CNV Amplitude in Relation to Time Perception:

A Comparison Between Schizophrenia and Non-Psychiatric Control

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Abstract

The perception of time is a variable subjective experience, and this variability is predominantly observed in individuals with schizophrenia compared to neurologically typical individuals. The variability resulting from functional deficits in people with schizophrenia is emphasized for auditory modalities compared to visual ones. Therefore, the current study aims to investigate the underlying neural mechanisms of time perception and how it changes among healthy individuals and patients with schizophrenia. To explore this, we will recruit participants from schizophrenia patients and non-psychiatric individuals. The participants will be presented with a "standard duration" that they have to memorize. Following this, they will answer a question regarding if the "test stimuli", consisting of different time intervals, matches the standard duration in intermixed trials. The stimuli will consist of two types of modalities which are auditory and visual in separate blocks. During the task, the electrophysiological activities of the participants will be recorded through EEG, and their CNV (contingent negative variation) activities which is an ERP component associated with anticipating the upcoming stimuli will be compared. The independent variables are the two modalities (visual and auditory), the participant groups (healthy and schizophrenia), and the duration of the stimuli (490, 595, 700, 805, and 910 ms). Dependent variables are reaction times, accuracy rates, and CNV activation. We expect to observe differences in CNV amplitudes between healthy subjects and schizophrenia patients as well as between auditory and visual modalities within groups. We hypothesize that the patients with schizophrenia will exhibit reduced CNV amplitude and variable CNV onset compared to healthy subjects on auditory stimuli. However, we expect no significant differences between the healthy group and schizophrenia patients on the visual modality regarding CNV amplitude and onset. Likewise, we do not predict the impact of durations on CNV for both groups and modalities.

Key words: time perception, CNV (contingent negative variation), schizophrenia

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Time perception is a subjective cognitive function that is recognizing the duration of a certain event or a stimulus. According to the internal clock theory, individuals count the duration of a stimulus with some kind of an inner timekeeper (Wearden, 2015). When the speed of the timekeeper relatively increases, people count more ticks on their internal clock, and they judge the passed time as longer (Penton-Voak et al., 1996). On the contrary, when their timekeeper relatively slows down, the ticks they count become less, and the perceived time becomes shorter (Wearden, 2008). Thus, the perception of the passage of time is open to alterations, and it might not fit the real duration of the stimulus.

Various elements might manipulate the internal clock. One of the early studies on time perception investigates how body temperature might impact the internal clock (Wearden & Penton-Voak, 1995). In their research, Wearden and Penton-Voak concluded that increased body temperature above normal levels led to overestimating time, while lower body temperatures gave rise to an underestimation. The results are explained by a chemical or biological internal clock speed up when the body temperature is high. A possible explanation for such a mechanism is proposed to be changed arousal as a result of temperature manipulation. Some of the later studies examined the arousal levels of participants and how it alters the internal clock (Chan & Saqib, 2022). Fayolle and her colleagues manipulated the arousal levels of the participants by exposing them to an electric shock to investigate emotion-related time distortion (Fayolle, Gil & Droit-Volet, 2015). They found that participants perceived the trials with electric shocks as longer than their actual duration, and they concluded that fear increases the speed of the internal clock. In another study that supports the increased level of arousal speeds up the internal clock, participants were presented with neutral and angry faces. The results showed that participants judged the duration of the angry faces as longer than the neutral faces (Klincewicz & Herbst, 2015). Dopamine levels are also associated with altering the perceived durations. To examine the dopamine levels, Terhune et al. (2016) recorded the spontaneous eye blinks of individuals, which is previously demonstrated to be an indicator of increased dopamine levels. The authors concluded that the trials with subsequent blinks resulted in an overestimated time duration. Hence, many different factors can influence the internal clock and perceived time. In brief, perception of time is a subjective cognitive component that is able to be manipulated and varies according to different conditions.

In addition to the behavioral studies, neuroimaging techniques are applied to investigate the underlying neural mechanisms of time perception. EEG is a suitable method for sub-second timing due to its high temporal resolution. While the lack of spatial resolution aggregates source localization, this method enables tracking the perception of timing and its electrophysical correlates. This advantage of EEG led to studies investigating electrical activities and their link to time perception. One of the well-studied ERP components in the literature regarding time perception is "contingent negative variation" (CNV) observed by Walter et al. (1964) for the first time. This component is associated with expecting the stimuli and localized around the frontocentral regions of the brain. If the experiment requires an estimation of when the stimulus will appear, CNV amplitude may reveal information regarding the participant's perception of time. Therefore, this ERP component is widely used to study temporal judgments.

As the perception of time is sensitive and influenced by many internal and external factors, the experimental task can change the expected CNV amplitudes. The temporal reproduction task is one of the ways in which participants were instructed to reproduce the duration of a reference interval. In one of the early examples of such studies, Macar and Besson (1985) provided a 2.5 seconds reference interval by using visual cues. Researchers found enhanced negativity in CNV activity when participants overestimated time. In other words, the longer reproductions led to increased negativity in the CNV component. The negativity decreased as the reproduction matched and shortened in the frontocentral regions. The results are explained by the Scalar Timing Theory (STT) in which a pacemaker accumulates time by emitting the pulses of the internal clock (Gibbon, 1977). Because longer reproductions accumulate more pulses, CNV negativity is enhanced. And for the shorter reproductions, an attenuation is observed as a result of the accumulation of fewer pulses. On the other hand, it is not possible to reach a direct conclusion since other studies with reproduction tasks found different patterns of CNV activity since the experimental paradigms have changed (Kononowicz et al., 2015; Tamm et al., 2014). Li et al. (2017) examined one of the possible indicators of CNV amplitude in temporal estimations: duration adaptation. This phenomenon refers to the over or underestimation of a time interval affected by formerly presented stimuli. They found that when the former time interval is short, the CNV activity increases, and when it is long, CNV activity decreases.

Like reproduction tasks, perceptual judgment tasks evoke a CNV amplitude in accordance with the expected time duration. Participants judge the subsequent duration in this task by comparing it with a prior reference duration. CNV activity occurs when the comparison interval deviates from the target interval (Macar & Vidal, 2003). Vallet et. al. (2019) furthered this finding and investigated how emotional stimuli impact time perception and electrophysiological correlations. To this end, participants have presented either positive, neutral, or negative emotional stimuli followed by a duration comparison task. An enhanced CNV amplitude was observed in the negative condition and when the reference duration was longer. The findings align with the STT as well since negative emotional stimuli can increase the pulses and more prolonged stimuli lead to more accumulation.

CNV amplitude and onset changes across modalities in addition to the tasks. N'Diaye et al. (2004) conducted research to examine the underlying electrophysiological mechanism of perceptual differences across visual and auditory modalities. The experimental design consisted of a duration discrimination task which a 700 ms standard duration to be compared to 490, 595, 700, 805, or 910 ms comparison intervals. A light was presented for the visual modality, while a pure tone was used for the auditory modality. An enhanced CNV activity was observed in frontocentral regions for both modalities and all duration conditions. For this reason, the authors concluded that CNV activity is mainly localized on frontocentral sites and its location is independent from the duration and the modality. CNV onset time was more consistent for auditory modality compared to the visual that the latency of the CNV amplitude for the visual stimuli was more variable In addition, response times for auditory stimuli were shorter than for the visual stimuli, suggesting faster processing.

Time perception is subjective and can vary from one individual to another. However, individuals with schizophrenia experience differences in time perception not because of factors such as arousal levels, but due to disturbances in this cognitive function. To examine the impairment present in this population, a pilot study by Davalos et al. compared individuals with schizophrenia and a control group across visual and auditory modalities (2002). The results of this study suggested that the former group experienced deficits when comparing intervals in both the visual and auditory tasks (Davalos et al., 2002). A complementary study by the same researchers examined the physiological responses of these two populations during auditory temporal processing using mismatch negativity (Davalos et al., 2003). The latter is an ERP component that occurs as a response to an irregularity. The reported electrophysiological data indicated a weakened response to temporal irregularities in individuals with schizophrenia, thus supporting the results of the preliminary study. Consistent with these findings, another study found that individuals with schizophrenia were less precise than control groups in making judgments about time (Carroll et al., 2008). However, this deficit was restricted to the auditory modality. Another study which is a meta-analysis review of time processing in schizophrenia agreed that it is more variable in this population but found that the effect of schizophrenia on the accuracy of time perception and temporal processing is dependent on the type of task. For instance, temporal bisection tasks found that schizophrenia patients are more likely to underestimate the time, whereas verbal time estimation tasks yielded significant effects between the two groups in the opposite direction (Thoenes & Oberfeld, 2017). The latter task requires that participants express the subjective experience of duration into objective time units (Mioni et al., 2014). Temporal bisection tasks, on the other hand, such as the one used in Carroll et al.'s study (2008) require participants to make subjective judgments about objective time durations or intervals. Because of these diverging results of patients with schizophrenia between time production and time estimation tasks, Meck explains that an acceleration of the internal clock is the reason behind the impairment of temporal processing in this population (1996, as cited in Ciullo et al., 2015)). That means that patients' internal time pacer internally counts more ticks in an interval than healthy individuals do.

Previous behavioral and electrophysiological research regarding time perception brings crucial findings to the literature. Nevertheless, these studies mainly focus on the time perception processes of healthy individuals. Behavioral studies with a psychiatric population such as schizophrenia and their comparison with non-psychiatric individuals regarding their time perception abilities exist, yet the schizophrenia patients are still understudied with the neuroimaging techniques. Behavioral research exhibits the differences between individuals with schizophrenia and non-psychiatric participants in their reactions in response to tasks related to time perception. However, the possible differences between these two groups in their neurological processes are still unknown. Applying electrophysiological methods to investigate underlying neural mechanisms of time perception of patients with schizophrenia has the potential to reveal novel insight into the processing of time for both psychiatric and non-psychiatric individuals. To this aim, we research to what extent the ERP scores of schizophrenia patients differ from those of non-psychiatric individuals in response to the perception of time? We hypothesize that schizophrenia patients will exhibit lower CNV amplitude in response to auditory modality compared to the non-psychiatric condition. We do not expect any differences in amplitudes for visual time perception task for the groups. In addition, for both groups, we expect lower CNV amplitude for the visual condition than for the auditory condition.

Methods

Participants

Ten volunteers will be recruited as participants in each group whose ages range between 25 and 45 and with an even distribution of gender. The recruitment process will occur through snowball sampling and advertisements. The control group will consist of 10 non-psychiatric individuals who do not have any history of psychosis in their family. In the schizophrenia group, participants will be recruited if they have been previously diagnosed with schizophrenia. Participants of both groups will also undergo a structured interview with a mental health professional to ensure that the participants of the patient group fit the criteria in the DSM-V and the participants of the control group do not fit the criteria of the diagnosis. In addition, all participants should not have any neurological disorder, or symptoms of any other psychiatric disorder and should not be using any substances. Considering the effects of typical neuroleptics on performance in timing tasks (Gibbon, Malapani, Dale, & Gallistel, 1997, as cited in Davalos et al., 2002), participants in the patient group who are using this type of neuroleptics will not take part in the study. Lastly, participants will sign a consent form before participating in the research, and a debriefing form will be presented after the experiment is done.

Design

The current study will employ three-way mixed ANOVA. The first independent variable will be the psychiatric conditions of the participants which is a between-subject factor. It will have two levels: schizophrenia patients and non-psychiatric subjects. The following factors will be within-subject. The second independent variable will be the modality of the stimuli that also has two levels which are visual and auditory. The third independent variable will be the duration of the stimuli and has five levels which are 490 ms, 595 ms, 700 ms, 805 ms, and 910 ms. There will be three dependent variables: reaction times (RTs), correct response rates, and ERP data as the latency and the peak amplitude of the CNV activation.

Stimuli

Auditory stimuli

We will use the same 500 Hz pure tones used in N'Diaye et al.'s study (2004), varying in durations (490 ms, 595 ms, 700 ms, 805 ms, and 910 ms). On the other hand, the intensity of the sounds will remain constant across trials and will be determined based on the intensity that each participant will rate as clear. The participants will be seated in a soundproof room to block any external sounds. The auditory stimuli will be presented through earphones.

Visual Stimuli

Following N'Diaye et al.'s methodology (2004), a blue light beam from light-emitting diodes will appear on a blackboard placed at the same distance from each participant (65 cm). To control for any magnetic artifacts, the LED projecting onto the black panel will be placed outside the room. Similar to the duration of the auditory stimuli, the visual stimuli will be presented in the following durations (490 ms, 595 ms, 700 ms, 805 ms, and 910 ms).

Procedure

The study will consist of two tasks assessing the auditory and visual modalities. Both tasks will require the comparison between the standard duration (700ms) and the test stimuli. In the auditory temporal generalization task, the participants will memorize the standard duration by listening to the 500 Hz pure tone six times consecutively. The following 100 trials will present the same auditory stimuli in random order in the shorter durations (490ms, 595ms), the standard duration (700 ms) and in the longer durations (805ms, 910 ms). After the presentation of each duration, the participants will indicate if the tone was presented for the same interval by pressing the space bar, or if it was presented for a shorter or longer interval by pressing the key “S” or “L” respectfully. The visual modality task is also a temporal generalization task that follows the same procedure but instead of the auditory stimuli, the participants will have to compare the durations of the blue LED light being presented on the black wall.

Data Analysis

The participant's performance on the discrimination task will be obtained by calculating the correct response rates. A three-way mixed ANOVA (analysis of variance) will be used for participant conditions, modality and durations as the independent variables. The offset of the comparison interval will be the baseline for response time (RT). Three-way mixed ANOVA will be used again with the same factors as the correct response rates.

Preprocessing steps will be conducted with EEGLAB (Delorme & Makeig, 2004). Filtering will be used to improve the signal-to-noise ratio and analyze the activities most likely to be related to brain function. 1 Hz will be used as a high-pass filter, while 120 Hz will be used as a low-pass filter and down-sampling to 500 Hz. The noisy channels will be manually removed. The recorded electrodes will be referenced to mastoids on both sides to avoid lateralization bias. ICA (independent component analysis) will be used to compensate for eye, heart, and muscle activity. The removed channels due to artifacts will be interpolated according to the nearest-neighbor electrodes. The data will be averaged over stimulus duration, two modalities, and participant conditions to attain event-related potentials (ERPs). The continuous data will be epoched based on 2-seconds trials with 100 ms pre-trigger and 1900 ms post-trigger intervals. -100 ms pre-trigger will be the baseline for correction for EEG amplitude. The ERPs will be statistically analyzed using three-way mixed ANOVA for participant conditions (schizophrenia vs. non-psychiatric) x modality (visual vs. auditory) x duration (490, 595, 700, 805, and 910 ms) factors. The peak amplitude and latency of the CNV component on frontocentral regions (FC5 and FC6) will be in focus since it is shown to be related to time perception.

Results

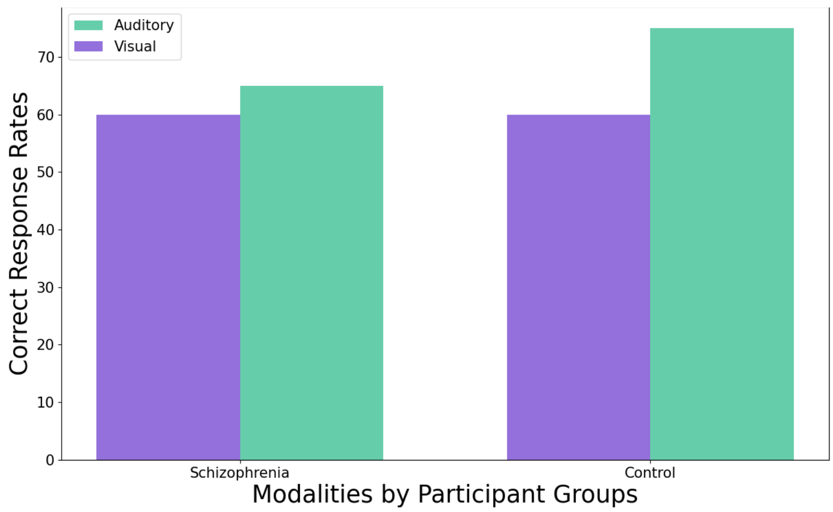
Behavioral Data

We expect the correct response rates of the control group to be similar to N'Diaye et al. (2004). Therefore, the predicted correct response rate for the visual modality is approximately 60%, and for the auditory modality is close to 70% (Figure 1). Carroll et al. (2008) conducted a behavioral study on the perceptual judgments of schizophrenia and control groups and found no effect of participant condition on visual modality. Therefore, we predict the schizophrenia patients exhibit similar correct response rates to the control group for the visual modality, around 60%. We expect to observe a decrease for the individuals with schizophrenia compared with the control group in correct response rates for the auditory modality with correct response rates close to 65%. For the ANOVA results, we expect an interaction between participant group and modality, a decreased correct response rate for auditory modality for schizophrenia. We expect a general effect of modality with lower correct response rates for visual modality. We expect a mean effect of duration with extreme durations (490 and 910 ms) being correctly recognized more than the intermediate durations (595 and 805 ms), and an interaction between duration and modality with increased correct response rate for extreme durations in auditory compared to visual.

We expect a significant main effect of comparison interval duration with decreased RT as the comparison interval duration increases. Specifically, we expect shorter RT (550 ms) for long durations, and longer RT (750 ms) for short durations for the control condition (N'Diaye et al., 2004). We also expect an interaction between duration and participant condition with an increase in RT for long duration for schizophrenia. We expect an interaction between modality and participant group with longer RT for auditory condition for schizophrenia group.

Figure 1

Correct Response Rates



Note. A significant decrease in reaction times in response to auditory stimuli for the schizophrenia patients compared to the control group is expected (p<.05). No significant difference between the two groups is expected for the visual modality (p>.05).

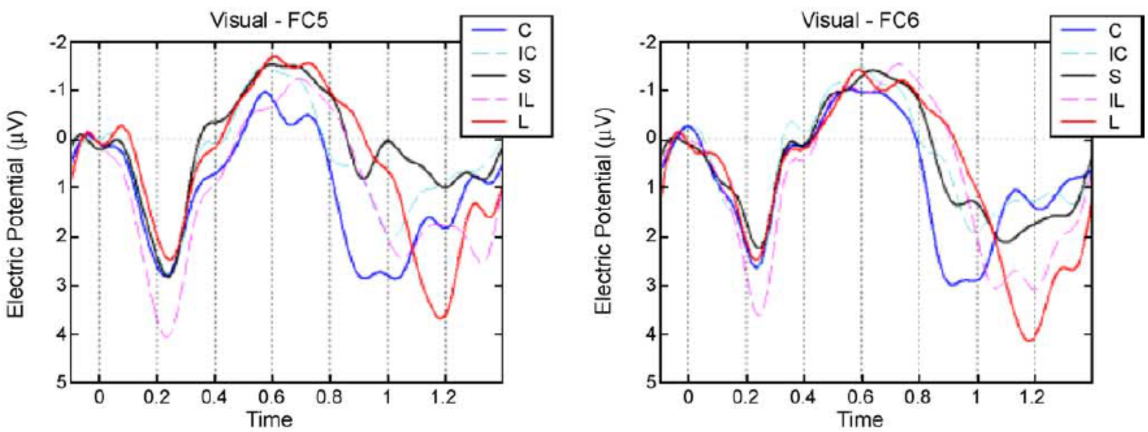
EEG Data

Visual Condition

In accordance with the finding of N'Diaye et. al. (2004), for each duration condition, we expect CNV activation around 650-700 ms in particular on fronto-central regions and accordingly on electrodes FC5 and FC6 for healthy subjects as shown in Figure 2. In comparison with the healthy control group, we predict no significant difference between the healthy group and the schizophrenia patients on their ERP scores based on the behavioral results of the study by Caroll et. al. (2008) (Figure 3). In other words, we expect that both groups of participants exhibit similar latency and amplitude of CNV activity in response to visual stimuli. In addition, we do not expect a significant effect of duration on CNV activation for both groups on the visual stimuli condition (p>.05).

Figure 2

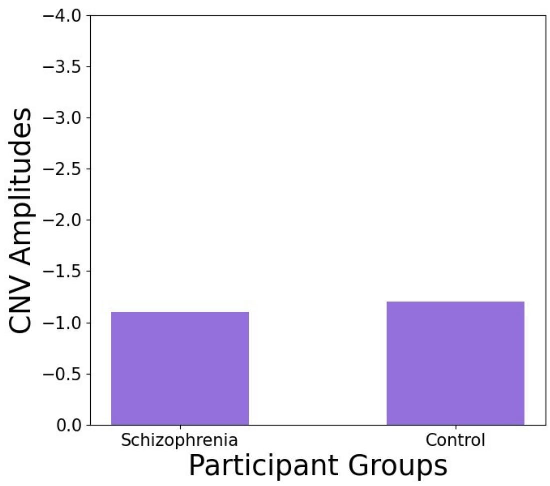
Electrical Scalp Potential in Response to Visual Stimuli of Healthy Subjects



Note. The figure displays the expected CNV activation recorded from left and fronto-central regions of healthy individuals during the presentation of the visual stimuli, *p*<.05 (N'Diaye et. al., 2004). Colorful lines are utilized to indicate the different duration conditions. C refers to the short, IC refers to the intermediate-short, S is standard, IL is for long and L refers to the long stimuli.

Figure 3

CNV Amplitudes for Visual Modality



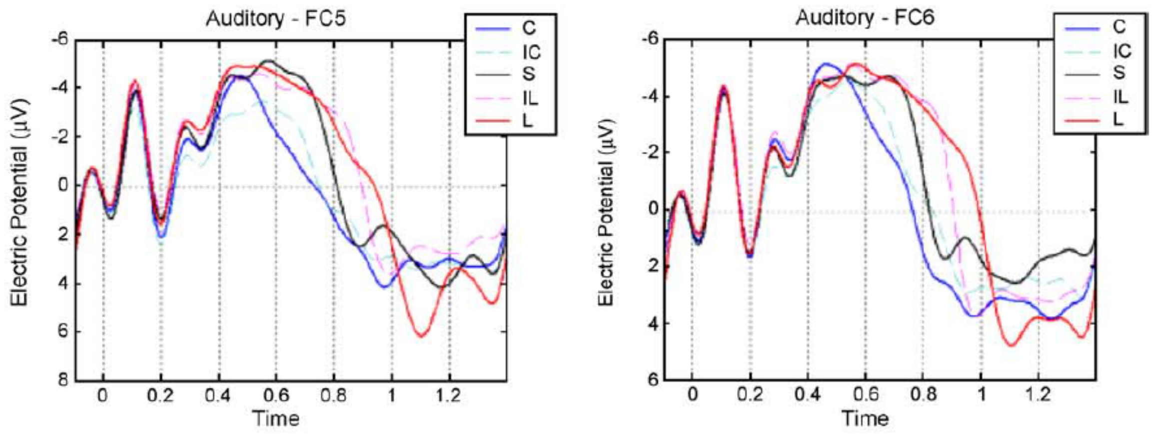
Note. No significant difference in amplitudes of CNV between the control group and patients with schizophrenia are expected (p>.05).

Auditory Condition

We predict that the healthy subjects exhibit peak amplitude of CNV at around 570 ms on fronto-central sites as shown on the Figure 4 (N'Diaye et. al., 2004). Opposite to the expected results of the visual condition, we predict to observe significantly decreased peak amplitude as well as more variable latency of the peak amplitude in response to auditory stimuli for patients with schizophrenia in comparison to the control group (Figure 5). Regarding the influence of the duraion on CNV activity, we do not expect a significant effect of duration on for both groups during the presentation of the auditory stimuli (*p*>.05).

Figure 4

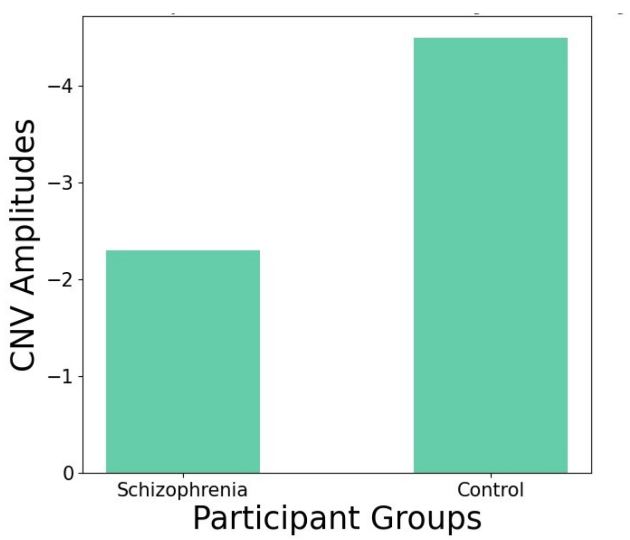
Electrical Scalp Potential in Response to Auditory Stimuli of Healthy Subjects



Note. The figure displays the expected CNV activation recorded from left and fronto-central regions of healthy individuals during the presentation of the auditory stimuli, p<.05 (N'Diaye et. al., 2004). Colorful lines are utilized to indicate the different duration conditions. C refers to the short, IC refers to the intermediate-short, S is standard, IL is for long and L refers to the long stimuli.

Figure 5

CNV Amplitudes for Auditory Modality



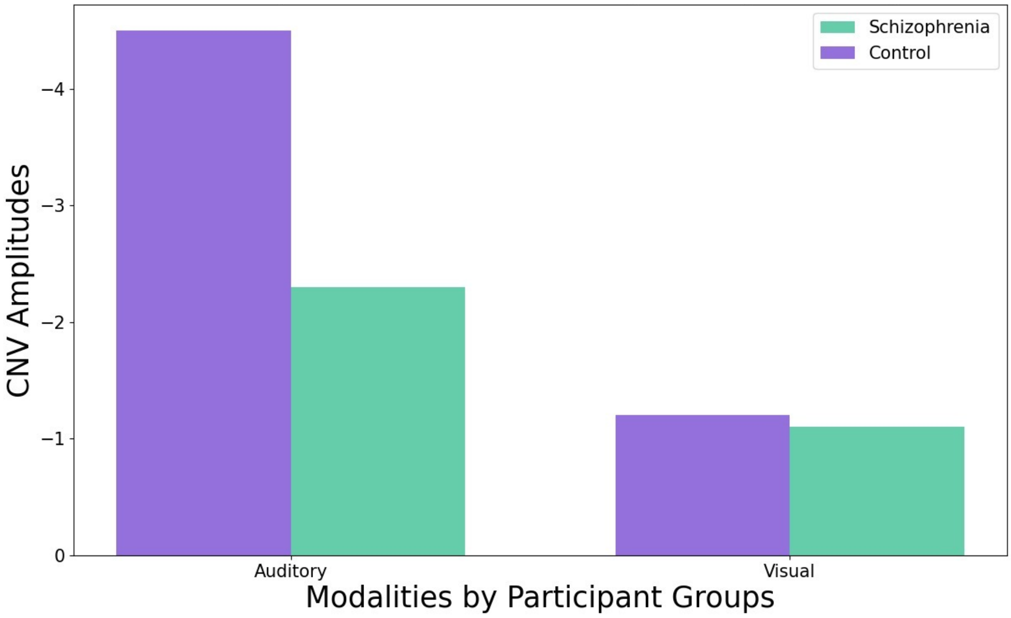
Note. A significant decrease in peak amplitudes of CNV activity is expected for the individuals with schizophrenia in response to auditory modality compared to the control group (p<.05).

Comparison between Auditory and Visual Conditions

According to the findings of N'Diaye et. al. (2004), we predict that healthy subjects demonstrate greater CNV amplitude in response to auditory stimuli than visual stimuli. We expect to observe similar results for the schizophrenia patients in which they exhibit larger CNV amplitude for the auditory condition than the visual condition. To compare the ERPs scores of the healthy control group and the schizophrenia patients, we expect that healthy subjects show the greatest amplitude of CNV for auditory stimuli in contrast with the other modality and psychiatric conditions (Figure 6). Further, the schizophrenia patients are expected to have lower CNV amplitude in response to the auditory condition compared with the controls in the auditory modality, yet larger CNV amplitude than the healthy controls as well as schizophrenia patients in the visual modality. In other words, we predict to observe the greatest CNV amplitude for healthy subjects in the auditory condition followed by schizophrenia patients in the auditory condition. We predict both schizophrenia and healthy groups exhibit similar and lowest CNV amplitude.

Figure 6

CNV Amplitudes of Each Group of Participants for Auditory and Visual Modalities

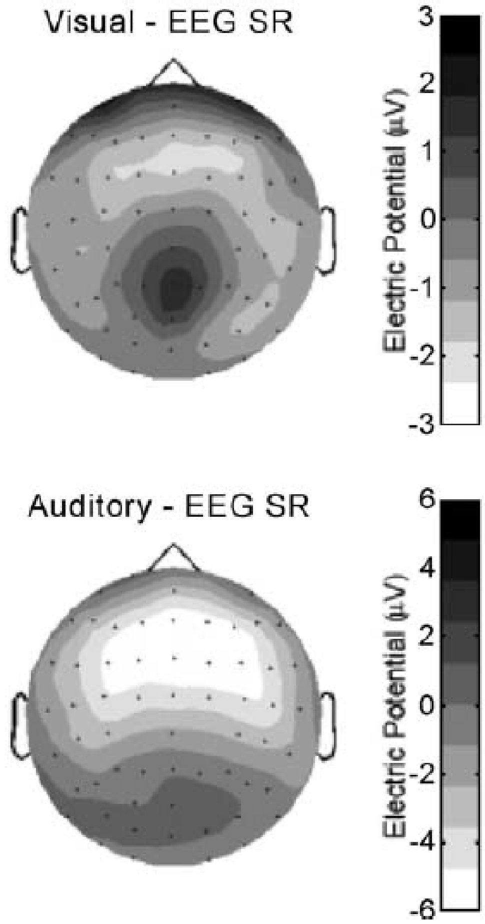


Note. We predict the highest CNV amplitude is exhibited by the control group in response to auditory modality ($p<.05$). It will be followed by schizophrenia patients for auditory modality ($p<.05$). We expect the lowest peak CNV amplitudes are shared by schizophrenia and control groups for the visual modality ($p<.05$).

For both patients with schizophrenia and healthy control groups, we expect to observe the CNV activation is localized in fronto-central regions. We expect more negative electric potential in response to the auditory condition than the visual condition as demonstrated in Figure 7.

Figure 7

Scalp Distribution of CNV Activity



Note. CNV activation is expected to be localized especially on fronto-central sites. The first row demonstrates the EEG scalp distribution for the visual condition and the the second row represents the EEG scalp distribution for the auditory condition. Significantly more negative peak amplitude is predicted for the auditory condition than the visual condition.

Discussion

The current study investigates the time perception processes of schizophrenia patients and non-psychiatric individuals by measuring their ERPs. Specifically, the study compares the CNV activation of these two groups of participants in response to five different durations of auditory and visual stimuli. Based on the previous research regarding CNV activation by N'Diaye et al. (2004) and individuals with schizophrenia by Carroll et al. (2008), we expect schizophrenia patients to exhibit significantly reduced CNV peak amplitude and more variable CNV latency for the auditory modality compared with the non-psychiatric group. On the other hand, we do not predict a significant difference between these two groups for the visual modality. For both groups of participants, we expect they demonstrate higher peak amplitude in response to auditory modality than the visual stimuli. In addition, we do not predict a significant effect of different durations on CNV peak amplitude for both participant groups in both modalities. Regarding the response rates of the participants, we predict the control group demonstrates around 70% of the response rate for auditory modality and 60% for visual modality. We expect to observe a significant reduction in the auditory modality for individuals with schizophrenia, and around a 65% of response rate. Whereas we do not expect a significant difference between response rates of control and schizophrenia groups for visual modality.

The expected results of the current study have the potential to reveal the underlying neural mechanisms of time perception. Perception of time is a cognitive process, and schizophrenia is a disease that leads to cognitive deficits (Green, 2006). According to the behavioral and electrophysiological results of the study by N'Diaye et. al. (2004), our expected results demonstrate that when individuals judge the duration of time more accurately, higher peak amplitude of CNV activation is observed. For instance, as patients with schizophrenia judge the time less accurately than the non-psychiatric individuals for the auditory modality, their peak CNV amplitude is lower. Similarly, as both groups of participants judge the duration of time with similar accuracy rates, their peak CNV amplitudes do not significantly differ. Regarding the latency of the CNV activity, our expected results go parallel with the studies stated above and indicate the latency of the CNV activation is associated with the expectancy of the duration of the given stimulus as CNV is related to the expectancy and patients with schizophrenia have deficits on estimating time. When the individuals try to predict a certain duration, their CNV amplitude peaks. Thus, our expected results bring a novel approach to the activation of CNV in response to the perception of time and reveal the reasons behind the degree and latency of the peak amplitude of the CNV.

Alternatively, visual modality results might change in line with the previous study conducted by Davalos et al. (2002). This study shows that individuals with schizophrenia show deficits in both modalities. Their experimental task was also similar to the current study and the research by Carroll et al. (2008). All experimental paradigms were temporal judgment tasks with a reference interval followed by a comparison interval to be judged if it matches the reference. Therefore, there might be different results due to the differences between the presentation of the stimuli, experimental procedure, or other potential factors. The expected results of the current study show a decrease in the auditory modality and no difference in the visual modality for schizophrenia patients compared to the control group. Therefore, we expected interaction between modality and participant group. On the other hand, it is also possible to observe the main effect of a participant group with decreased CNV activity for both visual and auditory modalities in the schizophrenia group which is in line with the results of Davalos et al. (2002). The literature has inconsistent results for temporal judgements of individuals with schizophrenia. To better understand how time perception is variable in schizophrenia, future studies can replicate the same study while using a variety of verbal time estimation vs. time production tasks while also employing different methodologies such as behavioral, EEG, MEG or fMRI.

One possible explanation for this result is the strong correlation between memory and time perception because both reproduction and temporal judgment tasks require memorizing the reference interval. Researchers have shown a gradual increase in negativity in the CNV component during memorization tasks, suggesting that there can be relative differences between individuals' long-term memory (LTM) (Wearden, 2004). Also, PET scanner studies support this possible explanation for differences between the two subject groups since the researchers suggest a significant difference between people with schizophrenia and control groups under n-back tests. The functional connectivity analysis has suggested that disturbed frontotemporal interaction in people with schizophrenia can be the underlying cause of low working memory (WM) (Meyer-Lindenberg et al., 2001). Knowing such behavioral tasks are based both on memory and decision making related to that, WM and LTM may be confounding to the expected results of our study. Since these differences are known, further studies may target differentiating the memory interruption on neurophysiological time perception tasks.

The perceptual differences between modalities may result from earlier lower-level perceptual differences. We expect to find a modality difference for both expected and alternative results. The CNV activation is present regardless of the modality, which strongly relates to perceived time. However, the perceptual differences of lower-level activities occur before the CNV amplitudes in different regions for different modalities (N'Diaye et al., 2004). The early differentiated activities for modalities are crucial to understanding the nature of CNV and can provide a potential explanation for differences between modalities. Mazaheri and Picton (2005) conducted a study to understand the electrophysiological differences between modalities. The authors found that P300 and sensory-evoked potential onset were earlier for auditory modality than for visual modality. The N1 component also had a significant difference between modalities. Hence, further research can also focus on these components to investigate if there is a difference in the earlier activities between individuals with schizophrenia and the control group. Since the early sensation-related activities can impact CNV amplitudes, differences between subject groups might differ in that sense. Results might give valuable information about how lower-level mechanisms can impact perceived time.

Duration adaptation is another potential confound in this study. Duration adaptation refers to the effect of previous temporal exposure on the current judgment. In a previous EEG study, Li et al. (2017) found that if the duration in the former interval is short, the CNV amplitude decreases for the subsequent trial. The CNV amplitude increases if the previous trial includes a long time interval. Damsma et al. (2021) also found an effect in previously exposed durations on the current judgments. In their study, a reproduction task was used, and the EEG data was recorded during the task performance. Interestingly, the authors found that former longer durations decreased the CNV activity. They also found an effect of mean durations of all previous trials, which shows an active impact of subsequent trials. Therefore, the CNV is not only a reflection of the target task's judgment but also affected by the earlier trials, which should be considered in future research.

Conclusion

The current study aims to investigate electrophysiological differences between non-psychiatric individuals and patients with schizophrenia. To research it, we measure the CNV activity of the participants from both groups in response to five different durations of visual and auditory stimuli. We predict significant reductions in CNV amplitude for individuals with schizophrenia for audştory modality, but not for visual modality. In the study, there might be confounding variables such as the influence of memory, modality, previous duration, and different ERP components. These possible confounding variables might be assessed in further research. Nevertheless, our methodology and expected results have the potential to bring a novel approach to the literature regarding ERPs of schizophrenia patients for their processes of time perception and contribute to the literature in terms of grasping the underlying neural mechanisms of perception of time for both psychiatric and non-psychiatric populations.

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