# AUDITORY SENSORY GATING IN AUDITORY BRAINSTEM RESPONSE (ABR) WITH PSYCHOLOGICAL TASK IN AUTISM SPECTRUM DISORDER (ASD) CHILD: A CASE STUDY

FATIN AMIRA SHAHRUDIN
DEPARTMENT OF AUDIOLOGY AND SPEECH-LANGUAGE PATHOLOGY, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, PAHANG, MALAYSIA

**AHMAD AIDIL ARAFAT DZULKARNAIN** (CORRESPONDING AUTHOR)
DEPARTMENT OF AUDIOLOGY AND SPEECH-LANGUAGE PATHOLOGY, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, PAHANG, MALAYSIA

ahmadaidil@iium.edu.my

NORASHIKIN CHAHED
DEPARTMENT OF AUDIOLOGY AND SPEECH-LANGUAGE PATHOLOGY, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, PAHANG, MALAYSIA

NADZIRAH AHMAD BASRI
DEPARTMENT OF PSYCHIATRY, KULLIYYAH OF MEDICINE, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, PAHANG, MALAYSIA

FATIN NABILAH JAMAL
DEPARTMENT OF AUDIOLOGY AND SPEECH-LANGUAGE PATHOLOGY, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, PAHANG, MALAYSIA

SHAHRUL NAIM SIDEK
DEPARTMENT OF MECHATRONIC ENGINEERING, KULLIYYAH OF ENGINEERING, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, KUALA LUMPUR, MALAYSIA

HAZLINA MD YUSOF
DEPARTMENT OF MECHATRONIC ENGINEERING, KULLIYYAH OF ENGINEERING, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, KUALA LUMPUR, MALAYSIA

SITI RAFIAH ABD HAMID
DEPARTMENT OF EDUCATIONAL PSYCHOLOGY AND COUNSELLING, KULLIYYAH OF EDUCATION, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, KUALA LUMPUR, MALAYSIA

**ABSTRACT**

Studies related to auditory sensory gating have primarily focused on the higher processing center of the auditory system (frontal and temporal lobe), either using electroencephalography (EEG) or magnetoencephalography (MEG). There are limited studies investigating auditory sensory gating from the auditory brainstem region or descending pathways connecting the auditory cortex and brainstem, especially in the autism spectrum disorder (ASD) population. In this report, the auditory sensory gating function of an ASD child using auditory brainstem response (ABR) with a psychological task was compared to typically developing children. Two 10-years old children participated; one diagnosed with ASD and another a typically developing child. They underwent audiological assessment and had normal audiograms with type A tympanograms. The ABR with and without psychological tasks (congruent, incongruent, and neutral conditions) was then conducted. The ABR waveforms (amplitude and latency) and the Stroop variables (percentage score and response time of correct responses) differences were examined among the participants. This case report highlights the six important sensory gating features, i.e., percentage score, response time, facilitation effect, Stroop interference, cognitive interference, and interference concept between an ASD and typically development child. The findings are expected to contribute to future research in the same niche.

**KEYWORDS:** Case Reports; Auditory Brainstem Responses; Autism Spectrum Disorder; Sensory Gating; Psychological Inhibition

## INTRODUCTION

Auditory Brainstem Response (ABR) is a well-known electrophysiology measurement founded by Jewett and Williston (1). Auditory Evoked Potentials (AEPs), including ABR, measure the electrical signals the central nervous system produces along the auditory pathway when stimulated by a stimulus (2). The ABR measures the earlier components of the path within the first 10 to 15 msec following a transient acoustic stimulus and the neural pathway mainly located at VIII nerve and the brainstem. (2). Clinically, ABR is commonly used to estimate the hearing threshold for difficult-to-test patients such as those with comorbidities and as a support for diagnosis. Furthermore, it acts as neurodiagnostic testing that measures impairment that may occur along the auditory pathway from the outer ear to the auditory brainstem.

ABR was used in neurophysiological research and has been studied continuously by scientists in different areas until today (3, 4). ABR’s area of research includes those for cognitive and behavioural function, hearing screening, diagnosis, and prognosis of the disorders and development of behaviour and emotion regulation, also brain development from the neuroscience angle. Recently, study has been focused on understanding the sensory gating function using ABR as an assessment tool (3, 4). Sensory gating is defined as the situation when any redundant or irrelevant information obtained from the environment is filtered before being processed by the brain (5). Sensory gating is usually determined by the presence of responses at 50 msec after the presentation of the auditory stimulus, known as the P50 component. A previous study has used cognitive tasks while the ABR is recorded, and the authors hypothesised that attention and cognitive function might have a particular influence on the ABR waveforms (4). Brännström (3) also investigated cognitive function when presented with cognitive interference, namely Stroop Task (ST).

The ST measures the ability to inhibit cognitive interference but is also used for measuring attention and processing abilities as part of the cognitive function. There are different versions of ST, e.g., the original ST by Stroop in 1935, emotional ST, day and night ST, and counting digit ST (this version in this study). In the conventional ST (Stroop Color and Word Test), congruency exists when a word's meaning and font colour are identical (congruent). For example, the word "green" is printed in green ink. Incongruent is the complete opposite. That is, the word's meaning and the printed colour does not correspond, e.g., "green" could be printed in red ink. In other words, participants must do a less automated job (i.e., naming ink colour) while suppressing the interference caused by a more automated task (i.e., reading the word). This difficulty in preventing a more automated process is known as the Stroop effect (Stroop, 1935).

Brännström (3) suggested that cognitive interference generated by the ST could trigger inhibition at the brainstem level to suppress information processing. The suppression could be present as a reduction of wave V amplitude (3). This suggests that wave V amplitude will be smallest in incongruent conditions as the brainstem receive the highest cognitive interference than in the congruent and neutral conditions. Based on this report, it can be inferred that the ABR may have the potential to be used as an assessment tool to diagnose sensory gating impairment in support of other evaluation methods such as the P50, P300, and N100 test (cortical auditory evoked potential, CAEP) as well as a parental or self-reported questionnaire.

Even though ABR shows potential in the study of sensory gating, there is a need to be more information on its ability as an assessment tool to measure sensory gating since the neural substrates for efferent pathways still need to be better understood. The information on the sensory gating function reported from the previous studies involves other electrophysiological test such as CAEP (6) and involves other mode of testing such as using magnetoencephalography (MEG) (6) instead the typical Electroencephalography (EEG) mode (6). These tests measure brain responses, focusing on cortical connection and spontaneous brain activities (7). In contrast, the ABR measures the vestibulocochlear (VIII) nerves up to the inferior colliculus of the midbrain (2).

In children with ASD, impairment to the sensory gating is usually observed as auditory hypersensitivity (8). ASD children exhibit sound hypersensitivity by covering their ears, dislike or have difficulty with a specific sound, may get startled and distracted easily, and may notice a sound that others did not. Studies reported that about 30% to more than 90% of the ASD population either ignore or overreact to familiar sensations (9).

However, as mentioned above, the scarce findings restrict our ability to understand the process of the auditory sensory gating function in the brainstem, which is very important for the future diagnosis of ASD. This case study explores the effect of auditory sensory gating on ABR with psychological tasks in a child with ASD compared to a typically developing child by highlighting the essential features of this research area.

## CASE PRESENTATION

*Participant*

This case study was conducted on a patient diagnosed with ASD recruited from a healthcare institution, while the typically developing child was recruited using a convenience sampling technique among parents who are volunteers. This study received ethical approval from the institution's research committee. Two children that fit the inclusion criteria, aged ten years old, were involved. Both children had passed their hearing assessment: precise otoscopy examination, normal audiogram, type A tympanogram, and presence of all acoustic reflexes. The exclusion criteria are having fever or flu, presence of comorbidity, and impaired understanding ability (important for understanding and following instructions). The parents have given full written and informed consent for participating and publishing this report.

*ABR with psychological task (ST) procedure*

Participants were seated in front of a laptop and were advised to remain still to reduce any noise and artefacts in the ABR. Before the test, the skin was prepared by applying Nu-Prep skin preparation gel (Weaver and company, Colorado, USA) to both sides of the high forehead, lower forehead, and mastoid. The disposable silver/silver chloride electrodes (Ambu A/S, Ballerup, Denmark) were placed in the prepared areas. When the patient was ready, the audiologist gave the instructions for ST verbally and in writing. For ST, they must count the digit/s displayed on the screen and respond as quickly and accurately as possible by pressing the correct number key on the numerical keypad. Trials in each ST condition were presented randomly (60 trials of neutral, 60 trials of congruent, and 60 trials of incongruent). These trials were presented on a laptop using the E-prime 3.0 software interface (Figure 1). Each trial was displayed for 4000 msec before the interface moved to the following trial. Participants were given practice before they proceeded with the actual task.

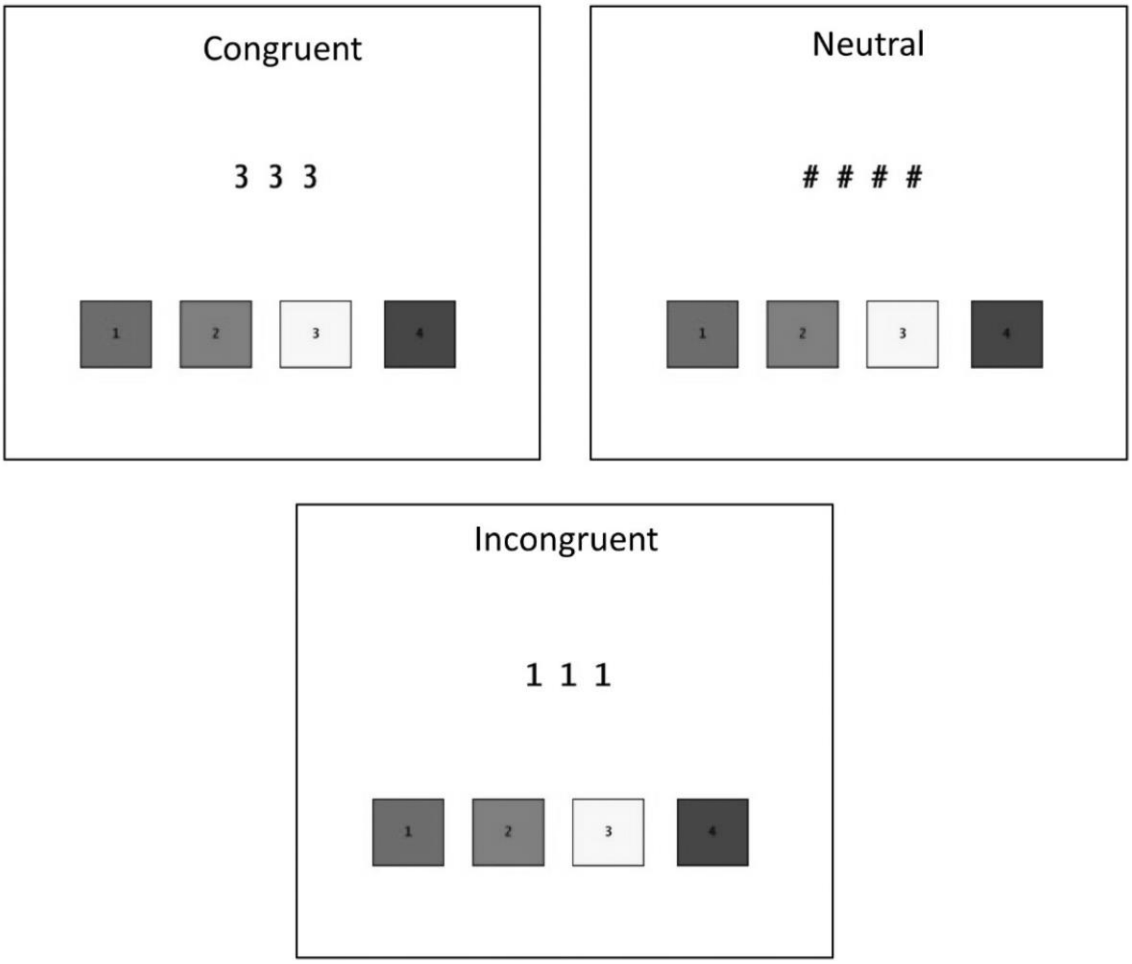


**Figure 1:** Stroop task condition (congruent, incongruent, and neutral) presented using E-prime 3.0.

The ABRs were recorded at the same time the participant did the ST. The ABR waveforms were recorded in the four conditions: 1) without ST (baseline), 2) neutral, 3) congruent, and 4) incongruent, and the sequence of the four conditions was randomized for both participants. The incongruent condition involves presenting numbers, but the digit display is different from the number of digits presented. For instance, the digit “2" might be written as “3 3”. Participants are asked to identify the number of digit while ignoring the actual digit. The incongruence between the digits and number of digits creates cognitive conflict, as there's a tendency to automatically read the digit, which can interfere with accurately identifying the number of digits displayed. As for congruent condition, the digit and number are the same e.g., digit “2” is presented as “2 2”. While neutral condition uses symbols instead of digits, for example “# #”.

The ABR was elicited by presenting a tone burst of 1000 Hz at 70 dBnHL with a stimulus repetition rate of 33.1 Hz on the test ear (right) through an Eclipse ER-3A insertphone (Interacoustic A/S, Middlefart, Denmark). Meanwhile, white noise was presented as a contralateral masking noise continuously on the non-test ear (left) at 40 dBnHL below the stimulus presentation at the test ear. ABR testing was conducted using two-channel Eclipse ABR equipment (Interacoustic A/S, Middlefart, Denmark). The average response was filtered using a 100 – 3000 Hz band-pass filter to remove unwanted activities unrelated to ABR. The level of individual electrode impedance was maintained below < 5000Ω to ensure an optimal common mode rejection. Two ABR waveforms were recorded from each participant in each condition to check for repeatability.

*Data analysis*

ABR waveforms in each condition from all participants were analysed based on their presence or absence, the amplitudes and latencies. The cognitive interference of wave V amplitude for each participant was then determined by subtracting wave V amplitudes of ABR in incongruent conditions from wave V amplitudes of ABR in a neutral condition. In addition, the percentage reduction of wave V amplitude (%) was calculated to compare the participants.

For ST, the response time (msec) and percentage score (%) of correct responses from each condition was calculated using descriptive statistics. The response time and percentage score for each participant was calculated by averaging the value from 60 trials in each condition. Next, Stroop interference (measures inhibitory control) for response time and percentage score was determined by subtracting response time / percentage score in incongruent conditions from response time / percentage score in the neutral condition (3).

*Typically developing children*

A ten-year-old Malay girl came as a participant with her parents. History suggests no significant history related to childhood development, and she did not report any issues with hearing. The audiological assessment results were as follows; (i) a normal audiogram with normal audiometric hearing thresholds, (ii) tympanometry with type A which suggests a normal middle ear function, and normal acoustic reflex thresholds at all stimulation and frequency bilaterally.

Referring to Table 1, ABR with and without psychological task suggested normal absolute latencies and the presence of wave V amplitudes in all conditions, with the largest amplitude found in the congruent and incongruent conditions. In contrast, the smallest amplitude was found in the baseline ABR (without psychological task). The cognitive interference obtained was 0.13, with a 38.88% increase in wave V amplitude from neutral to incongruent test conditions.

The percentage score is 100% in both congruent and incongruent conditions and 96.67% in the neutral condition. For the response time, the fastest time was obtained from the neutral condition, followed by incongruent and congruent. The Stroop interference for both percentages score and response time are 3.33 and 154.36 msec, respectively (Table 1).

**Table 1:** Summary of the ABR sensory gating result from a typically developing child and a child with ASD.

| **ABR with Stroop Task** | | **ASD** | **Typically development Child** |
|---|---|---|---|
| Baseline | Wave V amplitude | 0.520 | 0.332 |
| | Wave V latency | 7.30 | 6.80 |
| Congruent | Wave V amplitude | 0.449 | 0.457 |
| | Wave v latency | 7.43 | 6.83 |
| | Correct Response (%) | 100 | 100 |
| | Response time (msec) | 1035.13 | 1018.40 |
| Incongruent | Wave V amplitude | 0.417 | 0.456 |
| | Wave V latency | 7.33 | 6.83 |
| | Percentage score (%) | 93.33 | 100 |
| | Response time | 1545.68 | 837.92 |

| | | | |
|---|---|---|---|
| | (msec) | | |
| Neutral | Wave V amplitude | 0.457 | 0.326 |
| | Wave V latency | 7.37 | 6.90 |
| | Percentage score (%) | 96.67 | 96.67 |
| | Response time (msec) | 1247.82 | 683.55 |
| Stroop Interference Percentage Score | | 297.86 | 154.36 |
| Stroop Interference Response Time | | -3.34 | 3.33 |
| ABR Amplitude Cognitive Interference | | -0.04 | 0.13 |

*Child with ASD*

A ten-year-old Malay girl with mild ASD was diagnosed by a psychiatrist when she was five. At the time of the appointment, she has a scheduled appointment with a psychiatrist and occupational therapist. The parent reported that she has no other comorbidity and no history of hearing problems. Her audiological assessment shows normal hearing, type A tympanogram suggesting normal middle ear function and presence of all reflexes bilaterally.

The findings from ABR show normal absolute latencies for wave V in ABR without and with the psychological task (congruent, incongruent, and neutral). The wave V amplitude was the largest from congruent and the smallest from incongruent. The cognitive interference of wave V amplitude was -0.04, with the wave V amplitude reduction of -8.75% was noted.

For the ST (Table 1), the percentage score and response time for congruent, incongruent, and neutral are 100% and 1035.13 msec, 93.33% and 1546.68 msec, 96.67%, and 1247.82 msec, respectively. Stroop interference response time is 560.06 msec, while the Stroop interference percentage score is -3.34.

*Typically Development versus ASD child*

ABR wave V amplitude and latencies in all conditions show a similar value between the two children. The amplitude of wave V is descriptively larger for the ASD child in the baseline and neutral conditions and relatively similar in congruent and incongruent conditions compared to the typically development child. This suggest that the sensory gating ability is intact in both child when looking at the findings in congruent and incongruent condition. Also, the difference seen in baseline and neutral might be cause by individual variation. Comparing the findings with the norms, the latency of both children is within normal limits (10). The ABR of the study participants is also valid and reliable based on the robustness of wave V, as expected in typical tone burst ABR recordings (10).

Furthermore, wave V amplitude from neutral to incongruent test conditions was reduced in the ASD child compared to the typically development child with an increment of the wave V amplitude (Figure 2). As for cognitive interference, only the child with ASD shows a negative interference pattern. To ensure that the result obtained is not affected by noise interference, the value for Signal-to-Noise ratio (SNR), F at multiple points (Fmp), and residual noise level (RNL) was computed. The SNR, Fmp, and RNL of the ABR in each condition, in general, exceeded the recommended guideline of i) SNR > 3.0, 2) Fmp >3.1, and 3) RNL sufficiently low < 80nV (11).

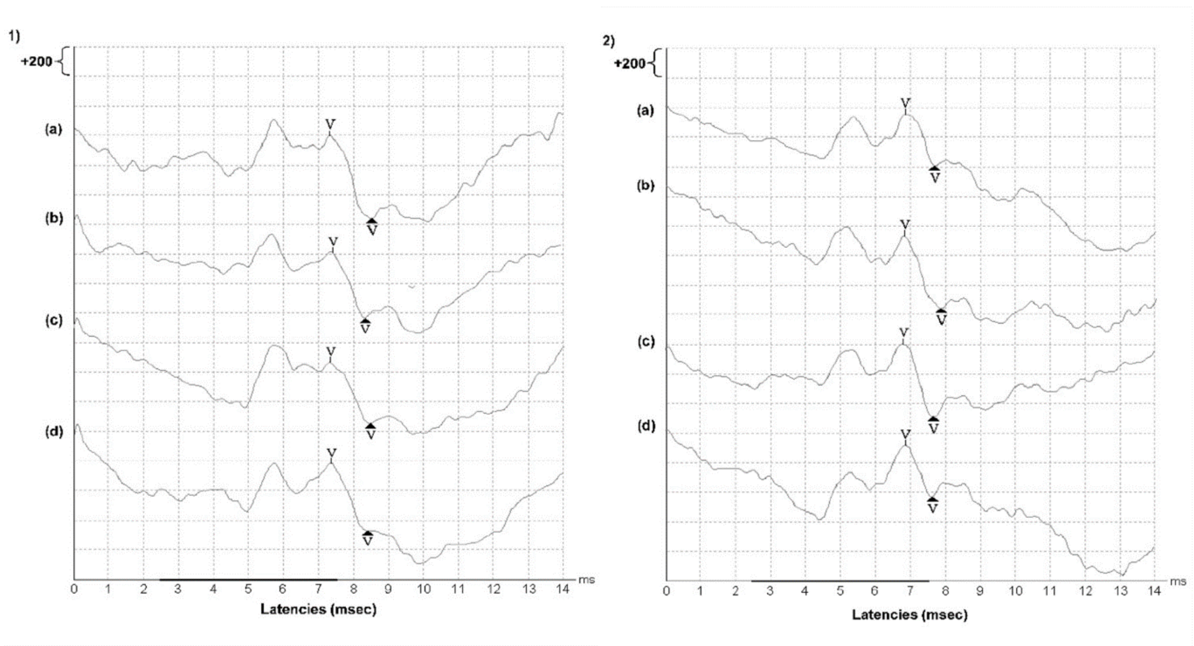


**Figure 2:** ABR waveform of (1) typically developing child and (2) autism spectrum disorder child in Stroop task condition; (a) baseline, (b) congruent, (c) incongruent, and (d) neutral.

The response time in all conditions was lower for the typically development child than for the ASD child. At the same time, the percentage score is almost similar between the children except for the incongruent condition in which the typically development child scores better than the ASD child. In Stroop interference response time, the typically development child has a smaller value suggesting that she had an excellent cognitive ability to respond better during the challenging task than the ASD child. Stroop interference percentage score also shows a higher value for the typically development child.

## DISCUSSION

The information on auditory sensory gating in the brainstem is limited, especially among ASD children. Additionally, it is hypothesised that the ABR has great potential in its applicability as a measurement tool for sensory gating because it is associated with working memory and cognitive function (12). It prompts the investigation using ABR with psychological tasks among ASD children compared to typically development child. The data from this study suggests that the typically development child had a better cognitive response than the ASD child.

In previous ST studies for typically development children, the response time and percentage score decreased and increased respectively from the congruent condition to the neutral condition and finally to the incongruent condition (13). Contrary to this account, the typically development child in this study did not show the classical performance pattern for both ST measurements. To note, mental fatigue as a result from demanding task for a long period of time might influence the percentage score and response time which explain why the findings did not follow the classical pattern. Thus, looking at the normative data from Sulaiman's study (13), the value obtained is within range for normal children's norms in each condition, suggesting that the results are normal even if it did not follow the pattern. The individual result obtained in this study may coincide with some of the individual result in past study (12, 13). Therefore, a clinically significant in comparison to research significant may provide a different finding, which means even the finding is not significant statistically, but a real-life effect might be present that could not be measured due to factors such as sample size.

Furthermore, it can be observed that the typically development child had a better response time in all conditions than the ASD child that suggests better selective attention and sensory gating abilities. This is expected with prior studies (14) which suggest typically development to have faster response suggesting good cognitive ability to inhibit cognitive interference. However, this result also differs from other findings obtained from a prior study (15), which shows comparable results for the response time between typically development and ASD children. Yasumuru's (15) and Zhou (16) findings suggested no deficits in cognitive inhibition in ASD children as measured by the ST. The authors argue that the inhibitory control skills increase from three to six years (17); thus, by the age of seven years old, the inhibitory control is developed, which explains the no difference between ASD and typically development children in inhibitory control skill. Therefore, it is expected that there is not much difference in the response time between the ASD and typically development children. The large difference for incongruent condition partly may be caused by the variety in the spectrum of ASD. Some children may have issue in inhibitory control as compared to the other ASD children as shown by the individual participated in the present study.

On the other hand, facilitation effect was also observed in this study but only in ASD children. The facilitation effect is defined as the fastest Response for the congruent condition compared to the typically development child. The hyper-systemising theory of autism proposed by Baron-Cohen (18) explains that those with ASD have a higher systemising mechanism (SM); the brain processes the information to identify the pattern or law that governs the system. Due to the autistic traits, the ASD child will perform at its maximum or even better, resulting in them noticing the pattern of congruent condition earlier than the typically development child. Although similar to the point discussed in the previous paragraph, the difference is slight and requires further investigation to identify whether the difference is statistically or clinically significant.

Based on the normative value of Stroop interference obtained from a study by Olivia and colleagues (19), the result indicates that the typically development child has normal Stroop interference of correct response while the ASD child did not. A similar study measuring the inhibitory control as revealed by the Stroop interference is comparable to the typically development group suggesting unimpaired inhibitory control (20).

Cognitive interference, as mentioned previously, is the value of amplitude wave V in an incongruent condition minus the value of amplitude wave V in a neutral condition. The value obtained is assumed to be in a negative pattern as the amplitude of wave V in incongruent should be smaller than the neutral due to the suppression or inhibition of the cognition from the ST interference (13). The present finding suggests that the ASD child yielded a negative pattern compared to the typically development child. According to Brännström (3), a few of their normal participants had negative patterns, while others did not. Thus, the participants might not exhibit the negative pattern as the negative pattern is not a universally acceptable result that can be observed even in typically developing children. All the data obtained has a good recording (based on the value of FMP, RNL, and SNR as in the result section), suggesting that technical factors do not influence the results obtained; thus, the result is valid and reliable.

## CONCLUSION

To conclude, the present case study highlights the essential features of the sensory gating between an ASD and typically development child: 1) Percentage of the correct response, 2) Response time of correct responses, 3) Facilitation effect, 4) Stroop Interference, and 5) Cognitive interference (ABR). The findings also expand the concept of interference from the ST and the suppression of wave V amplitude in ABR with the psychological task. Extensive research is required to explore this study's key features with a detailed analysis of each component. The information will help us understand the sensory gating mechanism and its relationship with ASD. It is recommended for this study to be extended in the future using a larger sample size using a fully randomized controlled trial experiment method that would allow the researchers to make generalization and to further understand the relationship and the causal-effect between the ST findings and ABR ST findings with ASD.

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## DECLARATION OF INTEREST

The authors declare no conflict of interest.

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