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Event-related brain potential study of expectancy and semantic matching in schizotypy

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ABSTRACT

Priming studies have revealed semantic processing abnormalities in subjects that display high schizotypal traits. The objective of the present study was to further elucidate the contribution of predictive (expectancy) and integrative (semantic matching) context processing to the semantic deficit described in schizotypy. Thirty-six participants were assigned into high or low schizotypy groups according to their score on the Schizotypal Personality Questionnaire (SPQ), and event-related brain potentials were recorded while these individuals performed semantic judgments based on asymmetrically associated word pairs. Viewed in one direction (forward), the target was highly predictable from the prime, whereas in the backward direction, the prime-to-target association was weak. It was assumed that the forward condition would be dependent on expectancy generation, while the backward condition would rely on semantic matching. In the low-SPQ group, forward and backward related words evoked a reduced (less negative) N400 amplitude compared to unrelated words, resulting in a significant forward and backward N400 priming effect, respectively. By contrast, only forward related words were facilitated in the high-SPQ group, resulting in significant forward priming and a lack of backward priming. Furthermore, the N400 amplitude for forward related words was less negative within the high-SPQ group in comparison to the low-SPQ group, which indicated easier semantic access to predictable words for high-SPQ individuals. Therefore, schizotypy may be associated with an imbalance in the use of predictive and integrative context processing strategies, namely preserved, if not overallocated, expectancy generation along with altered integration of unpredictable words due to semantic matching deficit.

1. Introduction

Schizotypy describes a personality organization that is closely linked to schizophrenia (Claridge, 2009; Lenzenweger, 2006; Meehl, 1962, 1990). There is growing interest in cognitive studies involving schizotypal subjects. Indeed, they may provide useful insight into the schizophrenic condition because the effects of confounding factors are limited in these subjects (e.g., medication and repeated hospital stays).

Odd or disorganized speech is a primary characteristic of schizophrenia (Bleuler, 1911), and this trait is also present in individuals with schizotypal personality (Minor and Cohen, 2010). It has been suggested that the emergence of odd speech in schizophrenia is related to a deficit in semantic context processing (Hardy-Baylé et al., 2003; Kerns and Berenbaum, 2003). The semantic priming paradigm is one of the most frequently used methods for assessing semantic processing in schizophrenia and schizotypy. This simple assessment involves presenting pairs of prime-target words to subjects, who must decide whether the target is part of the lexicon (lexical decision task) or belongs to the same semantic category as the prime (semantic categorization). Subjects are asked to respond to these tasks as quickly and accurately as possible. Response time (RT) is usually reduced, and accuracy improved, when the target word is related to its prime (e.g., *sugar-honey*) in comparison to an unrelated condition (e.g., *sugar-table*). This effect, which is called "semantic priming", is thought to reflect the effect of the semantic context (the prime word) on target processing (Neely, 1991). At the neurophysiological level, the N400 component of event-related potentials (ERPs) reflects the brain activity associated with semantic processing, with its amplitude inversely related to the ease with which the word is accessed in its semantic context (Kutas and Federmeier, 2011). During priming tasks, related words evoke reduced (less negative) N400 amplitudes compared to unrelated words (Bentin et al., 1985). The amplitude difference between related and unrelated conditions, which is termed the "N400 effect", can be considered the neurophysiological counterpart of behavioral semantic priming. Several semantic priming studies have demonstrated a reduced N400 effect in schizophrenics (reviewed in Mohammad and DeLisi, 2013; Wang et al., 2011) and in individuals with schizotypal traits (Kiang and Kutas, 2005; Kiang et al., 2010; Prevost et al., 2011, 2010), providing empirical support for the hypothesis of impaired use of semantic context in schizophrenia and schizotypy.

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However, despite the large body of research using the priming paradigm, few studies have focused on the context processing mechanisms themselves. Indeed, priming models have described two controlled context processes that might underlie semantic priming, in addition to the automatic spreading of activation within the semantic network that depends on the stimulus characteristics and task parameters (Neely et al., 1989). Therefore, when the subjects realize that the material contains a high proportion of strongly related words and the stimulus onset asynchrony (SOA) is long enough (>400 ms), they can utilize this information to generate expectancies about the most likely upcoming target given the prime (i.e., "prospective prime-generated expectancies"). If the target shares characteristics with the expected word, its recognition is facilitated; if not, there is a need to inhibit the pre-activated concept to process the target, leading in both cases to an *expectancy-induced* priming effect. If expectancy is not favored by the experimental conditions (i.e., weakly related words, lower relatedness proportion, and/or shorter SOA), subjects are thought to evaluate the relationship between the target word and its context before making a decision (i.e., "retrospective semantic matching"). Therefore, in cases involving matches, the response is facilitated, but when there is a mismatch, it is inhibited. This phenomenon gives rise to a significant *matching-induced* priming effect. Notably, these prospective/predictive and retrospective/integrative semantic processes are not restricted to the single-word priming paradigm and are thought to underlie normal comprehension (Kutas and Federmeier, 2000; Kutas and Federmeier, 2011).

Thus, although "context processing deficits" were consistently evidenced in schizophrenia and schizotypy, it remains unclear whether both the predictive and integrative mechanisms are altered. This question has arisen because some priming studies have failed to show a reduced N400 effect in schizophrenia (Koyama et al., 1991, 1994) or schizotypy (Niznikiewicz et al., 2002; Wang et al., 2013), which suggests that context processing is not always impaired.

To our knowledge, only two ERP studies have assessed the predictive and integrative context processing strategies in schizophrenia spectrum disorders. The first was conducted with schizophrenia patients (Kostova et al., 2003). The authors compared the N400 priming that occurred during a word-pairs lexical decision task with a low proportion of related words, which is assumed to favor semantic matching, to the N400 priming for highly predictable sentence-final words, which is thought to foster expectancy. For the schizophrenia group, the investigators observed a reduced N400 effect during semantic matching conditions and a normal N400 effect during expectancy. Nevertheless, an important limitation of the study was that it compared word vs. sentence context, not only predictive vs. integrative context processing. In addition, another recent study compared the N400 evoked by the left and right hemisphere-processed sentence-final words in a group of healthy subjects with schizotypal traits (de Loye et al., 2013). Based on psycholinguistic models (Federmeier and Kutas, 1999), the authors posited that the left hemisphere's processing ability is driven by expectancy, whereas the right hemisphere is used for integration. Interestingly, the subjects with schizotypal traits were found to be capable of both prediction and integration of words consistent with their context. However, differences in clinical status (subclinical vs. clinical population), stimulus characteristics (word vs. sentence context), and task (lexical decision vs. semantic judgment) make it difficult to compare the results between these studies and to draw conclusions regarding the functioning of the semantic context processes in the schizophrenia spectrum.

The objective of the present study was to further elucidate the role of predictive (expectancy) and integrative (semantic matching) context processing in the previously described schizotypy-related semantic deficit. For this purpose, we adapted the method used by Kandhadai and Federmeier (2010). Healthy participants were assigned to high or low schizotypy groups according to their score on the Schizotypal Personality Questionnaire (SPQ), and ERPs were recorded while they performed semantic judgments on asymmetrically associated word pairs. When viewed in one direction (forward), the target was highly predictable from the prime, whereas in the backward direction, the prime-to-target association was weak. The SOA was fixed at 750 ms. In the forward condition, subjects could make semantic decisions based mainly on a priori predictions generated from the prime word, whereas in the backward condition, subjects had to check the compatibility of the pair a posteriori. Importantly, the word pair plausibility (i.e., the compatibility of the pair) was the same in the forward (prime-to-target) and backward (target-to-prime) directions. In line with previous research (Kostova et al., 2003), we expected to find reduced backward priming resulting from a deficit in retrospective semantic matching and normal forward priming resulting from preserved prospective prime-generated expectancies.

2. Materials and methods

2.1. Participants

This investigation was conducted in accordance with the latest version of the Declaration of Helsinki and all participants gave written informed consent. Forty healthy participants were recruited from the population of undergraduate students of the university campus. Four subjects were excluded because of technical problems (three subjects) or a history of neurological disorders (one subject). Therefore, a total of 36 participants were included in the analyses. These individuals were 19–34 years of age ($M = 23.31$; $SD = 4.07$) and were all right-handed native French speakers. Verbal intelligence quotients were estimated using the Binois and Pichot vocabulary test (Binois and Pichot, 1959), and the Edinburgh Handedness Inventory was used to determine handedness (Oldfield, 1971). We employed the French version of the Raine's Schizotypal Personality Questionnaire (SPQ) to assess the presence of schizotypal traits (Dumas et al., 1999; Raine, 1991). Participants were assigned to the low or high schizotypy group based on their scores on the schizotypy scale ($M = 14.69$; $SD = 9.56$; range 1–34). The median score was used to split the group: participants with a SPQ score ≤ 13 ($n = 18$) were considered to display low schizotypy traits (low-SPQ), whereas those with a SPQ > 13 ($n = 18$) were placed into the high schizotypy trait group (high-SPQ). The sociodemographic and clinical characteristics of the two groups are presented in Table 1.

2.2. Stimuli

The stimuli consisted of 92 asymmetrically associated prime-target word pairs. The word pairs were selected based on word association norms (Debrenne, 2010a,b; http://dictaverf.nsu.ru/), such that when viewed in one direction (forward), the target was highly predictable from the prime (e.g., *drop-water*). However, in the backward direction, the prime-to-target association was weak (e.g., *water-drop*). In the forward direction, the mean prime-to-target association was 38.0%

Table 1
Socio-demographic and clinical characteristics of participants.

	Low-SPQ group (n = 18)	High-SPQ group (n = 18)
Age (years)	23.06 (2.73)	23.56 (5.15)
Educational level (years)	14.72 (1.13)	14.44 (1.04)
Verbal intelligence	27.61 (3.01)	26.67 (3.77)
Handedness (%)	85.78 (12.61)	81.22 (17.56)
Gender	M: 3 (17%) W: 15 (83%)	M: 3 (17%) W: 15 (83%)
SPQ total score (/74)	**7.00 (4.51)**	**22.39 (6.52)***
SPQ cognitive–perceptual factor (/33)	**2.17 (2.33)**	**8.44 (3.35)***
SPQ interpersonal factor (/33)	**3.22 (2.67)**	**9.11 (3.64)***
SPQ disorganized factor (/16)	**1.72 (1.53)**	**5.61 (2.28)***

Note. Values correspond to means with standard deviations in parentheses. Significant differences are shown in bold.
* $p < .001$.