Visual event-related potentials and stroop tests results compared between patients with schizophrenia and healthy individuals

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Abstract

We discuss the features of cognitive dysfunctions in schizophrenia through visual event-related potential (ERP) tests using color stimulation and stroop tests in patients with schizophrenia and a control group consisting of healthy individuals. Significantly prolonged latency of P300, decreased P300 amplitude, and enhanced stroop effects in ERP were observed in the schizophrenia group. A correlation was observed between ERP and stroop tests in the healthy individuals but not in the schizophrenia group. Factors such as age, P300 latency, and stroop tests were correlated in the control group. In the schizophrenia group we observed correlations between reaction time and psychopathologic scale of positive and negative syndrome, and between Stroop tests and duration of disease. According to these results we conjectured a disorder in successive processes from visual recognition to perceptual-motor coordination in schizophrenia and observed a temporal change of disorders in information-processing more clearly in the perceptual-motor reaction process than in the information evaluation and selection processes.

1. Introduction

Impaired attention and disorders in information processing in patients with schizophrenia occurs in every stage and status. However, they may manifest differently. Not all information processes are impaired, and they show complexities related to the psychological causes of schizophrenia and social disorder. The event-related potential (ERP) is a psychophysiological test that readily measures these cognitive dysfunctions. A study using various stimulation methods and paradigms have been performed with visual ERP.

In the field of color cognition there is a reaction, the “Stroop effect”, in which the act of providing the name of a color is delayed in trying to name a color when the word for the color is presented in a different color from the meaning, compared to simply naming a color sample. The Stroop test is based on application of the effect and is known well as an exercise of cognitive psychology. The Stroop test reflects conflicting interactions between linguistic information (words) and non-linguistic information (colors). The test assesses selective attention in meaning because one must pay attention to specific stimulus attributes and neglect extraneous information. It is used frequently as a functional test of the frontal cortex and a cognitive function test in mental diseases such as schizophrenia.

In this study we performed visual ERP and stroop tests simultaneously on patients with schizophrenia and a control group of healthy persons. The features of cognitive dysfunction in schizophrenia are discussed by comparing the results from these tests.

2. Materials and methods

The subjects comprised a control group of 20 individuals (9 men and 11 women) and a schizophrenia group of 20 (12 men and 8 women) who satisfied the ICD-10 diagnostic criteria seen at the Kashiwazaki Kosei Hos-
pital of the Tachikawa Medical Center. All subjects were right-handed and none had motor or visual disorders, nor any defect in color perception.

Mean ages were 34±12 years for the control group and 32±7.2 years for the schizophrenia group, with no significant difference. The mean duration of active schizophrenia was 7.2±4.0 years in the schizophrenia group, with further classifications present as paranoid (10), hebephrenic (3), catatonic (2) and undistinguished forms (5). The mean total dose of antipsychotics was 9.7±6.0 mg, calculated as haloperidol equivalent. On the positive and negative syndrome scale the mean of the positive scale values was 20.0±6.5 and the negative scale mean was 24.5±5.8, which respectively indicates mild to moderate delusion/hallucination and restricted emotional expression. The mean of the psychopathological scale score was 43.4±11.5. The total mean was 88.9±22.0. Written, informed consent was obtained from all subjects. The research plan was approved by the ethical committee of the Tachikawa Medical Center.

Method

We used Neuropack (MEB-408) from Nihon Kohden [Remark 1] for ERP and instructed patients to sit 1.3 m in front of a color display (33.5×24.5 cm²) as 20×20 cm² colored squares were displayed. We used a visual stimulation category departing exercise as the stimulation. Patches colored red were used as the target stimulus (20%), and blue, yellow, and green patches were used as non-target stimuli (80%). Color stimuli were presented in random order, each stimulus was displayed for 1 s, and the display interval was 0.5 to 2 s. We instructed subjects to press a button when they saw red squares. Electrodes were placed as specified by the International 10-20 system.

Silver–silver chloride electrodes were placed on the scalp to record Cz, Pz, and Oz; electrodes connecting both ear lobules (A1, A2) were used for reference, and earth electrodes were placed on the frontal plains. Sensitivity was set at 50 µV/DIV and frequencies were band-pass filtered between 50 and 0.1 Hz. We performed 20 stimulations but excluded records including artifacts such as excessive amplitude and eye movements. The data were recorded at a sample frequency 1,000 Hz to a computer through an A/D conversion board. We set the largest cathode potential at N100 from 0 to 150 ms for Oz and the largest anode potential at P300 from 250 to 500 ms for Pz on each wave. We determined amplitudes from the difference between base-line and peak when the mean potential was set to zero for 100 s before stimulations. We measured reaction time (RT): the time between the target stimulus appeared and the button was pressed.

The Stroop test was performed as follows. Fifty Chinese characters representing red, blue, yellow, and green were randomized after printed in black on B5-size white paper at a size of 2×2 cm². We instructed the patients to read the characters aloud and measured the time required. We also instructed subjects to identify the color of 2×2 cm² squares presented randomly in red, blue, yellow, and green on white paper and measured the time required for them to identify the color (color card). In addition, 50 Chinese characters in different colors were shown to subjects. We instructed them to identify the colors and measured the time required for identification (Color–word card, CW card).

We compared the amplitude and latency of N100 of O1 and P300 of Pz in ERP and RT during the tests and the time to read W, C and CW cards in the Stroop test between the control and schizophrenia groups. We calculated the correlation between ERP and the Stroop tests for each group. Test results were related to age in the control group evaluated against age, affective duration, drug dose, positive, negative and psychopathological scales, and scale total positive and negative syndrome scale (PANSS) in the schizophrenia group.

We used the Student t-test as the statistic between group differences and the Welch test to compare mean values in each group. We used Pearson or Spearman correlations as appropriate. A value of P<0.05 was considered to indicate a statistically significant different.

3. Results

The grand average wave of ERP is presented in Fig. 1. A significant decrease in N100 amplitude, prolonged P300 latency and decreased of P300 amplitude in ERP were observed in the schizophrenia group compared with the control group (Table 1).

In the Stroop tests extended reading times were observed for the C and CW cards in the schizophrenia group compared with the control group, demonstrating an increased Stroop effect (Table 2).

In correlation between ERP and Stroop tests the relation between P300 latency and read-off time was strong but not statistically significant in the control group. A significant correlation was observed with W card tests. Significant correlations were observed between RT, W and C card tests (Table 3). No similar correlations were obtained from the schizophrenia group (Table 4). Significant correlations with other factors, including age, P300 latency, and Stroop tests were observed in the control group (Table 5). A correlation was observed between RT and the psychopathological scales of PANSS, and between the Stroop tests and the durations of active schizophrenia in the schizophrenia group (Table 6).
The schizophrenia group showed significantly lower amplitudes of N100 and P300, and prolonged latencies of P300 compared with the control group.

The schizophrenia group showed significantly prolonged reading times with C and CW cards. The Stroop effect was augmented in the schizophrenia group.
The Stroop test reflects conflicts within the selective judgment and is reactive to the evaluated stimuli. The visual information processing procedure includes a group ERP and stroop effect in the healthy control group.

The visual information processing procedure includes (a) processing cognition of stimulations for transmission to the visual system; (b) a process to evaluate stimuli in which cognitive stimulations are recognized, expected, or judged; and (c) a process reactive to the evaluated stimuli. Each of the processes reflects selective attention functions.

N100 is an exogenous potential originating in the first visual area and the visual association cortex that reflects visual transmission functions, so is categorized as an (a) process. P300 relates to the stimulation evaluation process (b). Its latency represents the time to evaluate stimuli and the amplitude stands for information processing capacity.

The Stroop test reflects conflicts within the selective attention process relating to the interaction between linguistic information (words) and non-linguistic information (colors). This test is likely indicative of the reaction process (c) after passing the cognitive process, and of conflicts in the selective attention process relating linguistic information (words) and the non-linguistic information (color). Therefore, the correlation between them supposedly reflects progression of processing from the evaluation of visual stimulation and selection to the reaction corresponding to perceptual-motor reactions. It is known that the frontal cortex has a major connection to attention-information processing.

In correlating ERP and Stroop tests there are studies that have used stroop conditions as exercises for ERP as well as those in which ERP tests and stroop tests were performed separately, as in our case.

When the Stroop conditions have been used as exercises for ERP it has been reported that they influence reading time but have almost no influence on P300 latency. Ilan and Polich (1999) conjectured that the different effects induced by Stroop stimuli on reading time and P300 latency do not correspond to the processes from stimulations to reaction. In other words, they suggested that simultaneous input of divergent information generates simultaneous information processes. Thus the reaction to "reading" not related to an exercise competes with the reaction to "color" during an exercise causing a delayed reaction but without influencing P300 latency. It is believed that P300 does not substantially reflect the reaction output system. This effect may be at work in the case of Stroop exercise using Chinese characters (Shen, 2006).

4. Discussion

1) ERP and stroop effect in the healthy control group

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On the other hand, it seems that the correlations are influenced by exercise conditions when ERP and the Stroop test are performed separately. We performed
visual ERP tests through exercises using colors and characters, conventional Stroop tests, and new Stroop tests that included a reverse-stroop effect. Our discussion focused on the respective correlations. We have reported significant correlations between RT and the Stroop test for color exercises, and between P300 latency and the new Stroop test in letter exercises. We also found suggestions that color exercises reflect an interactive processes from cognition to action and a tendency of letter exercises to reflect the stimulation evaluating process relating to cognition of letters, including the Stroop effect.  

In the control group we found a tendency toward high correlation between P300 latency and read-off time in the stroop tests that suggests simple selective attention functions, such as “select a red patch”. Processes related to evaluating stimuli are linked with personal abilities. A significant correlation was observed in W cards, suggesting that the ability of linguistic reading is most related to the selective attention function. Moreover, the fact that we observed significant correlations among RT, W cards, and C cards suggested that the RT of ERP corresponds to the process of reacting to evaluated stimuli and is reflected as personal ability. However, it could not reflect the Stroop effect in the case of CW cards, which made it difficult to comprehend the complex conflicts involved in relating the interactions of cognition. We also observed correlations among age, P300 latency, and stroop tests that confirmed prior research results.  

These results enabled us to separately evaluate the processes involved in evaluating stimulations and selecting reactions. A certain portion of them correlated with healthy cognitive status when visual ERP and Stroop tests were performed separately, and some simple exercises produced the same results as Stroop tests used for ERP.

2) Cognitive dysfunction relating to visual sense in schizophrenia

Past studies on visual ERP in schizophrenia have pointed to abnormalities in visual processing function, specifically a disorder of initial automatic processing function. Among the studies on visual ERP there is a reported decrease of amplitude in N100, with this phenomenon specifically related to schizophrenia, though there were some changes influenced by the different exercises used. Many studies have reported decreased P300 amplitude. But there are contradictory studies that observed no change. Although there are fewer studies reporting extended P300 latency than those reporting amplitudes, the variety of these results supposedly originated from differences in the selection of exercises and visual stimulation methods. RT is thought to be extended in schizophrenia.

It has been reported that the Stroop effect occurs more strongly in schizophrenics than in normal subjects. Wapner reported that read-off times for W, C, and CW cards were 46%, 36%, and 54% longer, respectively, in schizophrenics. Salo, et al. (2002) reported a correlation between severity of disease and chronicity of disease. Brazo reported that the Stroop effect occurs strongly in disorganized schizophrenia specifically, but pointed to differences in cognitive dysfunction in schizophrenia because different cognitive patterns were observed compared with other cognitive tests. According to Saito, mediates by linguistic information are stronger in patients with schizophrenia compared with healthy individuals because reading time was observed to extend in patients with schizophrenia when using stroop conditions as the ERP exercise.

It is supposed that the cause of disorders in schizophrenia is the result of abnormalities in glutamate neurons, which leads to insufficient dopamine transmission in the frontal cortex and dysfunction of the prefrontal region, and especially in the dorsolateral prefrontal region. This leads to disorders related to executive function and attention that make continuous processing difficult (Sawa and Snyder, 2002). The relatively low activity in the frontal cortex and relatively high activity in the subcortex, specifically depressed function in the frontal association area, dissociation of association among cortices, and dysfunction of cortical control caused by the subcortical core make their mechanical features, and also making the basis of continuous psychological and physiological abnormalities.

As shown in this study, extended evaluation time is observed in the stimuli evaluation process and the capacity to process information is decreased rather than prolonging P300 latency and decreasing the amplitude of ERP. An enhanced stroop effect reveals functional depression in the process from conflicts in the selective attention process to process of reaction. The correlations were observed between P300 and stroop tests, and between age, latency, and stroop test in the control group but not in the schizophrenic group.

Based on these results we propose a disorder in the serial process following visual cognition to the perceptual-motor associating reaction. In other words, there is dissociation of the usual coordination among cortices caused by depressed function in the frontal association area and dysfunction of cortical control by the subcortical core.

In schizophrenia the amplitudes and latency of P300 have no correlation with age and duration of affliction. Mori reported that P300 was extended in proportion to age and active schizophrenia duration in patients with schizophrenia, but we think this result was induced by differences in stimulation exercises and the
wide range of ages of subjects. On the other hand, we observed a significant correlation with the duration of active schizophrenia in the stroop tests. Accordingly, the temporal change in impaired information processing by schizophrenia is sharper in the process of perceptual-motor association reactions than in the processes for evaluating and selecting information.

5. Conclusion

We discussed the features of cognitive dysfunction in patients with schizophrenia relative to a control group consisting of healthy individuals using a visual ERP test of color stimulation and Stroop tests. By performing two types of tests we were able to evaluate the status of attention and information processing of visual cognition in a way that seemed to be clinically beneficial.

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結合失調症患者における視覚性事象関連電位とストルーブ・テストの比較

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健常コントロール対象者と統合失調症患者に対し、色刺激を用いた視覚性事象関連電位（ERP）検査とストルーブ・テストを施行し、統合失調症における認知機能障害の特徴について検討した。その結果統合失調症群では、ERPではP300の潜時の延長、振幅の低下とストルーブ効果の増強が有意に認められた。ERPとストルーブ・テストの相関関係は、コントロール群では認められたが、統合失調症群では認められなかった。脳疲困との相関関係は、コントロール群では年令とP300潜時、ストルーブ・テストに相関を認めた。統合失調症群では反応時間とPANSSの精神病理尺度、ストルーブ・テストと罹患期間に相関が認められた。以上の結果から統合失調症において視覚認知から知覚－運動協調反応関連する一連の過程における障害が推察され、その情報処理障害の経時的な変化は、情報の評価・選択過程より知覚－運動協調反応過程において顕著に認められた。

（キーワード） 識知機能障害、事象関連電位、ストルーブ・テスト、統合失調症