can confide in or talk to about personal problems? Y N
42. Some people find me a bit vague and elusive during a conversation. Y N
43. I am poor at returning social courtesies and gestures. Y N
44. Do you often pick up hidden threats or put-downs from what people say or do? Y N
45. When shopping do you get the feeling that other people are taking notice of you? Y N
46. I feel very uncomfortable in social situations involving unfamiliar people. Y N
47. Have you had experiences with astrology, seeing the future, UFOs, ESP or a sixth sense? Y N

48. Do everyday things seem unusually large or small? Y N
49. Writing letters to friends is more trouble than it is worth. Y N
50. I sometimes use words in unusual ways. Y N
51. I tend to avoid eye contact when conversing with others. Y N
52. Have you found that it is best not to let other people know too much about you? Y N
53. When you see people talking to each other, do you often wonder if they are talking about you? Y N
54. I would feel very anxious if I had to give a speech in front of a large group of people. Y N
55. Have you ever felt that you are communicating with another person telepathically (by mind-reading)? Y N
56. Does your sense of smell sometimes become unusually strong? Y N
57. I tend to keep in the background on social occasions. Y N
58. Do you tend to wander off the topic when having a conversation? Y N
59. I often feel that others have it in for me. Y N
60. Do you sometimes feel that other people are watching you? Y N
61. Do you ever suddenly feel distracted by distant sounds that you are not normally aware of? Y N
62. I attach little importance to having close friends. Y N
63. Do you sometimes feel that people are talking about you? Y N
64. Are your thoughts sometimes so strong that you can almost hear them? Y N
65. Do you often have to keep an eye out to stop people from taking advantage of you? Y N
66. Do you feel that you are unable to get "close" to people? Y N
67. I am an odd, unusual person. Y N
68. I do not have an expressive and lively way of speaking. Y N
69. I find it hard to communicate clearly what I want to say to people. Y N
70. I have some eccentric (odd) habits. Y N
71. I feel very uneasy talking to people I do not know well. Y N
72. People occasionally comment that my conversation is confusing. Y N
73. I tend to keep my feelings to myself. Y N
74. People sometimes stare at me because of my odd appearance. Y N

Appendix 2

PDI-21

(Peters, Joseph, Day & Garety, 2004)

This questionnaire is designed to measure beliefs and vivid mental experiences. We believe that they are much more common than has previously been supposed, and that most people have had some such experiences during their lives. Please answer the following questions as honestly as you can. There are no right or wrong answers, and there are no trick questions.

Please note that we are NOT interested in experiences people may have had when under the influence of drugs.

IT IS IMPORTANT THAT YOU ANSWER ALL QUESTIONS.

For the questions you answer YES to, we are interested in:

- (a) how distressing these beliefs or experiences are
- (b) how often you think about them; and
- (c) how true you believe them to be.

On the right hand side of the page we would like you to circle the number which corresponds most closely to how distressing this belief is, how often you think about it, and how much you believe that it is true.

If you answer NO please move on to the next question.

Examples:

Do you ever feel as if people are
reading your mind ?

☒ NO

YES

(please circle)

Not at all distressing					Very distressing
1	2	3	4	5	
Hardly ever think about it					Think about it all the time
1	2	3	4	5	
Don't believe it's true					Believe it is absolutely true
1	2	3	4	5	

Do you ever feel as if you could read
other people's minds ?

NO

YES

(please circle)

Not at all distressing					Very distressing				
1	2	3	4	5	1	2	3	4	5
Hardly ever think about it					Think about it all the time				
1	2	3	4	5	1	2	3	4	5
Don't believe it's true					Believe it is absolutely true				
1	2	3	4	5	1	2	3	4	5

1) Do you ever feel as if people seem to drop hints about you or say things with a double meaning ?

NO YES
(please circle)

Not at all distressing					Very distressing
1	2	3	4	5	
Hardly ever think about it					Think about it all the time
1	2	3	4	5	
Don't believe it's true					Believe it is absolutely true
1	2	3	4	5	

2) Do you ever feel as if things in magazines or on TV were written especially for you ?

NO YES
(please circle)

Not at all distressing					Very distressing
1	2	3	4	5	
Hardly ever think about it					Think about it all the time
1	2	3	4	5	
Don't believe it's true					Believe it is absolutely true
1	2	3	4	5	

3) Do you ever feel as if some people are not what they seem to be ?

NO YES
(please circle)

Not at all distressing					Very distressing
1	2	3	4	5	
Hardly ever think about it					Think about it all the time
1	2	3	4	5	
Don't believe it's true					Believe it is absolutely true
1	2	3	4	5	

4) Do you ever feel as if you are being persecuted in some way ?

NO YES
(please circle)

Not at all distressing					Very distressing
1	2	3	4	5	
Hardly ever think about it					Think about it all the time
1	2	3	4	5	
Don't believe it's true					Believe it is absolutely true
1	2	3	4	5	

5) Do you ever feel as if there is a conspiracy against you ?

NO YES

(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

6) Do you ever feel as if you are, or destined to be someone very important ?

NO YES

(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

7) Do you ever feel that you are a very special or unusual person ?

NO YES

(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

8) Do you ever feel that you are especially close to God ?

NO YES

(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

9) Do you ever think people can communicate telepathically ?

NO YES
(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

10) Do you ever feel as if electrical devices such as computers can influence the way you think ?

NO YES
(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

11) Do you ever feel as if you have been chosen by God in some way ?

NO YES
(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

12) Do you believe in the power of witchcraft, voodoo or the occult ?

NO YES
(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

13) Are you often worried that your partner may be unfaithful ?

NO

YES

(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

14) Do you ever feel that you have sinned more than the average person ?

NO

YES

(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

15) Do you ever feel that people look at you oddly because of your appearance ?

NO

YES

(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

16) Do you ever feel as if you had no thoughts in your head at all ?

NO

YES

(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

17) Do you ever feel as if the world is about to end ?

NO YES
(please circle)

Not at all distressing				Very distressing
1	2	3	4	5
Hardly ever think about it				Think about it all the time
1	2	3	4	5
Don't believe it's true				Believe it is absolutely true
1	2	3	4	5

18) Do your thoughts ever feel alien to you in some way ?

NO YES
(please circle)

Not at all distressing				Very distressing
1	2	3	4	5
Hardly ever think about it				Think about it all the time
1	2	3	4	5
Don't believe it's true				Believe it is absolutely true
1	2	3	4	5

19) Have your thoughts ever been so vivid that you were worried other people would hear them ?

NO YES
(please circle)

Not at all distressing				Very distressing
1	2	3	4	5
Hardly ever think about it				Think about it all the time
1	2	3	4	5
Don't believe it's true				Believe it is absolutely true
1	2	3	4	5

20) Do you ever feel as if your own thoughts were being echoed back to you ?

NO YES
(please circle)

Not at all distressing				Very distressing
1	2	3	4	5
Hardly ever think about it				Think about it all the time
1	2	3	4	5
Don't believe it's true				Believe it is absolutely true
1	2	3	4	5

21) Do you ever feel as if you are a robot or zombie without a will of your own ?

NO

YES

(please circle)

Not at all distressing		Very distressing		
1	2	3	4	5
Hardly ever think about it		Think about it all the time		
1	2	3	4	5
Don't believe it's true		Believe it is absolutely true		
1	2	3	4	5

Appendix 3

Beck Depression Inventory (Beck et al., 1961)

Instructions: This questionnaire consists of 13 groups of statements. Please read each group of statements carefully, and then pick out the one statement in each group that best describes the way you have been feeling during the past two weeks, including today.

- 1 I do not feel sad.
 I feel sad much of the time.
 I am sad all of the time.
 I am so sad or unhappy that I can't stand it
- 2 I am not discouraged about my future.
 I feel more discouraged about my future than I used to be.
 I do not expect things to work out for me.
 I feel my future is hopeless and will only get worse.
- 3 I do not feel like a failure.
 I have failed more than I should have.
 As I look back, I see a lot of failures.
 I feel I am a total failure as a person.
- 4 I get as much pleasure as I ever did from things I enjoy.
 I don't enjoy things as much as I used to.
 I get very little pleasure from the things I used to enjoy.
 I can't get any pleasure from the things I used to enjoy.
- 5 I don't feel particularly guilty.
 I feel guilty over many things I have done or should have done.
 I feel guilty most of the time.
 I feel guilty all of the time.
- 6 I feel the same about myself as ever.
 I have lost confidence in myself.
 I am disappointed in myself.
 I dislike myself.
- 7 I don't have any thoughts of killing myself.
 I have thoughts of killing myself, but I would not carry the out.
 I would like to kill myself.
 I would kill myself if I had the chance.

- 8 I have not lost interest in other people or activities.
I am less interested in other people or things than before.
I have lost most of my interest in other people things.
It's hard to get interested in anything.
- 9 I make decisions about as well as ever.
I find it more difficult to make decisions than usual.
I have much greater difficulty in making decisions than I used to.
I have trouble making any decisions.
- 10 I do not feel I am worthless.
I don't consider myself as worthwhile and useful as I used to.
I feel more worthless as compared to other people.
I feel utterly worthless.
- 11 I can concentrate as well as ever.
I can't concentrate as well as usual.
It's hard to keep my mind on anything for very long.
I find I can't concentrate on anything.
- 12 I am more tired or fatigued than usual.
I get more tired or fatigued more easily than usual.
I am too tired or fatigued to do a lot of the things I used to do.
I am too tired or fatigued to do most of the things I used to do.
- 13 I have not experienced any changes in my appetite.
My appetite is somewhat less than usual.
My appetite is much less than before.
I have no appetite at all.

THANK YOU

Appendix 4

STAI (Spielberger et al., 1983)

A number of statements which people have used to describe themselves are given below. Read each statement and then select the appropriate one to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

1/ I feel calm

Not at all
Somewhat
Moderately so
Very much so

2/ I feel secure

Not at all
Somewhat
Moderately so
Very much so

3/ I am tense

Not at all
Somewhat
Moderately so
Very much so

4/ I am regretful

Not at all
Somewhat
Moderately so
Very much so

5/ I feel at ease

Not at all
Somewhat
Moderately so
Very much so

6/ I feel upset

Not at all
Somewhat
Moderately so
Very much so

7/ I am presently worrying over possible misfortunes

Not at all
Somewhat
Moderately so
Very much so

8/ I feel rested

Not at all
Somewhat
Moderately so
Very much so

9/ I feel anxious

Not at all
Somewhat
Moderately so
Very much so

10/ I feel comfortable

Not at all
Somewhat
Moderately so
Very much so

11/ I feel self-confident

Not at all
Somewhat
Moderately so
Very much so

12/ I feel nervous

Not at all
Somewhat
Moderatly so
Very much so

13/ I am jittery

Not at all
Somewhat
Moderatly so
Very much so

14/ I feel 'high strung'

Not at all
Somewhat
Moderatly so
Very much so

15/ I am relaxed

Not at all
Somewhat
Moderatly so
Very much so

16/ I feel content

Not at all
Somewhat
Moderatly so
Very much so

17/ I am worried

Not at all
Somewhat
Moderatly so
Very much so

18/ I feel overexcited and rattled

Not at all
Somewhat
Moderatly so
Very much so

19/ I feel joyful

Not at all
Somewhat
Moderatly so
Very much so

20/ I feel pleasant

Not at all
Somewhat
Moderatly so
Very much so

THANK YOU

Appendix 5

CEQ (Lefebvre, 1981)

This questionnaire describes a number of situations that might occur in daily life, each followed by a thought in "quotations" that a person in the situation might have. Underneath this is a group of statements that describes how similar the thought is to how you would think in that situation

Please read each situation and imagine that it is happening to you. Then, read the thought (which is in "quotations") following that situation. Choose the statement underneath each thought that best describes how similar that thought is to how you would think in that situation."

Because you may not have had the experience described in some of the situations, it is important that you imagine that it is happening to you. Some of the situations, for example, assume that you have a back pain problem. If you don't, please try to imagine that you do. Be sure that you don't rate the situation, just rate how much the thought (which is in "quotation") is like the way you would think.

1/ Your boss just told you that because of a general slowdown in the industry, he has to lay off all of the people who do your job including you. You think to yourself, "I must be doing a lousy job or else he wouldn't have laid me off".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

2/ You are the manager in a small business firm. You have to fire one of your employees who has been doing a terrible job. You have been putting off this decision for days and you think to yourself, "I just know that when I fire her, she is going to raise hell and will sue the company".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

3/ Last week you painted the living room and your spouse said it really looked great. When you were cleaning up, you found that you had got paint on the rug and thought, "Boy, this wasn't a very good painting job".

Not at all like I would think
A little like I would think

Somewhat like I would think
A lot like I would think
Almost exactly like I would think

4/ You noticed recently that a lot of your friends are taking up golf and tennis. You would like to learn, but remember the difficulty you had that time you tried to ski. You think to yourself, "I couldn't learn skiing so I doubt if I can learn to play tennis".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

5/ You and your spouse recently went to an office party at the place where your spouse works. You didn't know anybody there and had a terrible time. When your spouse asks you if you want to go to the neighbours to visit, you think, "I'll have a terrible time just like at that office party".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

6/ You just finished spending three hours cleaning the basement. Your spouse however, doesn't say anything about it. You think to yourself, "(S)he must think I did a lousy job".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

7/ Last night, your spouse said (s)he thought you should have a serious discussion about sex. You think to yourself, "(S)he hates the way we make love".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

8/ You have been working for six months as a car salesperson. You had never been a salesperson before and were just fired because you had not been meeting your quota. You thought, "Why try to get another job, I'll just get fired".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

9/ Your job requires a lot of travel. You had hoped to drive 400 miles today but you hit bad weather that slowed you down. When you stopped for the night, you thought, "I didn't make that 400 miles; today was a complete waste".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

10/ You have just finished nine holes of golf. Totalling your score, you recall that although you got par on seven holes, you got two over par on the last two holes. You think to yourself, "Today I really played poorly".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

11/ You went fishing for the first time today with some of your friends who love fishing. Nobody got anything, and the group seemed to be discouraged. You thought to yourself on the way home, "I guess I made too much noise or did something that scared the fish off".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

12/ Your friends are all going out to ride their snowmobiles. Last time you went, you ran out of gas, and you think to yourself, "What if I run out of gas again; I'll freeze to death".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

13/ You have three children who generally do quite well in school. One of your children came home today and told you that he had to stay after school because he got into a fight. You think to yourself, "He wouldn't have gotten that detention if I disciplined him more".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

14/ You are taking your coffee break when your boss stops by and remind you of some work that has to get done today. You think to yourself, "If I don't start getting back to work earlier, I'm going to lose this job".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

15/ You have noticed that many of your friends have begun playing tennis and are now urging you to play too. You had taken golf lessons with your spouse last year and had difficulty learning to play golf. You think to yourself, "I had so much trouble learning golf, I doubt if I could learn tennis".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

16/ Your seven-year-old son normally does very well in school. Last week, he brought home a paper which he had done incorrectly and was supposed to do over. You think to yourself, "Oh no, now he's having trouble in school. I better make an appointment with his teacher".

Not at all like I would think
A little like I would think
Somewhat like I would think

A lot like I would think
Almost exactly like I would think

17/ Earlier today, your spouse asked to have a serious talk with you after work about some things that were troublesome at home. You have no idea what's going on and you think, "We don't communicate enough; Our marriage is going to fall apart".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

18/ On your last job, you had not received a raise even though a co-worker with similar experience had. You are now up for a raise in your present job and think, "I didn't get a raise the last time and I probably won't now".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

19/ Your teenage daughter has just asked if two of her friends can stay overnight. You recall that you got very upset when your son had some friends over for pizza several weeks ago and they had made a lot of noise. You think, "If they come over, I'll get upset again".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

20/ You run a day care center. Today, the mother of a child you have been having difficulty with calls and notifies you that she has quit work and will be withdrawing her child from your program. You think, "She probably thinks I wasn't handling him as well as I should".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

21/ You took your children to the neighbourhood pool for the afternoon. Although your kids urged you to swim with them, you were enjoying laying in the sun. Later you look up and see them arguing over a float. You think to yourself, ""If I had gone in the water, they probably wouldn't be fighting now".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

22/ You went shopping for some new clothes today and were unable to find anything you liked. You think, "What a waste of a day".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

23/ You met with your boss today to discuss how you have been doing on your job. He said that he really thought you were doing a good job, but asked you to try to improve in one small area. You think to yourself, "He really thinks I'm doing a lousy job".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

24/ Last time you went skiing, you took a hard fall and got shook up. You're supposed to go skiing this weekend but think, "I'll probably fall and break my leg and there will be no one to help me".

Not at all like I would think
A little like I would think
Somewhat like I would think
A lot like I would think
Almost exactly like I would think

THANK YOU

Appendix 6

Adapted from Bodner & Mikulincer (1998)

Select on a scale from 1 (not at all) to 7 (extremely) :

1/ I feel that my behaviour is being analyzed	1	2	3	4	5	6	7
2/ I feel that people talk about me	1	2	3	4	5	6	7
3/ I feel that people are hostile to me	1	2	3	4	5	6	7
4/ I feel that I am being selected	1	2	3	4	5	6	7
5/ I feel that others are examining my actions	1	2	3	4	5	6	7
6/ I feel that others influence my performance	1	2	3	4	5	6	7
7/ I do not trust other people's intentions	1	2	3	4	5	6	7