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Increased automatic spreading activation in healthy subjects with elevated scores in a scale assessing schizophrenic language disturbances

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ABSTRACT

Background. Previous studies on semantic priming have suggested that schizophrenic patients with language disturbances demonstrate enhanced semantic and indirect semantic priming effects relative to controls. However, the interpretation of semantic priming studies in schizophrenic patients is obscured by methological problems and several artefacts (such as length of illness). We, therefore, used a psychometric high-risk approach to test whether healthy subjects reporting language disturbances resembling those of schizophrenics (as measured by the Frankfurt Complaint Questionnaire subscale 'language') display increased priming effects. In addition, the Schizotypal Personality Questionnaire was used to cover symptoms of schizotypal personality. Enhanced priming was expected to occur under conditions favouring automatic processes.

Methods. One hundred and sixty healthy subjects performed a lexical decision semantic priming task containing two different stimulus onset asynchronicities (200 ms and 700 ms) with two experimental conditions (semantic priming and indirect semantic priming) each.

Results. Analyses of variance revealed that the Frankfurt Complaint Questionnaire-'language' high scorers significantly differed from low scorers in three of the four priming conditions indicating increased automatic spreading activation. No significant results were obtained for the Schizotypal Personality Questionnaire total and subscales scores.

Conclusions. In line with Maher and Spitzer it is suggested that increased automatic spreading activation underlies schizophrenia-typical language disturbances which in our study cannot be attributed to confounding variables such as different reaction time baselines, medication or length of illness. Finally, results confirm that the psychometric high-risk approach is an important tool for investigating issues relevant to schizophrenia.

INTRODUCTION

Over the past thirty years a growing body of evidence has been accumulated suggesting that semantic memory is based upon map-like structures in which concepts (represented as nodes) are placed according to semantic relatedness (see Collins & Loftus, 1975; den Heyer & Briand, 1986). If a certain node (for example, the word 'dog') is activated, activation is thought to spread to adjacent (i.e. related) concepts (for example, 'cat' or 'bone') until it decays either by some kind of inhibitory process or because of fading strength. Activated nodes are considered to have lowered thresholds for items matching their identity so that processing of these items is facilitated once a node is activated (see Neely, 1991, for a review). Recent findings share the common assumption that the

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strength of spreading activation is rather state-dependent: spreading activation is modulated by several factors such as alertness (Spitzer *et al.* 1993*a*), anxiety (fear is considered to limit spreading activation; Mintz, 1969), mood (Hänze & Hesse, 1993), drug usage (psilocybin has been found to trigger more remote associations; Spitzer *et al.* 1996) and psychopathology (see below).

Semantic memory builds up over the entire life-span of the individual and is thus not predetermined in its development. However, association norms gathered in large population samples suggested that most common words generate similar associations in different people. For example, approximately half of the 300 subjects investigated by Russell (1970) associated 'white' with 'black', one-third associated 'chair' with 'table'. Common techniques to assess semantic memory are semantic priming experiments. In such tasks, pairs of words with different associative strength as indicated by association norms – for example, unrelated (paper – gold), directly related (father – son), indirectly related (black – chalk) – are presented to the subject. In word pronunciation experiments, the subject is instructed simply to read the second word (the *probe*) as fast as possible, whereas the first word (the *prime*) is either to be ignored or to be read silently. Lexical decision tasks, in contrast, require the subject to decide whether the probe is either a real word (for example, 'hat') or a mere string of meaningless characters ('irgte'). Empirical data from both tasks obtained from normal subjects reveal that the response to targets preceded by semantically related words is significantly facilitated compared to unrelated pairs (referred to as semantic priming effect; Meyer & Schvanefeldt, 1971; Neely, 1991).

Much research has been devoted to the distinction between automatic and controlled processes, introduced by Posner & Snyder (1975). Semantic priming tasks using stimulus onset asynchronicities (SOA: the duration between prime onset and probe onset) below 500 ms are considered to tap automatic processes with only little impact of conscious (controlled) factors. Controlled processes are thought to play a major role when longer SOAs are used (Neely, 1991). However, as we will discuss later, this distinction is valid only if certain conditions are met.

The distinction between controlled and automatic processes bears special importance for cognitive theories of schizophrenia. Therefore, several semantic priming studies have been conducted with schizophrenic patients. Research in this area falls into two main camps. One body of research suggests that schizophrenics' performance is marked by a defect in the decay or inhibition of automatic spreading activation, as predicted by Frith (1979) and Maher (1983). Several authors (Maher *et al.* 1987; Manschreck *et al.* 1988; Kwapil *et al.* 1990; Spitzer *et al.* 1993*b*, *c*, 1994; Henik *et al.* 1995) have demonstrated that schizophrenic patients reveal enhanced semantic priming especially for tasks using SOAs $\leqslant$ 500 ms. Interestingly, for longer SOAs no significant differences emerged (Spitzer, 1993*c*) in most studies, suggesting that enhanced priming effects reflect impaired automatic spreading activation. Moreover, Spitzer was able to demonstrate that the difference between schizophrenic patients and control subjects was even more pronounced when indirect (mediated) associations were employed (for example, prime: 'lemon' (non-displayed mediator: 'sour') probe: 'sweet'). Furthermore, mean differences remained significant after correction for different reaction time (RT) baselines. Spitzer argued that spreading activation in schizophrenics is not only faster but also farther-reaching than in healthy controls. On the symptom level, this is reflected by symptoms such as loosened speech, derailed thinking and concretism. In line with these suggestions, Manschreck *et al.* (1988) and Spitzer *et al.* (1993*b*, 1994) found that thought-disordered patients were the only schizophrenic subgroup displaying significantly enhanced priming effects relative to controls.

In contrast to this line of thought Callaway & Naghdi (1982) have argued that automatic spreading activation is relatively normal in schizophrenics, whereas controlled processes are assumed to be deficient. In a series of studies, semantic priming in schizophrenics was found to be either attenuated or normal (Chapin *et al.* 1989, 1992; Henik *et al.* 1992; Vinogradov *et al.* 1992; Blum & Freides, 1995; Ober *et al.* 1995; Barch *et al.* 1996; Passerieux *et al.* 1997). The hyper-priming of schizophrenics found in the studies described above has been attributed by some researchers to a deficiency of those controlled processes, such as expectancy and

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semantic matching, which cannot be ruled out to contribute to semantic priming even in tasks with SOAs lower than 500 ms (see Vinogradov *et al*. 1992, for a discussion of different mechanisms underlying semantic priming). However, it has been objected that most studies which have failed to find differences between healthy and schizophrenic subjects did not separate schizophrenic patients according to symptoms of thought disorder and that most studies investigated chronic samples (for the significance of this variable, see below).

An important obstacle to progress refers to the confounding of semantic priming effects in schizophrenia by a wide range of variables other than diagnosis and specific psychopathology, respectively: length of illness; medication; and problems of pre-attentional processing.

Length of illness

Maher *et al*. (1996) demonstrated that semantic priming effects are inversely correlated with length of illness. In other words, schizophrenics with a long history of psychosis tend to show diminished semantic priming. Maher *et al*. (1987), therefore, account for the failure of Vinogradov *et al*. (1992) to demonstrate significant semantic priming by the chronicity of their sample. Schizophrenics with a long-term diagnosis of schizophrenia were also investigated by Chapin *et al*. (1989, 1992), Ober *et al*. (1995) and Henik *et al*. (1992, 1995).

Medication

There are several lines of direct and indirect evidence suggesting an augmentation of semantic priming by neuroleptics, though Chapin *et al*. (1989) and Spitzer *et al*. (1993*b*) reported no effects of medication on semantic priming. First, the application of L-dopa in healthy subjects has been shown to decrease semantic priming (see Spitzer, 1997, for further details). Secondly, results obtained by Barch *et al*. (1996) suggest that more highly medicated patients display strongest semantic priming effects. Medication dosage was significantly correlated with semantic priming. Therefore, enhanced semantic priming, like disturbed Stroop, Continuous Performance Test (see Cohen & Servan-Schreiber, 1992) and WCST performance (Siever, 1994) has been presumed to be generated by pre-frontal hypodopaminergic activity. This, in turn, is regarded as a major contributing factor for negative symptoms (Weinberger, 1987; Davis *et al*. 1991) and may also underlie disorganization.

Problems of pre-attentional processing

Schizophrenic patients have been found to exhibit severe problems in the processing of briefly presented displays (critical stimulus duration; see Spaulding *et al*. 1989; Braff, 1993). A short prime presentation (100 ms – Blum & Freides, 1995; Barch *et al*. 1996; 50 ms – Vinogradov *et al*. 1992; Ober *et al*. 1995) may consequently account for some results that show decreased to normal semantic priming in schizophrenia as probe facilitation depends on the processing of the prime (for a similar view see also Blum & Freides, 1995). Due to intact preconscious attentional resources, healthy subjects are likely to have fewer problems to perceive and process briefly presented prime words. Furthermore, perceptual problems may be even more pronounced for complex stimuli like words. For example, Frith (1979) hypothesized that schizophrenic patients should exhibit problems with highly automatized skills like reading, due to the intrusion of irrelevant material into consciousness. This has been confirmed empirically by Bäumler (1985).

Moreover, semantic priming research in schizophrenia faces two major methological problems due to the generally slowed RTs found in most studies. First, Kwapil *et al*. (1990) point out that slow responses will tend to increase difference scores as computed for semantic priming and thus either produce artificial 'hyperpriming' or increased reversed priming (for example, reaction times twice as long as normal reaction times will produce twice as much difference). Although recent studies have corrected priming effects using different algorithms (Barch *et al*. 1996; Spitzer *et al*. 1993*b*), this artefact was not ruled out in all studies.

Secondly, the assumption that conditions with SOAs shorter than 500 ms tap automatic processes rests on the condition that reaction times are short (see Barch *et al*. 1996). Long reaction times increase the possibility that controlled processes interfere with automatic spreading activation. Although this possibility is unlikely to be the case in schizophrenics as 'schizophrenics are notoriously poor at directing their attention' (Kwapil *et al*. 1990, p. 220) inter-

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pretations concerning automatic processes have to be made cautiously if responses are slowed down for SOAs only slightly lower than 500 ms.

Since the direct investigation of schizophrenics is confronted with numerous artefacts, research which focuses on schizotypal and psychosis-prone features in healthy subjects has increasingly been used as an alternative approach to psychotic cognitive dysfunction within the last ten years (see Claridge, 1994). As cognitive and neuropsychological data, together with prospective (Fenton & McGlashan, 1989), genetic (Torgersen *et al*. 1993) and biochemical studies (Siever, 1994, 1995), confirm strong similarities between schizophrenic patients and subjects with elevated scores in measures that tap schizotypal symptoms or features commonly reported by schizophrenics (such as body image aberrations; see Chapman *et al*. 1978), the investigation of healthy subjects (i.e. with no axis I disorder according to DSM-IV; APA, 1994) appears to be an appropriate tool to shed light on the pathology of schizophrenia (Claridge, 1972).

Previous investigations concerning semantic priming and schizotypy/psychosis-proneness have failed to provide unequivocal support for each one of the two theories described above (see Lencz *et al*., 1995, for a brief review). However, indirect semantic priming remains to be investigated within the concept of schizotypy/psychosis-proneness. Moreover, past psychometric high-risk studies primarily focused upon positive features (such as sensory irritations, magical ideation), whereas results obtained by both Maher and Spitzer indicate that increased semantic and indirect semantic priming are restricted to, or at least more pronounced for, those schizophrenics with language and thought deviations.

In this study we investigated whether healthy subjects scoring high in a self-report questionnaire measuring schizophrenic language disturbances show different semantic *and* indirect semantic priming effects when compared with low scoring subjects.

The terms 'language disorder' and 'formal thought disorder' are used synonymously by most clinicians since the diagnosis of formal thought disorder almost entirely relies on language disturbances such as disordered language production (concretistic speech, derailed speech), language comprehension and (sometimes) written evidence (Cutting & Murphy, 1988; Ebert, 1991; Pfuhlmann, 1997). Non-linguistic forms of thought sometimes categorized under the term 'central executive' or 'abstract thinking' are usually separated from the diagnosis of thought disorder; for example, the Positive and Negative Syndrome Scale (Kay *et al*. 1989) has distinct scales for measuring formal thought disorder and abstract thinking. Moreover, semantic networks that are the 'playground' of the present study are hypothesized to underlie both language production and comprehension. Therefore, a scale that assesses schizophrenic language disturbances can be considered appropriate to contribute to previous research focusing on formal thought disorder as operationalized in most rating scales and symptom check lists.

Since several studies that have failed to show enhanced semantic priming in schizophrenia have not differentiated schizophrenics into subgroups, we also employed a scale assessing symptoms of schizotypal personality disorder (the Schizotypal Personality Questionnaire (SPQ) Raine, 1991; German adaptation by Klein *et al*. 1997) which parallels the symptoms of schizophrenia on a lower symptomatic level. SPQ total score high scorers have been found to reveal a number of similar disturbances as schizophrenics (Raine *et al*. 1994; Klein *et al*. 1999).

METHOD

Subjects

One hundred and sixty German-speaking subjects with no mental illness and normal or corrected-to-normal vision were recruited for this study. Subjects were told that the aim of the study was to investigate the relationship between personality and various mental skills such as attention. The demographic characteristics of the tested participants, are shown in Table 1.

Subjects were first tested on a wide range of neuropsychological functions including memory, attention, central executive and inhibition. The neuropsychological test session took approximately 70 min and was performed by medical students (F.D., E.P., T.M. and G.K.). To avoid experimenter effects, the four

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Table 1. *Demographic characteristics of subjects*

Sample size (*N*)	160
Age in years: mean (S.D.)	29·8 (5·8)
Gender: male/female	77/83
School education in years: mean (S.D.)	12·5 (1·4)

experimenters were extensively trained. Instructions were read aloud by the experimenters, so that each group received the same information. After neuropsychological assessment the subjects were given several questionnaires contained in a prepaid envelope; participants were instructed not to leave their name on any of the questionnaires to ensure anonymity and to return the completed questionnaire, in the envelope, to the first author.

Apparatus

Experiments were presented on Macintosh Classic computers. Program, stimuli and testing procedure were identical to previous testings conducted by Spitzer and colleagues; for further details see Spitzer *et al.* (1993*b*, *c*). Four different conditions were set up: (*a*) unrelated condition (18 trials, e.g. sofa–wing); (*b*) semantic priming condition (18 trials, e.g. hen–egg); (*c*) indirect semantic priming condition (18 trials, e.g. lemon–sweet); and (*d*) non-word condition (54 trials, e.g. drift–kribe).

Word pairs (font Geneva, point 18) were derived from sets of different published (normed) associations (see Spitzer *et al.* 1993*b*). All words were German.

Each trial consisted of two strings (prime: word; probe: word or non-word). Prior to the presentation of each trial, the computer screen was blank. A fixation point was displayed for 700 ms in the centre of the screen after a trial was initiated by the subject and immediately followed by the prime. The probe was presented until response was made. Subjects were instructed to read the first word silently and to respond as fast as possible to the second string without making too many mistakes. Trials were self-paced by mouse-click and required a lexical decision after the presentation of the second string of characters. The key 'n' had to be pressed using the index or middle finger of the dominant hand if subjects thought that the second string was a non-word. The key 'b' had to be pressed in case subjects thought that the second string was a German word.

Before starting the actual experiments, subjects performed a brief practise task consisting of 24 trials. After that, subjects either performed a short (200 ms) or a long SOA (700 ms) condition; prime presentation was in both cases 200 ms, so that the inter-stimulus interval (ISI) was either 0 to 500 ms (a blank screen appeared during the 500 ms interval). The second experiment (with the other SOA condition) was performed in direct succession to the first one.

Stimulus lists for both experiments consisted of different word pairs with no word reappearing in the other list (neither as a singular nor as a plural word). In a procedure similar to that conducted by Spitzer *et al.* (1993*c*), subjects were pseudorandomly assigned to: order of stimulus set (two lists); and order of ISI (either 200 ms or 700 ms). Thus, there were equal numbers of subjects ($N = 40$) at each of the four possible combinations.

Questionnaires

Language disturbances were assessed with the 10-item subscale (yes-or-no-answer) 'language' taken from the Frankfurt Complaint Questionnaire (FCQ; Süllwold, 1991) which has been translated into several languages, including English (see Williams *et al.* 1984) and Spanish (Peralta *et al.* 1992). The items of the questionnaire are derived from the verbal complaints of schizophrenic patients. The items refer to expressive (for example, 'I find it hard to talk longer sentences') and receptive language problems ('When someone speaks to me I hear the words, but do not get their meaning'). The FCQ is a questionnaire that measures so-called schizophrenic 'basic symptoms', which have been most prominently investigated by Süllwold & Huber (1986) and Klosterkötter (1992). Peralta *et al.* (1992) reported that basic symptoms share little overlap with negative symptoms. Instead, in line with Giessen (1981) and Christ (1984) they pointed out that basic symptoms are consistently correlated with formal thought disorder (see also Süllwold & Huber, 1986, for similar findings). Moreover, a specific and strong relationship between formal thought disorder and the FCQ-subscale

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'language' has been presumed by Süllwold (personal communication).

Additionally, symptoms of schizotypal personality according to DSM-III-R (American Psychiatric Association, 1987) were measured using the Schizotypal Personality Questionnaire (SPQ) (Raine, 1991; Klein *et al*. 1997). Although the SPQ contains a subscale assessing 'odd speech', recent studies question the validity of this scale (Moritz & Mass, 1997). 'Odd speech' can be considered a cognitive lie scale rather than reflecting an analogue of schizophrenic language disturbances, as many items are too easy to answer. This was confirmed in a recent study conducted by Klein *et al*. (1999): 'Odd speech' significantly correlated with a scale that assessed the tendency to answer in a social desirable way ($r = 0{\cdot}40$; no other SPQ scale correlated beyond $r = 0{\cdot}28$). However, other SPQ-subscales covering the three syndromes of schizotypy and the SPQ total score have been construct-validated in a wide range of both neuropsychological and psychophysiological tasks (see for example Raine *et al*. 1994; Klein *et al*. 1995, 1999; Moritz *et al*. 1998).

Strategy of data analysis

Like Passerieux *et al*. (1997), Blum & Freides (1995) and Henik *et al*. (1992, 1995) we computed priming effects as follows: median RT unrelated condition – median RT experimental condition (semantic or indirect semantic priming condition). Thus, a positive difference indicates a semantic priming effect and indirect semantic priming effect, respectively.

In schizotypy research, a common method to separate high and low scorers is the median split procedure (see Claridge, 1994). Following this, several two-way ANOVAs were conducted with questionnaire score (low *versus* high scorers) as group and priming type (experimental condition *versus* unrelated condition) as within-factor.

RESULTS

Questionnaire data of two subjects were not obtainable. Data of two other participants were excluded due to overall error rates that exceeded 70%. Hence, data from 156 subjects were submitted to statistical analysis. Table 2 shows means and standard deviations of RTs and percentage of errors. Only correct responses were used for measuring RTs.

Separate two-way ANOVAs (two-tailed tests) were conducted with questionnaire score (high *versus* low FCQ 'language' scores) as group, priming type (experimental (indirect semantic priming and semantic priming) *versus* unrelated condition) as within-factor and RT as dependent variable. Whereas the group factor did not achieve significance ($P > 0{\cdot}40$) in any of the four analyses, indicating equal reaction times for both groups, priming type was highly significant for all comparisons (semantic priming *versus* unrelated condition (SOA 200), $F = 110{\cdot}7$, df = 1,154, $P < 0{\cdot}0001$; indirect semantic priming *versus* unrelated condition (SOA 200), $F = 25{\cdot}7$, df = 1,154, $P < 0{\cdot}0001$; semantic priming *versus* unrelated condition (SOA 700), $F = 61{\cdot}7$, df = 1,154, $P < 0{\cdot}0001$; indirect semantic priming *versus* unrelated condition (SOA 700), $F = 34{\cdot}3$, df = 1,154, $P < 0{\cdot}0001$). The interaction of group and priming type was significant for three of the four analyses (semantic priming effect (SOA 200), $F = 4{\cdot}3$, df = 1,154, $P < 0{\cdot}05$; indirect semantic priming effect (SOA 200), $F = 5{\cdot}1$, df = 1,154, $P < 0{\cdot}05$; semantic priming effect (700), $F = 4{\cdot}5$, df = 1,154, $P < 0{\cdot}05$): high scorers showed significantly enhanced priming as compared to low scorers. The indirect semantic priming effect for the long SOA condition did not achieve significance.

Mean differences for semantic and indirect semantic priming effects are presented in Fig. 1. For the error data, no significant group × priming type interaction was found ($P > 0{\cdot}5$ for all analyses). No significant group differences or interaction for group × priming type emerged when SPQ data were split into low and high scorers; SPQ-subscales high and low scorers did not significantly differ with regard to priming-effects ($P > 0{\cdot}2$ for all analyses).

Unpaired *t* tests with low and high questionnaire score as the independent and RT (computed across all conditions) as the dependent variable confirmed that RT baselines were not significantly different for low and high scorers in the FCQ-subscale 'language' and the SPQ. Moreover, male and female subjects did not significantly differ in any of the psychometric and priming measures.

Furthermore, correlations were computed for priming effects with age and years of school,

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Table 2. *Reaction times* (*means and standard deviations*) *and percentage of errors of participants* (N = 156) *at two stimulus onset asynchronicities* (*SOA*)

	SOA					
	200 ms			700 ms		
	RT		% error	RT		% error
Condition	Mean	(S.D.)	Mean	Mean	(S.D.)	Mean
Unrelated	693·9	(130·2)	3·9	717·8	(182·1)	3·4
Non-word	752·9	(157·7)	3·4	770·8	(180·6)	3·2
Related	642·3	(122·0)	1·5	662·3	(154·0)	1·5
Indirect	666·2	(125·5)	1·6	674·2	(147·9)	1·7
SP	51·7*			55·4*		
ISP	27·7*			44·5*		

SP, Semantic priming effect; ISP, indirect semantic priming effect.
* $P < 0{\cdot}0001$ (two-tailed).

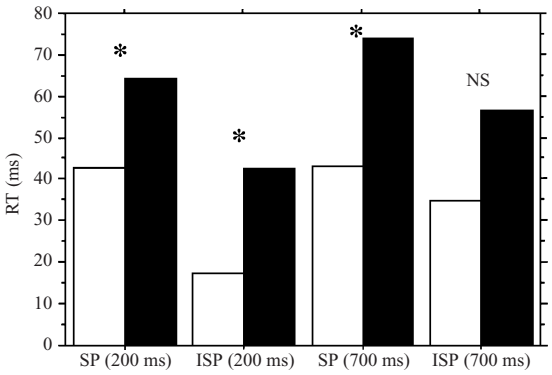


FIG. 1. Mean differences for semantic and indirect semantic priming effect (SP/ISP; 200 and 700 SOA condition) for FCQ-subscale 'language' high (■) and low (□) scorers ($N = 156$). (* $P < 0{\cdot}05$; NS, not significant.)

respectively. None of these analyses reached significance or trend level. Finally, as Barch *et al.* (1996) have reported a significant correlation between slowed down RTs and increased priming in healthy controls, we also correlated priming effects with RTs. Whereas there was no significant correlation for both priming effects and RTs at the short SOA ($r = 0{\cdot}06$, NS (semantic priming effect), $r = 0{\cdot}04$, NS (indirect semantic priming effect)), there was a highly significant correlation for both effects with RTs at the long SOA ($r = 0{\cdot}29$, $P < 0{\cdot}0005$ (semantic priming effect), $r = 0{\cdot}34$, $P < 0{\cdot}0001$ (indirect semantic priming effect)).

DISCUSSION

Differential semantic priming effects in schizophrenics have been attributed by various authors to problems of lexical access and thought disorder. For the present study, we investigated 160 healthy subjects with a measure of schizotypal personality and language disturbances (derived from the verbal complaints of schizophrenic patients) as assessed by the Frankfurt Complaint Questionnaire (FCQ) subscale 'language'. The rationale for this procedure has two cornerstones. First, a large number of studies suggest that high scorers in questionnaires assessing schizophrenia-like experiences and behaviour show neuropsychological deficits that resemble the performance of patients with schizophrenia (see Braff, 1993, for a review). Secondly, a psychometric high-risk approach avoids several methological problems and artefacts that limit the interpretation of conventional psychopathological studies (i.e. studies that compare psychiatric patients with healthy controls) like chronicity of illness, different performance baselines in RT tasks or medication, which have all been found to affect semantic priming heavily. However, as psychosis-prone subjects only reveal mild and subclinical symptoms (for example, sensory irritations instead of hallucinations) and not overt psychosis, certain protective factors have to be assumed that contradict entirely identical cognitive profiles in schizotypy/psychosis-proneness and schizophrenia.

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Our results suggest that those subjects who report language problems that resemble those reported by schizophrenics show enhanced semantic and indirect semantic priming. In line with Spitzer *et al.* (1993*c*), these effects were more pronounced for short SOAs, which suggests that language disturbances are related to increased automatic spreading activation. For the long SOA condition, differences between groups were found to be decreased. Longer SOAs reflect controlled processing, which is thought to be impaired in schizophrenics as well as in psychometrically identified schizotypal individuals (Raine *et al.* 1992). The fact that reaction times for both groups (high *versus* low scorers) do not significantly differ renders the idea of 'inflated' differences as the source of increased priming effects unlikely. It rather adds further validity to the hypothesis that automatic spreading activation is deficient in FCQ subscale 'language' high scorers as only delayed responses can account for inflated priming effects. Besides, priming effects and overall RTs did not correlate, at least at the short SOA condition.

Neither expectancy nor semantic matching can account for the results. First, expectancy strongly depends on the proportion of related prime-probe trials in a task. As only 16·67% of all prime–probe pairs were either related or indirectly semantically related, the strategy to generate possible target sets after visualizing the prime word would not have been successful and would have contributed to a failure to show any priming at all. More importantly, expectancy effects are thought to play a role for SOAs $>$ 400 ms (Vinogradov *et al.* 1992), and thus cannot explain enhanced semantic and indirect semantic priming at the short SOA condition (200 ms). Semantic matching, the second possible controlled mechanism in short SOA conditions (working at a post-lexical stage), also heavily depends on the proportion of related prime-probe pairs, so that this mechanism was unlikely to contribute to group differences. Moreover, in an experiment conducted by Neely (1977) semantic matching and expectancy did not occur at conditions using SOAs of 250 ms. Finally, correlations revealed that age and years of school did not modulate priming effects in our study.

In general, our results support the approach pursued by Maher *et al.* (1987) and Spitzer (1997), i.e. to isolate and investigate certain subgroups within the schizophrenic spectrum (see also Ober *et al.* 1995) since it becomes increasingly obvious that schizophrenia and schizotypy are rather heterogeneous disorders with different neurocognitive disturbances underlying various syndromes (Liddle & Morris, 1991; Siever, 1995). In line with this, in our sample a valid measure of schizotypal personality disorder, which has been construct validated for several paradigms (i.e. subjects scoring high in this measure revealed impairments similar to those found by schizophrenics) failed to yield significant results.

Although our study avoided some of the problems reported in schizophrenia research, several open questions remain. For example, in a very elaborated study Barch *et al.* (1996) also divided their sample into low and high thought-disordered patients and found no support for enhanced semantic priming in thought-disordered schizophrenics. Whether short prime presentation times (100 ms), as noted above, and a high percentage of related pairs (50%) can account for their results has to be investigated further. Moreover, more studies on indirect semantic priming in schizophrenia are clearly needed.

Our results should be regarded as promising, but they need cautious interpretation given some major limitations. A self-report approach may not detect highly disturbed subjects who are less able to self-reflect their language deviances, so that assessment by experienced clinicians is necessitated. Finally, the subscale 'language' covers only a few symptoms relevant for the syndrome of formal thought disorder, so that scales that assess a broader spectrum of features should be included for future studies.

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