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Original Research

Visual Verbal Information Processing under Conditions of Reading and Categorization in Schizotypy: An Event-Related Brain Potential Study

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Abstract

Background: Some individuals exhibit symptoms that resemble schizophrenia, but these manifestations are less in the degree to those seen in schizophrenia. Such a latent personality construct has been called schizotypy. It is known that schizotypal personality traits have an impact on cognitive control and semantic processing. The present study aimed to examine whether visual verbal information processing is modulated by enhancement of top-down processes applied to different words within one phrase in subjects with schizotypal personality traits. The tasks employed were based on differences in the involvement of cognitive control in visual verbal information processing and hypothesized that subjects with schizotypal traits would demonstrate failure in top-down modulation of word processing within a phrase. **Methods**: Forty-eight healthy undergraduate students were enrolled in the study. Participants were screened for schizotypy with the Schizotypal Personality Questionnaire. Word combinations consisting of an attribute and a noun were used as stimuli. Participants were asked to categorize one word in a phrase and to passively read the other word in the pair. To obtain neurophysiological data during task performance, the event-related brain potential N400 was measured. **Results**: In the low schizotypy scores group, an increased N400 amplitude was revealed for both attributes and nouns during passive reading compared to categorization. This effect was not observed in the high schizotypy scores group; therefore, word processing was modulated weakly by the experimental task in subjects with schizotypal personality traits. **Conclusions**: Changes observed in schizotypy can be regarded as a failure in top-down modulation of word processing within a phrase.

Keywords: event-related potentials; N400; visual verbal information processing; reading; semantic categorization; top-down; bottom-up; schizotypy

1. Introduction

Schizotypy is a latent personality organization which can manifest in an imperceptible manner or give rise to a variety of schizophrenia spectrum disorders [1]. Non–disordered high schizotypy individuals are considered to demonstrate mild and transient signs of the symptoms and impairments manifested in schizophrenia [2]. Individuals that achieve elevated scores on psychometric measures of schizotypy are assumed to be at increased risk for schizophrenia and schizophrenia-related psychoses [1–3]. Therefore, the signs of schizotypy are significant for identifying high-risk groups for psychosis in the population, as well as for uncovering the mechanisms that lie on the path from schizotypal personality organization to clinically diagnosed schizophrenia [4]. Schizotypy includes changes in behaviors, cognitions, and emotions, but these changes are less pronounced than in schizophrenia [5]. It is known, that thought disorder is a defining feature of schizophrenia [6] and schizotypy [7]. Disorders of thought are psychopathological phenomena that seem to result from deficits of semantic processing in schizophrenic and schizotypal subjects [7].

It is known that bottom-up processes take in information from the external world and require little input from higher-level knowledge. On the other hand, the uptake of information controlled by top-down processes is guided by an individual's prior knowledge and current goals [8,9]. Neurophysiological models of schizophrenia focus on distributed brain dysfunction with both bottom-up as well as top-down components as reflected in the literature [10,11]. Fewer studies are devoted to the changes in top-down and bottom-up control in schizotypy. Contradictory data were obtained in various research paradigms modeling the use of top-down and bottom-up control in schizotypy: on the one hand, there is a shift towards top-down control [12], in other studies, a top-down deficit is observed [13,14]. An altered balance in the combination of bottom-up sensory evidence and top-down prior knowledge is considered a fundamental trait that contributes to the emergence of psychosis and this imbalance is considered to explain both the hallucinatory experiences and the bizarre delusional beliefs of psychotic patients [12]. Top-down control has an impact on the semantic processing of information [15], however as far as is known, the influence of top-down and bottom-up factors on the semantic processing of visual verbal information in healthy people with schizotypal personality traits has not been highlighted in the literature.

At the neurophysiological level, the scalp-recorded event-related brain potentials (ERPs) component peaking approximately 400 ms after presentation of any potentially meaningful stimulus (N400) is thought to reflect the brain activity associated with semantic processing [16]. This component is used to assess the verbal information processing in schizotypy [17–21] and schizophrenia [22]. The N400 is widely used in studies of semantic priming. Semantic priming is the most common method employed in studies focused on disorders of semantic processing in schizophrenia [7]. It is a lexical decision test that examines the character of associations between mental concepts. Usually, a decreased response amplitude is observed with related, congruent concepts and an increased response amplitude is observed with unrelated, incongruent concepts. This difference in amplitudes provides the so-called N400 effect. A reduced N400 effect is frequently reported in schizotypy [17,18,21]. This anomaly is thought to reflect a less than normal inhibition or greater than normal activation of unrelated information during semantic processing [18]. However, it is known that the N400 component is modulated not only by lexical and semantic features but also is sensitive to bottom-up and top-down processes during semantic operations [23]. One factor that allows modulation of the top-down and bottom-up control of information processing is a variation of the task conditions performed by the participants. It appears to be useful for experimental tasks that require unequal cognitive resources and use differing amounts of top-down information involvement. There is some evidence that semantic decision tasks increase top-down modulation [24], so it would seem to be useful to study the top-down control of semantic processing by manipulating the task (implicit versus explicit semantics). There is published evidence that confirms the sensitivity of the N400 component to the experimental task. For example, Kreher *et al*. [25] examined direct and indirect ERP semantic priming during an implicit semantic monitoring task and an explicit semantic matching task. In the explicit task, patients with schizophrenia showed a decrease in direct and indirect semantic priming compared with a healthy control group. Alternatively, in the implicit task, patients with schizophrenia demonstrated a normal or, in positively thought-disordered patients, increased direct and indirect N400 priming effects compared with healthy controls. Based on these data, the authors have concluded that the introduction of semantic decision-making can result in abnormally reduced semantic priming in schizophrenia. Several studies have shown that the N400's amplitude is greater for task irrelevant than for task relevant stimuli [26,27]. A study by Shang and Debruille [26] revealed that the N400 potential elicited by a word was more negative when the meaning of this word was inappropriate to the task than when it had to be taken into account and used for task performance. These results contrast with the idea that the N400 reflects the brain activity associated with lexical access, activation or integration processes, but confirm an alternative point of view that the N400 component could index the inhibition of representations that have been inappropriately activated. Another study by Mar'ina [27] demonstrated that the N400 amplitude was larger for pseudowords when compared to meaningful words under conditions of reading and conditions of the task required a response to meaningful words. This result was consistent with the idea that pseudowords elicit an increased N400 amplitude. On the contrary, N400 amplitudes became larger for meaningful words when compared to pseudowords under the task requirement of responding to pseudowords. Such increased N400 amplitude for meaningful words was interpreted as an effect of the irrelevance to the task. This effect was preserved in schizophrenia patients [28]. Nevertheless, task manipulations revealed some features of semantic processing in schizophrenia. It should be noted that the N400 ERP has been studied in sufficient detail as a semantic correlate, however, the number of studies devoted to the modulation of this component induced by experimental task manipulations is quite limited in schizotypy and schizophrenia.

In the current study, a model was employed that was based on differences in the top-down involvement in visual-verbal information processing in a simple context presented as the combinations of attributes and nouns. Passive reading of verbal information is more of a bottom-up process [9], whereas semantic categorization is a more controlled process that activates the mechanisms of top-down control [29]. Therefore, participants were asked to categorize one word in a phrase and to passively read the other word in the pair. This makes it possible to evaluate the restructuring of information processing within the word pair related to differences in the top-down involvement. It was an aim to use the N400 to examine whether the visual verbal information processing is modulated by enhancement of top-down processes applied to different words within one phrase in subjects with schizotypal personality traits. It was hypothesized that subjects with more pronounced schizotypal traits would demonstrate failure in top-down modulation of word processing within a phrase.

2. Materials and Methods

2.1 Participants

The study was performed in accordance with the Declaration of Helsinki (2013) and approved by the Ethics Committee of the Privolzhsky Research Medical University (protocol No 8, 2019). All participants provided written informed consent in accordance with the Declaration of Helsinki (2013). In order to reveal persons with schizoty-

Table 1. Clinical characteristics of participants.

	Low-SPQ group (n = 24)	High-SPQ group (n = 24)
SPQ total score	13.58 (4.07)	33.53 (8.08)
SPQ cognitive perceptual factor	1.25 (0.61)	3.04 (0.83)
SPQ interpersonal factor	1.83 (0.92)	4.49 (1.41)
SPQ disorganized factor	1.54 (0.92)	3.94 (1.66)

pal organization, the Schizotypal Personality Questionnaire (SPQ) [30] was used. Depending on their SPQ total score, the participants were assigned to the low or high schizotypy group. Based on a large scale screening among university students (n = 270), we found the median score was 18 points. This median score was used to split the group. Thus, participants with an SPQ score <18 (n = 24) were classified as having low schizotypal traits (low-SPQ group) and those with an SPQ score >18 (n = 24) were classified as having high schizotypal traits (high-SPQ group). In general, forty-eight healthy undergraduate students aged between 18 and 25 years (median (M) = 21.24; standard deviation (SD) = 1.94) were enrolled in the study. The clinical characteristics of the two groups are presented in Table 1.

2.2 Stimuli

The stimulus material consisted of 120 word pairs in Russian representing combinations of nouns and their attributes. The stimuli were distributed equally into two lists for two distinct series of presentations. The first list included 60 pairs of words compiled in such a way that the attributes expressed a qualitative or ordinal characteristic. This list was used in the first series of presentations, where the attributes were the targeted words for categorization. The second list included 60 pairs of words compiled in such a way that nouns signified a tool or an interior design. This list was used in the second series of presentations, where the nouns were the targeted stimuli for categorization. Across the conditions, attributes and nouns were matched for mean length and frequency of usage. The mean length of attributes was 7.25 (SD = 1.13) letters in the first list and 7.48 (SD = 1.08) letters in the second list. The mean length of nouns was 6.03 (SD = 0.97) letters in the first list and 5.72 (SD = 1.17) letters in the second list. The mean frequency of attributes usage was 19.01 (SD = 18.72) per million in the first list and 18.51 (SD = 24.75) per million in the second list. The mean frequency of noun usage was 19.64 (SD = 18.16) per million in the first list and 16.78 (SD = 23.16) per million in the second list [31]. Examples of the stimuli are given in Table 2.

Table 2. Examples of the stimuli.

Condition	Category	Example
Target attribute	qualitative	green plate
	ordinal	seventh button
Target noun	tool	durable screw
	interior design	trendy lamp

2.3 Procedure

Subjects were seated comfortably in a dimly lit room in front of a computer screen placed 1 m from their eyes. Word pairs were presented using PsychoPy (v1.83.01, Peirce, Nottingham, UK) one word at a time in the center of the screen in white, lower-case letters against a gray background. Each trial began with a fixation cross appearing at the center of the screen for 1000 ms and blank for 200 ms. The first word was presented for 1200 ms, the screen then became gray for 200 ms before the next word was displayed (stimulus-onset asynchrony (SOA) of 1400 ms). The next word was presented for 1200 ms and then the gray background (200 ms) which was then replaced by a question mark. The subjects responded by pressing the left or the right button of the keyboard while the question mark appeared on the screen. In the first series, subjects were asked to decide whether the attribute expresses a qualitative characteristic or an ordinal one (e.g., the "seventh" or "green"). The following noun was read passively without a categorization task. In the second series, subjects were asked to decide whether the noun signifies a tool or an interior design (e.g., "screw" or "lamp"). The preceding attribute was read passively. The participants were told to hold their response until the question mark appeared. The question mark remained until participants responded. They responded by pressing the right (ordinal, tool categories) or left (qualitative, interior design categories) button on the keyboard. Experimental pairs were presented in a different random order for each participant. There were 60 trials in the first series and 60 trials in the second series. Participants were given a short break after the first series. The experimental procedure is illustrated in Fig. 1.

It should be emphasized that the underlying concept of this task measuring required a different involvement of top-down control in the semantic processing.

2.4 Electrophysiological Recording and Analysis

Electroencephalographic activity (EEG) was recorded with a Neuron-Spectrum-4/EPM amplifier (№0494KT, Neurosoft, Ivanovo, Russia) using 20 Ag/AgCl electrodes embedded in an elastic electrode cap MCScap 10–20 (205-19, Medical Computer Systems, Moscow, Russia) following the extended international 10–20 system and was referenced to the left and right ipsilateral mastoids. A cephalic electrode placed in the middle of FPZ and FZ was used as

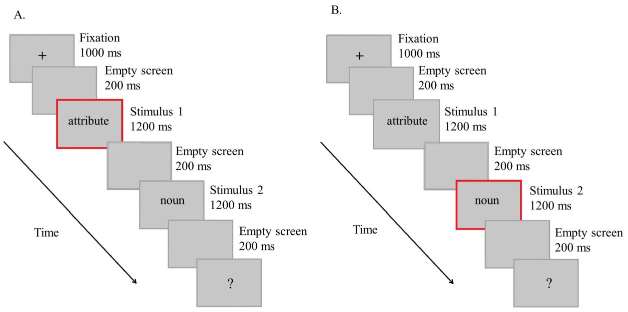

Fig. 1. Experimental procedure in (A) the first series and in (B) the second series. Rectangles containing target words are highlighted in red. True colors were white letters on a grey background.

ground. Electrode impedance was maintained below 10 kΩ. The EEG recordings were continuously digitized at 1000 Hz. To avoid slow signal drifts, the data were processed with a 0.5–13 Hz bandpass offline filter. EEG data were analyzed offline by Neuron-Spectrum.NET software (1.3.10.0, Neurosoft, Ivanovo, Russia). Artifacts were reduced by rejecting epochs with voltages exceeding $\pm 90\ \mu$V in any EEG channel. Eye-blink artifact components were detected in the EEG from the frontal electrodes and were discarded.

The EEG over each recording site was averaged separately for each participant within each experimental condition. The number of averages for each type of stimuli for each subject ranged from 30 to 40. For each subject, the N400 in the ERP to target and non-target words was identified as the most negative peak between 250 and 500 ms following stimulus onset based on visual inspection of the grand averages. Peak amplitude measurements (baseline-to-peak) were made relative to the –100 ms pre-stimulus interval which served as the baseline.

2.5 Statistical Analysis

N400 amplitude modulation was analyzed using a three-way mixed model repeated measures ANOVA, with condition (task, passive) and position (first, second) as within-group factors and group (low-SPQ, high-SPQ) as the between-group factor. Significant interactions between group and condition were followed with repeated-measures ANOVA for the low- and high-SPQ group separately, with the within-subjects factors of condition and position, and for each level of condition, with group and position as between- and within-subject factors. For this analysis the N400 amplitude averaged across central-parietal electrodes (C3, Cz, C4, P3, Pz, P4) was used.

Main effects and interactions were followed up with *post hoc* comparisons. For all analyses, probabilities of less than 0.05 were considered significant. Effect sizes for significant effects are reported using the partial eta-squared method (η_p^2).

To assess the difference in the N400 effect between the two groups, the amplitudes of the difference waves averaged over the central-parietal electrode sites (N400 amplitudes under passive condition—N400 amplitudes under task condition) were analyzed separately for the first and second words between groups using an independent samples *t*-test.

Finally, Spearman's correlation coefficients (ρ) were calculated between the N400 effect amplitudes (averaged over the central-parietal electrode sites) and total SPQ scores.

Behavioral data were calculated using the Mann-Whitney test and presented as percentiles due to the non-normal distribution. Response times faster than 250 ms and slower than 1500 ms were scored as missing data.

3. Results

3.1 Behavior

The response time of the target attributes in the high-SPQ group 0.47 [0.41; 0.68] and the low-SPQ group 0.48 [0.42; 0.59] were found to not be significantly different. The response time of the target nouns in the high-SPQ group 0.5 [0.42; 0.7] and the low-SPQ group 0.48 [0.39; 0.57] were also not significantly different.

3.2 Electrophysiology

Grand-averaged ERPs observed in the low-SPQ and high-SPQ groups in response to the presentation of the word at the first (attributes) and second positions (nouns) under two experimental conditions are presented in Figs. 2,3 respectively. Grand-averaged ERPs at the Pz electrode site time-locked to the second word onset in the low-SPQ and high-SPQ groups are presented in Fig. 4.

In the N400 time window, the three-way ANOVA revealed a main effect of condition (F (1,00) = 19.955; $p < 0.001$, $\eta_p^2 = 0.303$): stimuli under the passive condition elicited N400 amplitudes that were more negative than under the task condition. There was also a main effect of position (F (1,00) = 11.499; $p = 0.001$, $\eta_p^2 = 0.200$): Stimuli at the first position elicited N400 amplitudes that were more negative than at the second position. The main effect of the group was not significant (F (1,00) = 0.171; $p = 0.681$, $\eta_p^2 = 0.004$), but the group interacted with the condition (F (1,00) = 11.816; $p = 0.001$, $\eta_p^2 = 0.465$). Further analyses of this interaction revealed that in the low-SPQ group, the N400 amplitudes for the passive condition were more negative than the N400 amplitudes for the task condition (F (1,00) = 23.105; $p < 0.001$, $\eta_p^2 = 0.501$), whereas in the high-SPQ group, there was no significant effect of condition (F (1,00) = 0.818; $p = 0.375$, $\eta_p^2 = 0.034$). The group did not interact with condition and position (F (1,00) = 2.610; $p = 0.113$, $\eta_p^2 = 0.054$). The position interacted with the condition (F (1,00) = 5.129; $p = 0.028$, $\eta_p^2 = 0.100$). *Post hoc* comparisons revealed that the amplitude for the first word was higher than the amplitude for the second word under

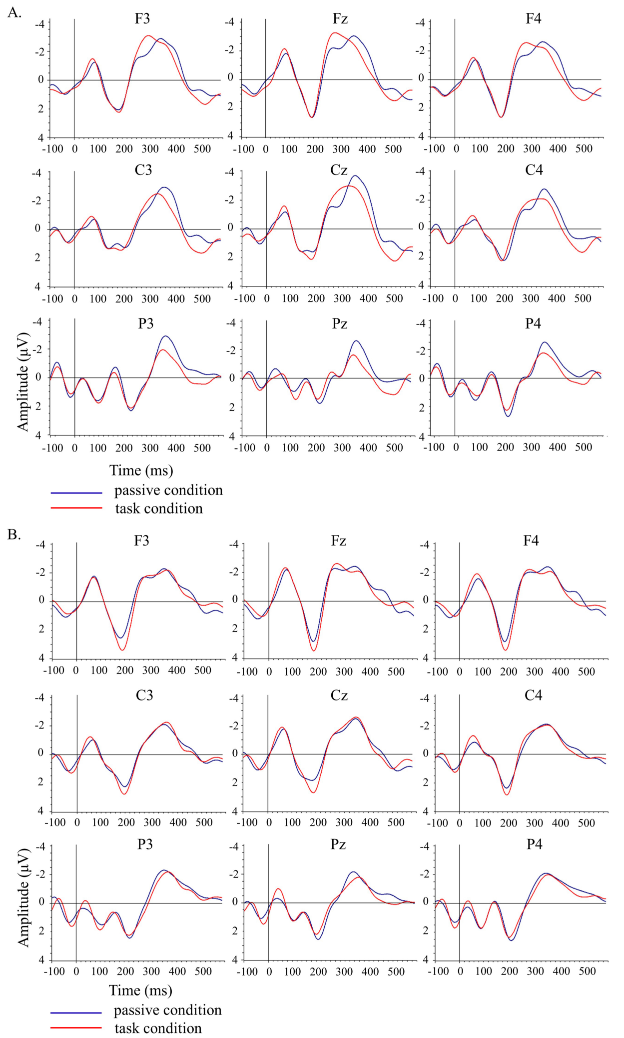

Fig. 2. Grand-averaged ERPs time-locked to the first word onset in the two experimental conditions in (A) the low-SPQ group and (B) the high-SPQ group. Grand average ERPs at nine representative electrode sites for the first word under the reading condition (blue line) and the task condition (red line). (A) The ERP waveforms in the low-SPQ group (upper plots). (B) The ERP waveforms in the high-SPQ group (lower plots).

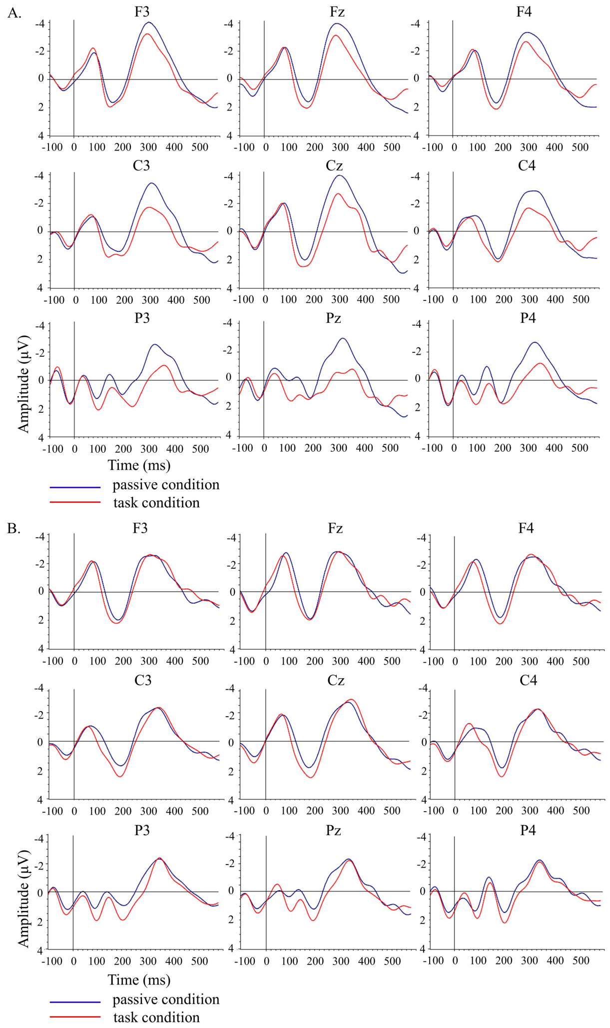

Fig. 3. Grand-averaged ERPs time-locked to the second word onset in the two experimental conditions in (A) the low-SPQ group and (B) the high-SPQ group. Grand average ERPs at nine representative electrode sites for the second word under the reading condition (blue line) and the task condition (red line). (A) The ERP waveforms in the low-SPQ group (upper plots). (B) The ERP waveforms in the high-SPQ group (lower plots).

the task condition ($p < 0.001$). It was also revealed that there are differences between the N400 amplitudes for the first word in the passive condition and the second word in the task condition ($p < 0.001$) and differences between the N400 amplitudes for the second word in the passive condition and the second word in the task condition ($p < 0.001$).

Mean N400 amplitudes observed in the low-SPQ and high-SPQ groups in response to the presentation of the nouns under the two experimental conditions are given in Fig. 5.

An independent samples t-test on the difference waves for the second word, showed the amplitudes in high and low SPQ groups were significantly different ($p < 0.001$). An independent samples t-test on the difference waves for the first word showed no significant differences between the amplitudes in high and low SPQ groups.

Correlations. The N400 effect for the second word (N400 amplitude under the passive condition—N400 amplitude under the task condition) was correlated with total SPQ scores ($\rho = 0.513$; $p < 0.001$): these scores were higher when the N400 effect was less pronounced (see Fig. 6).

4. Discussion

In this study, the top-down control involvement in the semantic processing of word pairs was investigated in subjects with high and low schizotypal personality traits. In the low schizotypy scores group, an increased N400 amplitude was found for the first and the second words in a phrase un-

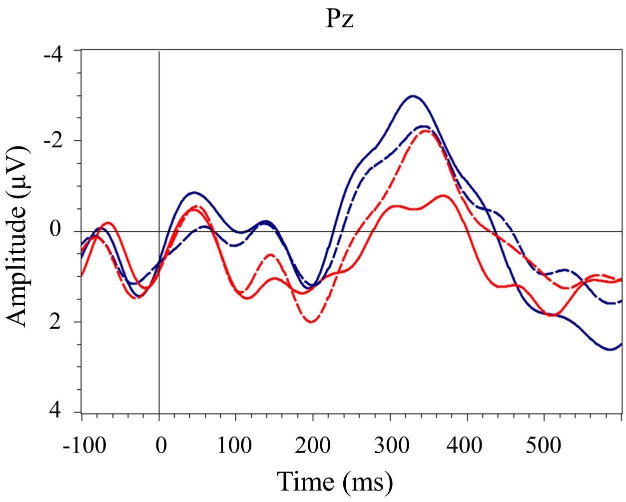

Fig. 4. Grand-averaged ERPs at the Pz electrode site time-locked to the second word onset in the two experimental conditions in the low-SPQ group and in the high-SPQ group. Grand average ERPs at the Pz electrode site for the second word under the reading condition (blue line) and the task condition (red line). The ERP waveforms in the low-SPQ group are plotted as a solid line; the ERP waveforms in the high-SPQ group are plotted as a dashed line.

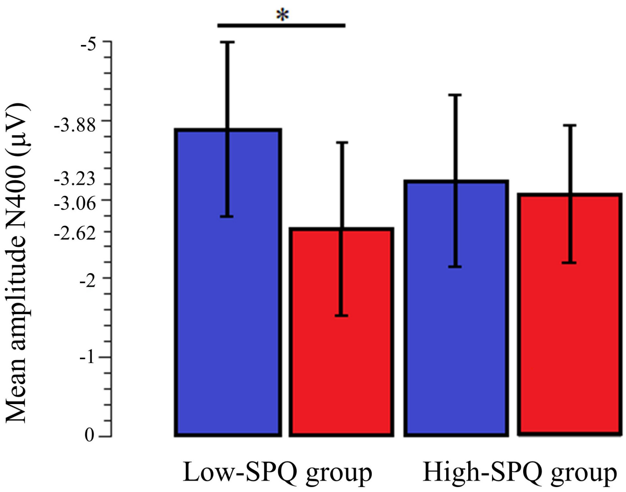

Fig. 5. Mean N400 amplitudes observed in the low-SPQ and the high-SPQ groups in response to the presentation of the second word under two experimental conditions. Mean N400 amplitude averaged across central-parietal electrodes (C3, Cz, C4, P3, Pz, P4) for reading condition (in blue) and task condition (in red) in the low-SPQ (left columns) and the high-SPQ (right columns) groups. The error bar denotes the standard deviation of the mean. $*p < 0.001$.

der the passive condition when compared to the task condition. An enlarged N400 amplitude in response to non-target stimuli is consistent with previous studies [26,27] which reported an increased amplitude of this component in re-

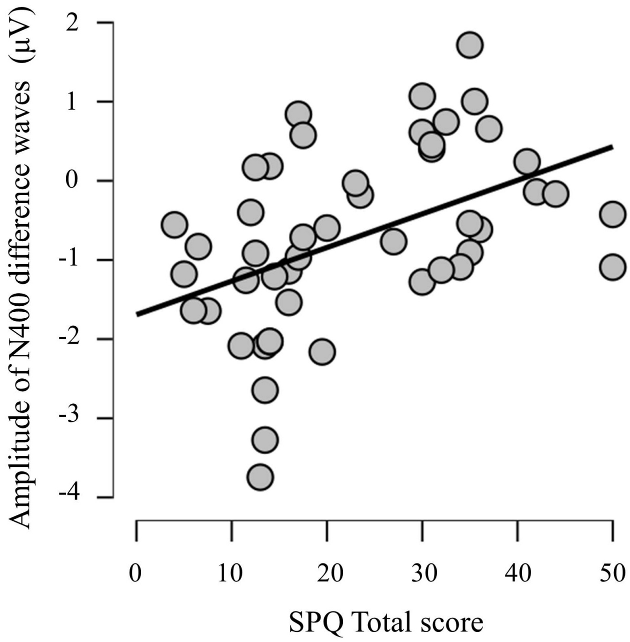

Fig. 6. Scatterplot of difference wave mean amplitudes for the second word (averaged across all central-parietal electrodes) vs. total SPQ scores.

sponse to the task-irrelevant stimuli. It is known that top-down processes may elicit less N400 activity [23] and the processing of task-relevant stimuli might be facilitated by increasing the "gain" of neurons in brain areas which process task-relevant stimulus information, while decreasing the gain of neurons in other areas and blocking the processing of task-irrelevant information [15]. Results reported for the low-SPQ group may be considered in line with this framework and demonstrate facilitation by top-down influence of the current goal in case of task-relevant stimuli.

However, this study did not reveal any statistically significant differences in the N400 amplitude between the task and passive conditions in the high-SPQ group. According to this finding, it is suggested that the resources spent on word reading were similar to those expended for word categorization in schizotypy. The theoretical framework in which N400 processes are of an inhibitory nature suggests that the inhibition of inappropriately activated representations could be impaired in schizotypy. Moreover, previous studies that operated with lexical and semantic features of stimulus material have also demonstrated a lack of inhibition of excessive information and as a result, a decrease in the N400 effect in subjects with high schizotypy [17,18,21]. On the other hand, from the perspective of the evidence that does not support an active top-down inhibition of task-irrelevant processing pathways [15], it can be assumed that enhanced processing of task-irrelevant stimuli increases the top-down influence from prefrontal areas in schizotypy.

Results reported here contradict results reported by Mar'ina *et al.* [27] who observed the persistence of the effect of irrelevance on the task in patients with schizophrenia

[28]. The difference can be explained by the different research models. The model employed for this study used a combination of words, in contrast with Mar'ina *et al*. [27] who presented single words as stimuli. Furthermore, this study also investigated the possibility of changing the processing of a word within a phrase depending on the task, so the results reported here should not be explain only in terms of the irrelevance to the task.

The findings reported here appear to reflect the fact that information processing is modulated weakly by a behavioral task that requires either less or more involvement of cognitive control networks in the high-SPQ group. Individuals with schizotypy appear to have difficulty in switching between top-down and bottom-up processing within one phrase. This is consistent with the idea of an imbalance between top-down and bottom-up processes in schizophrenia spectrum disorders [10,12,32]. It can be assumed that processing of information in the case of reading might be less passive in schizotypy, as it is quickly combined with stored memory representations, other sensory experiences, and top-down expectations. Such increased influence of top-down sensory expectations on conscious perception has been considered in schizophrenia patients [32–34].

One interesting result is that difference waves of the N400 effect are only significantly distinguished between the high- and the low-SPQ groups for the second word. On the one hand, the neurolinguistic features of the stimulus material could influence the results. More pronounced changes in the processing of nouns may be associated with a higher frequency of noun usage, which affects the processes of lexical access [35]. It is known that nouns account for 28.7% of word usage (the first place), whereas adjectives are used in 8.5% and numerals are used in 1.7% among the parts of speech [36]. On the other hand, the position of the word in the sentence and the compositional context could lead to the differences in the N400 effect between the attributes and the nouns in schizotypy in the reported paradigm. It is known that the processing of single words and words combined into phrases and sentences differ from each other. In another study, nouns in minimal compositional contexts ("red boat") were compared with those appearing in matched non-compositional contexts, such as after an unpronounceable consonant string ("xkq boat") or within a list ("cup, boat") [37]. It was found that only the two-word composition trials elicited an increase in activity in the ventromedial prefrontal cortex with an onset of about 400 ms. Perhaps the current findings demonstrate that the schizotypal traits have an impact on more semantically intensive expressions such as word pairs when compared to isolated words. Moreover, it is known that the N400 is sensitive to incremental build-up of semantic context in a sentence and the effects associated with this component undergo change depending on word position [38,39]. In this way, more pronounced changes in the processing of nouns can be observed due to their position in the sentence and due to the presence of a prime in the form of a preceding attribute. Perhaps a context of attributes may elicit an intrusion of common associations that influence the nouns perception in schizotypy.

Furthermore, the N400 amplitude was more pronounced for the first word under the task condition in one phrase compared to the second word under the task condition in another phrase. Also, the first word under a passive condition elicited a more pronounced amplitude of the N400 than the second word under task condition in this phrase. This is consistent with the idea that the N400 amplitude is sensitive to context and becomes smaller with increasing word position [38,39]. Statistical analysis revealed that the group did not interact with either condition or position.

This study has some limitations that should be mentioned. Firstly, the paradigm consisted of words belonging to different parts of speech so it is impossible to accurately establish the relationship of some effects with the position of the word in a phrase or with lexical characteristics of stimuli. Secondly, we didn't investigate the effects and interactions associated with the subscales of the SPQ, but instead tested on the general score. Thirdly, it was not clarified whether results were a consequence of deficits in active inhibition or an enhanced top-down influence in the high schizotypy group. This suggests the necessity of supplementary research in this area.

5. Conclusions

The findings reported here show neurophysiological differences between subjects with either high or low scores on a schizotypal questionnaire. In the low SPQ group, the N400 component demonstrated high sensitivity to task manipulation (an implicit passive reading vs. an explicit semantic categorization). In contrast, for subjects with more pronounced schizotypal personality traits, the N400 amplitude was modulated weakly by the behavioral task requiring unequal involvement of cognitive control networks in word processing. These findings confirm the idea of altered balance in the bottom-up and top-down control of visual verbal information processing in schizotypy and appears to demonstrate failure in the top-down modulation of word processing within the given phrases in these subjects.

Abbreviations

ERP, event-related potential; EEG, electroencephalogram; SPQ, Schizotypal Personality Questionnaire.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

PP and IM designed the research study. PP and NN performed the research, analyzed the data and wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

The study was performed in accordance with the Declaration of Helsinki (2013) and approved by the Ethics Committee of the Privolzhsky Research Medical University (protocol No 8, 2019). All participants provided written informed consent.

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Conflict of Interest

The authors declare no conflict of interest.

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