Cognitive Effort-Avoidance in Patients with Schizophrenia Can Reflect Amotivation: An event-related potential potential Study

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Abstract
Background: Amotivation is regarded as a core negative symptom in patients with schizophrenia. There are currently no objective methods for assessing and measuring amotivation in the scientific literature, only a trend towards assessing motivation using effort-orientated, decision-making tasks. However, it remains inconclusive as to whether cognitive effort-avoidance in patients with schizophrenia can reflect their amotivation. Therefore, this study aimed to find out whether cognitive effort-avoidance in patients with schizophrenia can reflect their amotivation. Methods: In total, 28 patients with schizophrenia and 27 healthy controls were selected as participants. The demand selection task (DST) was adapted according to the feedback-based Guilty Knowledge Test (GKT) delayed response paradigm, which was combined with the mean amplitude of contingent negative variation (CNV), considered as the criterion of motivation. Results: Our results showed that: (1) patients with schizophrenia showed a lower CNV amplitude for the target stimuli compared to the probe stimuli, whereas the control group showed the opposite trend (P<0.05); (2) among patients with schizophrenia, the high cognitive effort-avoidance group showed a smaller CNV amplitude for the target stimuli compared to the probe stimuli, whereas the low cognitive effort-avoidance group showed a higher CNV amplitude for the target stimuli compared to the probe stimuli; the opposite trend was observed in the control group (P<0.05). Conclusion: These findings support the claim that CNV amplitude can be used as a criterion for detecting amotivation in patients with schizophrenia. Within the context of the DST, the high and low cognitive effort-avoidance of patients with schizophrenia can reflect their state of amotivation; patients with high cognitive effort-avoidance showed severe amotivation.

Background
Negative symptoms—mainly characterized by emotional, information processing and behavioural deficits—are core constituents of schizophrenia (Earley et al.,2019). Schizophrenia patients can present a variety of behavioural and motivational deficits (Krynicki, 2018), and some researchers have suggested that amotivation is the central negative symptom (Fervaha et al., 2013). In recent years, researchers have begun to apply effort-orientated, decision-making tasks in their assessments.
of symptoms, especially in their assessments of amotivation (Gold, et al., 2013; Treadway, et al., 2015; Docx, et al., 2015). However, further research is still needed to verify whether the avoidance of cognitive effort in patients can reflect their motive state.

Previous studies have mostly used scale assessments as the criterion for amotivation, which are limited by their dual lack of objectivity and accuracy. As event-related potentials (ERPs) are highly correlated with patient condition (Atkinson R J et al., 2012; Rudd D S, 2014; Bachiller A et al. 2015; Dalecki A, et al., 2016), they provide a more reliable means for describing the characteristics of patients’ symptoms. Gerrig and Zimbardo (2013) proposed that motivation is the process by which an individual initiate, directs and maintains their physical or mental activities. In other words, motivation is the individual’s mental state while they are performing a task; which means that the measurement of motivation will require a relatively high temporal resolution. Therefore, ERPs, which have a high temporal resolution, provide us with the possibility of objectively quantifying and revealing amotivation.

In this study, we propose that the inconsistencies among the results of previous studies may be related to the types of tasks adopted in cognitive effort decision-making. Docx (2015) also points out that the discrepancies in experimental findings may have resulted from the differences in effort-based tasks. Furthermore, it has been shown that deceptive responses consume greater cognitive resources (Abe, 2011). Therefore, by building on the existing demand selection task (DST) paradigm, this study introduces a new cognitive task—the deception task.

The introduction of the mental processes of deception means that we will need a corresponding lie-detection paradigm. In this regard, the Guilty Knowledge Test (GKT) paradigm has been widely used in lie-detection studies (Haider et al., 2019). Using the GKT delayed response task, Cui (2009) found that target stimuli evoked the largest contingent negative variation (CNV) without feedback, whereas probe stimuli evoked the largest CNV with feedback; therefore, supporting the differentiation in CNV, under the influence of response motivation. In summary, this study aims to (1) incorporate the target and probe stimuli from the feedback-based GKT delayed response paradigm into the DST paradigm, (2) use the selection rates to group the participants into high and low cognitive effort-avoidance
groups based on the criterion of $M \pm 0.67SD$ (Kenklone, et al., 1999; Kjaer et al., 2019), and (3) employ CNV as the quantitative indicator of motivation: all in order to explore whether the cognitive effort-avoidance of patients with schizophrenia can reflect their amotivation.

Due to the presence of abnormalities in the emotional regulation of patients with schizophrenia (Hooker et al., 2014; Sanchez, Lavaysse, Starr, & Gard, 2014; Brown et al., 2016), this study evoked deceptive behaviours by requiring the participants to assist the researcher in the testing of a lie detector—thereby avoiding the adverse effects of ‘scenario simulation’ on patients. One PET study found that there were differences in the cognitive processes of spontaneous and passive deception (Abe, 2007). As such, spontaneity may affect CNV amplitude. In light of this, we propose the following hypotheses: (1) CNV can be used to detect amotivation in patients with schizophrenia, which will manifest as greater CNV amplitudes for target stimuli than probe stimuli in the control group, with the opposite trend manifesting in the patient group; and (2) the selection of high or low cognitive effort-avoidance by patients with schizophrenia in the DST will reflect their amotivation state, whereby patients with high cognitive effort-avoidance will show severe amotivation and have smaller CNV amplitudes for target stimuli than probe stimuli; and patients with low cognitive effort-avoidance will not show amotivation, having the opposite trend in CNV dissociation.

**Method**

**Participants**

Outpatients and inpatients from the psychiatric department of the Seventh People’s Hospital of Wenzhou, with schizophrenia diagnoses, were randomly selected as participants. Participants must: (1) meet the DSM-IV diagnostic criteria for schizophrenia; (2) not have organic mental disorders, or mental disorders caused by psychoactive or non-addictive substances; (3) be taking a stable dose of drugs for at least four weeks during the course of the study; (4) be literate and educated above the primary school level; (5) be right-handed; and (6) score above 35 points on the Brief Psychiatric Rating Scale (BPRS). Members of the control group must: (1) not have a history of mental disorders, neurological disorders or serious physical illness, not have a family history of mental disorders, and not be taking psychotropic drugs; and (2) be matched in terms of gender, age, education level,
handedness and other indicators as far as possible.

The normal participants signed consent forms and participated voluntarily in the study and consent from guardians was obtained from guardians of schizophrenia participants. None had previously participated in similar experiments. The participants were given the appropriate reimbursement after the experiment. See Table 1 for more details.

INSERT TABLE 1 ABOUT HERE

**Stimuli**

The cognitive effort decision-making materials included a picture showing a pair of circles with different colours (#1 and #2)—only one of which could be selected at a time. After making a selection, a blue or yellow word would appear inside the circle. If the word was blue, the participants were asked to determine whether they had seen it before; if the word was yellow, they were asked to determine if the number of characters was equal to 3. When a circle of one colour was selected, there was a 90% probability that the colour of the presented word would be the same colour as the word presented in the previous selection. This is known as the low-effort “spot.” If the circle of the other colour was selected, there was a 10% probability that the colour of the presented word would be the same colour as the word presented in the previous selection. This is known as the high-effort “spot.”

The lie-detection materials were based on the contents of the simulated murder questionnaire (Cui, 2009), where a word was selected from among the four categories of names, time, murder weapon and body bag; which the participant was asked to memorize before the experiment. Then, another four words were selected from the four respective categories, which were not revealed to the participant before the lie-detection test. From the time the participant entered the laboratory to the time of the lie detection test, the memorized word was regarded as the word the participant had seen, while the non-memorized words were regarded as words the participant had not seen.

**Procedure**

Before the start of the experiment, the participants were informed that there was a lie detector that needed to be tested. They were then asked to help with testing the lie detector, and were told they would be reimbursed at the end of the experiment.
During the experiment, the participants sat in a quiet laboratory, with both eyes fixated on the centre of the screen at a distance of approximately 60 cm. The participants were asked to minimize their movements; to avoid blinking between the stimulus onset and the key press; while also responding as quickly and accurately as possible. There were 40 selections per block, and there were 8 blocks. The participants could take a break after every 4 blocks. The experimental flow is shown in Figure 1.

**INSERT FIGURE 1 ABOUT HERE**

*ERP Data Recording and Analysis*

A 64-channel EEG system (ANT Neuroscan, the Netherlands) was used to record EEG. The leads of both mastoids were used as the reference electrodes. The filter bandpass was 0.05—80Hz, and sampling rate was 500Hz/channel. The data was processed offline with ASA1.0 and artefacts were fully excluded. Amplitudes greater than ±80μV were regarded as anomalies, and were automatically rejected. The ERP responses between the stimulus onset and the key press were analysed for the two groups. The ERP components after the stimulus onset were examined and the analysed epoch was 2000ms after the stimulus onset. The baseline was 200ms before the stimulus onset. The programming and collection of behavioural data were performed using E-Prime 2.0; statistical analyses were performed using SPSS 22.0.

**Results**

**Behavioural Data**

The participants were divided into the high and low cognitive effort-avoidance groups, based on their selection rate for the high-effort “spot” $(M \pm 0.67SD)$. A two-way (patient condition * cognitive effort-avoidance) analysis of variance (ANOVA) was performed on the selection rate, which showed that the main effect of cognitive effort-avoidance was significant (high cognitive effort-avoidance < low cognitive effort-avoidance), $F (1, 16) = 182.35, P<0.05, \eta^2 = 0.92$. The remaining results were not significant.

A three-way mixed design repeated measures; ANOVA was performed on the accuracy rate and reaction time (cognitive effort-avoidance * stimulus type * patient condition). The results of analysing the accuracy rates showed that: (1) the main effect of cognitive effort-avoidance was significant,
$F(1,16) = 5.76, p<0.05, \eta^2 = 0.27$; and (2) the interaction effect between patient condition and cognitive effort-avoidance was marginally significant, $F(1,16) = 4.12, p = 0.059, \eta^2 = 0.21$. Simple effects analysis indicated that, in the patient group, the difference in the accuracy rates between the high and low cognitive effort groups was not significant; in the control group, the accuracy rate of the high cognitive effort avoidance group was significantly lower than that of the low cognitive effort-avoidance group. Analysis of the reaction times showed that: (1) the main effect of stimulus type was significant, $F(1,16) = 4.66, p<0.05, \eta^2 = 0.23$; and (2) the reaction time for the target stimuli was significantly higher than that for the probe stimuli. No other effects of interest were significant. See Table 2 for details.

**INSERT TABLE 2 ABOUT HERE**

**ERP Analysis**

**CNV Dissociation**

The grand average map revealed that CNV was evoked between the stimulus onset and the key press. A total of 14 electrode sites (Fz, FCz, Cz, Pz, F3, F4, FC3, FC4, C3, C4, CP3, CP4, P3 and P4) were selected for this study. The CNVs evoked by different stimuli were analysed in each group. A three-way mixed design repeated measures ANOVA was performed using the mean CNV amplitude (from 400ms to 1200ms) as the indicator. The results indicated that: (1) the main effect of electrode sites was significant, $F(13,676) = 3.32, P<0.05, \eta^2 = 0.06$; (2) the interaction effect between electrode sites and stimulus types was significant, $F(13,676) = 5.25, P<0.05, \eta^2 = 0.09$; and (3) the three-way interaction effect was significant, $F(13,676) = 1.83, P<0.05, \eta^2 = 0.04$. Simple effects analysis showed that: (1) in the patient group, the probe stimuli evoked the largest CNV at Cz, which was not significantly different from those at C3 and C4, but significantly higher than those at the remaining electrodes ($P<0.05$); and (2) the target stimuli evoked the largest CNV at Cz, which was significantly higher than those at F3, F4, FZ, FC3, CP3 and P3 ($P<0.05$), but not significantly different from those of the remaining electrodes. At F3, FC3, C3, Cz and CP3, the CNV amplitudes evoked by the probe and target stimuli were significantly different; the difference was not significant for the
remaining electrode sites. In the control group, the probe stimuli evoked the largest CNV at Cz, which was not significantly different from those at F3, Fz, FCz, CP3, P3 and Pz, but significantly higher than those at the remaining electrodes ($P<0.05$); while the target stimuli evoked the largest CNV at Cz, which was not significantly different from those at FCz, FC4, C4, CP4 and Pz ($P<0.05$), but significantly higher than those of the remaining electrodes. At F3, FC4, C4 and CP4, the CNV amplitudes evoked by the probe and target stimuli were significantly different; the difference was not significant for the remaining electrode sites. We selected Cz, which had the largest CNV amplitude, and plotted the topographic maps and waveforms of different stimuli for each group. The independent $T$ test revealed that the waveforms at Cz were significantly different between the two groups, $T(53) = -2.37, P<0.05$. No other effects of interest were significant. See Figure 2.

**INSERT FIGURE 2 ABOUT HERE**

**Comparison of Amotivation**

A three-way (cognitive effort-avoidance * stimulus type * patient condition) mixed design repeated measures ANOVA was performed using the mean CNV amplitude (from 400ms to 1200ms) at Cz as the indicator. The results indicated that: (1) the interaction effect between patient condition and cognitive effort-avoidance was significant, $F(1,16) = 4.93, P<0.05, \eta^2 = 0.24$; and (2) the three-way interaction effect was significant, $F(1,16) = 4.98, P<0.05, \eta^2 = 0.24$. The remaining effects were not significant. The results of simple effect analysis showed that: (1) when presented with the target stimuli, the main effect of cognitive effort-avoidance was not significant in the patient group, $F(1,17) = 1.86, P>0.05$; and (2) the main effect of cognitive effort-avoidance was significant in the control group, $F(1,17) = 5.41, P<0.05$. When presented with the probe stimuli, the main effect of cognitive effort-avoidance was not significant in the patient group, $F(1,17) = 0.35, P>0.05$; while the main effect of cognitive effort-avoidance was not significant in the control group, $F(1,17) = 3.21, P>0.05$. See Figure 3.

**INSERT FIGURE 3 ABOUT HERE**

**Discussion**

Previous studies have focused on exploring whether the behavioural performance of patients with
schizophrenia can objectively reflect their amotivation. However, the use of clinical scales as the criterion of validity would inevitably go against their intended aim of achieving objectivity. In this study, we consolidated the previous findings showing that CNV can be affected by motivation, and used EEG data as the criterion of validity in order to examine whether cognitive effort-avoidance in patients with schizophrenia can reflect their amotivation.

One of our key findings was that while CNV dissociation was observed when the two groups of participants were presented with two types of tasks, the groups showed opposing trends of dissociation. Hypothesis 1, as proposed in this study, was verified by our findings. The topographic maps indicated that when the patient group was presented with the target stimuli, there was a substantial reduction in their left cortical activity; whereas the opposite trend was observed in the control group. Treadway et al. (2012) found that activity in the left striatum and the left ventromedial prefrontal cortex were correlated with a willingness to expend effort, thus indicating that the difference in CNV dissociation could reflect amotivation. Previous studies have generally found that patients with schizophrenia had deficits in switching (Ravizza, 2010; Lampietro et al., 2012). Studies have also shown that patients with schizophrenia have a tendency towards hyper-focusing; which is the tendency to concentrate limited resources on a specific stimulus, while ignoring other stimuli (Luck et al., 2014; Sawaki et al., 2017; Kreither et al., 2017). In addition, Soriano (2009) and Westerhausen (2011) found that patients with schizophrenia have impaired inhibitory functions, which are a prerequisite for the smooth implementation of other executive functions (Logue, 2014). When patients were presented with the target stimuli, they may have been unable to suppress the dominant response and displayed an impaired allocation of mental resources—thus resulting in lower cognitive input and motivation, which led to a smaller CNV amplitude compared with the probe stimuli. This finding also indicates that the amotivation of patients with schizophrenia may occur when patients are required to perform multiple tasks, whereas patients do not exhibit amotivation when performing a single task, but may instead show stronger motivation. Therefore, during the rehabilitation of patients’ cognitive functions, it may be beneficial to add targeted dual- or multi-task training.

Another key finding of this study was that patients with schizophrenia with different degrees of
cognitive effort-avoidance showed opposing trends of CNV dissociation. Given that Hypothesis 1 has been verified, this result supports Hypothesis 2. Gold (2015) proposed that the detection of cognitive effort can affect cognitive effort-avoidance. The detection of cognitive effort may be related to the patient’s weighing of costs against benefits. A piece of latent information in the DST is that the participant’s selection will not affect their final reward (Kool, 2010; Gold, 2015); hence selecting the high-effort “spot” when completing the experiment would result in a lower cost-to-benefit ratio.

Dopamine plays an important role in both cost-benefit assessment and weighing effort costs (Fervaha et al., 2013). Changes in its levels can have an impact on an individual’s degree of expended effort (Venugopalan et al., 2011) and can regulate their sensitivity to resources (Floresco, 2013). Studies have shown that abnormal striatal dopamine release is one of the mechanisms underlying the pathogenesis of schizophrenia (Fusar-Poli & Meyer-Lindenberg, 2012; Howes et al., 2013). On top of their insufficient resources, the high cognitive effort-avoidance group was also affected by dopamine abnormalities; hence they were more precise when weighing up resource consumption and costs, and were more sensitive to cognitive effort-detection. Tending towards the low-effort “spot” in decision-making can guarantee the smooth completion of the task, while also helping to avoid the substantial consumption of resources caused by task switching. The dissociation in the low cognitive effort-avoidance group was basically consistent with that of the control group. Their spot selection tended to be random and did not exhibit significant cognitive effort-avoidance.

It is perhaps surprising that, although opposing trends of CNV dissociation were also observed in the control group, in the different degrees of cognitive effort avoidance, these trends differed from those observed in the patient group. This suggests that the decision-making performance of the healthy population in this study may reflect a different mental state to that in the patient population. The high number of trials in the DST may affect the mental state of the participants (Wijnand et al., 2019).

Studies have also shown that CNV include participant’s processing and evaluation of stimuli (Gómez et al., 2001). We can infer that participants may want to complete the experiment as soon as possible, and performing a single task is undoubtedly the easiest and quickest way to achieve this.

Since the target stimuli would waste more time, the high avoidance group may have a more negative
evaluation of the target stimuli, ultimately leading to an increased CNV amplitude. The completion of the two tasks by the low cognitive effort-avoidance was superior to that by the high avoidance group. As the low avoidance group was more familiar with the rules and their responses were automatic, they did not need to invest significant cognitive resources; hence their “spot” selection also tended to be more randomized. For the control group, the difference in high and low cognitive effort-avoidance in the DST may only reflect the participant’s evaluation and preferences for the “spots”, rather than their motive state.

This study, however, has some limitations. First, we focused on the amotivation of patients with schizophrenia when completing cognitive tasks, but patients also exhibit amotivation when completing tasks that require physical effort (Barch et al., 2014; Hartmann et al., 2014). Therefore, when performing such a task, the validity of using a patient’s amotivation as an indicator to evaluate their overall amotivation is still debatable. Second, studies have shown that intelligence has an impact on cognitive effort-avoidance (Gold et al., 2015). However, standardized intelligence tests could not be administered to all participants in this study, and individuals who did not show extremely low intelligence during conversations were included; thus, intelligence level was not strictly controlled. Third, the patients did not have the same attending physicians. It was also difficult to control for their use and dosage of antipsychotic medications, as well as their rehabilitation training. The causes of schizophrenia are complex, diverse and highly heterogenous (Takahashi, 2013); therefore, it was also difficult to control for the impact of different causes on the findings.

Conclusions
From the findings of this study, the following conclusions can be made: (1) CNV can be used to detect amotivation in patients with schizophrenia; and (2) the high and low cognitive effort-avoidance of patients with schizophrenia when completing the DST can reflect their amotivation state, as patients with high cognitive effort-avoidance showed severe amotivation.

Abbreviations

*DST*: the demand selection task

*GKT*: the feedback-based Guilty Knowledge Test
**CNV:** contingent negative variation

**ERPs:** event-related potentials

**PET:** Positron Emission Computed Tomography

**DSM-IV:** Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition

**BPRS:** The Brief Psychiatric Rating Scale

**EEG:** Electroencephalogram

**SPSS:** Statistical Product and Service Solutions

**Declarations**

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**Authors’ contributions**

All authors contributed substantially and according to the BMC Psychiatry guidelines to be recognized as authors. Study concept and design: QZ. Data acquisition: LjZ. Identification and quality assessment of studies: YXL. Data analysis and interpretation: YXL. Manuscript preparation and Manuscript editing: LY and QZ. All authors have read and approved the final version of the manuscript.

**Ethics approval and consent to participate**

Participants provided written informed consent. The study was approved by Research Ethics Committee Review of Wenzhou Seventh people’s hospital (Reference number: 201830).

**Consent for publication**

Not applicable.

**Availability of data and materials section**

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

**Competing interests**
The authors declare that they have no competing interests.

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Tables

Table 1
Participant Demographics

| Group | N  | M/F | Age          | Education | BRPS total | Course of disease |
|-------|----|-----|--------------|-----------|------------|------------------|
| SC    | 28 | 23/5| 38.89 ± 8.44 | 9.79 ± 2.25 | 44.50 ± 3.70 | 12.86 ± 5.29     |
| HC    | 27 | 23/4| 37.11 ± 14.94| 10.19 ± 3.70|            |                  |

Note. SC=people with schizophrenia, HC=healthy controls, M=males, F=female, Standard deviation in parentheses

Table 2
Behavior Date Demonstration

|               | SC                        |               |               | HC                        |               |               |
|---------------|---------------------------|---------------|---------------|---------------------------|---------------|---------------|
|               | HCA(32.31%)              | LCA(60.00%)   | HCA(33.67%)   |                            |               |               |
| Accuracy (%)  | M 0.79                   | 0.84          | 0.85          | 0.83                      | 0.66          | 0.60          |
|               | SD 0.18                  | 0.10          | 0.14          | 0.14                      | 0.26          | 0.16          |
| RT(ms)        | M 1027.8                 | 1285.1        | 1410.4        | 1576.2                    | 973.1         | 1620.0        |
|               | SD 563.8                 | 924.3         | 628.9         | 880.2                     | 510.0         | 1003.0        |

Note. HCA=high cognitive avoidance, LCA=low cognitive avoidance, RT=react time, High effort patch selection rate in parentheses
Figures
Flow Diagram of Experiment (First, a pair of circles appeared on the screen with different colors (#1 and #2). After the subject pressed the corresponding key to select, the stimulus appeared in the selected circle for 500ms. The subject needed to recognize the stimulus but not to react. A black screen after the stimulus disappeared was given for the subject to prepare for reaction. After that, the prompt "☆" appeared, and the duration is not limited. When seeing the prompt, the subject can answer whether he has seen it or whether the word is less than or equal to 3. Then a feedback ("+2" or "-2") would be given. The feedback was preset, including 50% of "+2" and 50% of "-2". The two kinds of feedback appeared randomly. The feedback lasted for 500ms, then the subject would go to next trail.)
Figure 2

ERPs and Topographical map of brain for all conditions at CZ cite
Figure 3

The interaction effect between patient condition and cognitive effort-avoidance in CNV amplitude.