Research Article

Evaluation of Reaction Time during Asynchronous Oddball Paradigm

Elif Uğurgöl[1*], Demet Yeşilbaş[2], Miray Altınkaynak[3], Turgay Batbat[4], Ayşegül Güven[5], Nazan Dolu[6], Esra Demirci[7], Meltem İzzetoğlu[8]

[1] Erciyes University, Orcid ID: https://orcid.org/ 0000-0002-6071-9020, E-mail: bm.elifugurgol@gmail.com
[2] Erciyes University, Orcid ID: https://orcid.org/ 0000-0001-9070-4439, E-mail: demetyesilbass@gmail.com
[3] Erciyes University, Orcid ID: https://orcid.org/ 0000-0002-0258-2804, E-mail: eem.miray@gmail.com
[4] Erciyes University, Orcid ID: https://orcid.org/ 0000-0002-0128-2076, E-mail: turgaybatbat@erciyes.edu.tr
[5] Erciyes University, Orcid ID: https://orcid.org/ 0000-0001-8517-3530, E-mail: aguven@erciyes.edu.tr
[6] Medipol University, Orcid ID: https://orcid.org/ 0000-0002-3104-7587, E-mail: nazan.dolu@medipol.edu.tr
[7] Erciyes University, Orcid ID: https://orcid.org/ 0000-0002-8424-4947, E-mail: esrademirci@erciyes.edu.tr
[8] Villanova University, Orcid ID: https://orcid.org/ 0000-0002-1528-0127, E-mail: meltem.izzetoglu@villanova.edu
[*] Correspondence: bm.elifugurgol@gmail.com

Received 11 May 2024
Received in revised form 16 August 2024
In final form 15 October 2024

Reference: Uğurgöl, E., Yeşilbaş, D., Altınkaynak, M., Batbat, T., Güven, A., Dolu, N., Demirci, E., & İzzetoğlu, M. (2024). Evaluation of reaction time during asynchronous oddball paradigm. The European Journal of Research and Development, 4(3), 1-10.

Abstract

Reaction time, defined as the time between the presentation of a stimulus and the response to that stimulus, is widely used for evaluating cognitive functions. Prolonged reaction time is associated with delayed neuronal activity. The type, complexity and length of the stimulus affect reaction time. This study aimed to investigate whether there were differences in reaction time in the auditory and visual oddball paradigms, which are frequently used in cognitive studies and to examine the effect of prolonged task duration on reaction time. The study was conducted on 19 male healthy university students aged between 18-23 years. A dual-task with an oddball paradigm was applied to the participants. The paradigm consisted of 160 stimuli including 32 auditory targets, 32 visual targets and 96 standard stimuli. The participants were asked to press buttons as soon as they perceive the target stimuli. Reaction time of participants to each target was calculated automatically. The reaction time for both tasks compared statistically and it was observed that visual reaction time was significantly longer than auditory reaction time (p= 0,042). In addition, to examine the effect of task duration on reaction time, the first ten and last ten target stimuli were investigated in both tasks. It was observed that the reaction time was prolonged and errors increased towards the end of the task (p<0,01). As a result, this study demonstrated that auditory reaction time was *shorter than visual reaction time, and revealed that the type and length of the stimulus should be considered in reaction time studies.*

Keywords: *Reaction Time, Asynchronous Oddball Paradigm, Number of trials, Visual stimulus, auditory stimulus*

1. Introduction

Basically, reaction time (RT) is defined as the time interval between the presentation of a stimulus and the response to that stimulus [1]. Reaction time is the process in which the brain receives environmental stimuli from the sensory systems, decides on processing, and responds with motor action. This concept is a marker that provides information about the reaction speed of responders to stimuli and has been associated with cognitive performance of individuals [2]. Studies have shown that reaction time is a reflection of speed of nerve conduction, and faster reaction time has been associated with a better cognitive function [3, 4]. Therefore, RTs have been studied in situations requiring cognitive ability and have been associated with academic performance among medical students[5]. In addition, it has been shown in various studies that reaction time is an important indicator in the early diagnosis of psychiatric disorders [6] and neurological diseases [7, 8]. Reaction time corresponds to the time interval between stimulus and response and is affected by the type, duration and complexity level of the stimulus. Studies have shown that reaction time prolongs when task becomes more complex. Medina et al [9] demonstrated in their study that prolonged reaction time in complex tasks is associated with early Alzheimer's symptoms.

Some cognitive tasks are used to assess reaction time and oddball paradigm is one of them. Oddball paradigm which allows the technical measurement of people's attention status is a widely used method to evaluate cognitive ability and attention status [10]. This paradigm is based on an experimental setup in which a sequence of target and standard trials are presented consecutively, and participants perform the task by ignoring the standard stimuli and pressing the button when the target stimulus appears. Asynchronous oddball, which is created by presenting visual and auditory stimuli consecutively in the same paradigm, allows the measurement of divided attention [11]. In the Oddball paradigm, the prolongation of reaction time to stimuli has been associated with impairment in executive functions, and the changes in auditory and visual reaction time under certain conditions such as exercise and caffeine consumption have been frequently investigated. In the Oddball paradigm, prolongation of reaction time to stimuli has been associated with impairment in executive functions. The effect of specific conditions such as exercise and caffeine consumption on reaction time to auditory and visual stimuli has been frequently investigated [12]. The effect of the type of the stimulus and the demographic characteristics of the participants on reaction time has been examined in some studies. Shelton *et al.* [15] examined whether the reaction time to visual and auditory stimuli differed according to gender. They found that the reaction time to auditory stimuli was shorter compared to visual stimuli in both genders. Wadoo *et al.* [16]studied medical students aged 18-22 years. Their study revealed that the reaction time to auditory stimuli was faster compared to visual stimuli, male students responded faster than female students for both tasks, and students who engaged in physical activity had faster reaction times than students who had a sedentary life. In contrast to these studies, some studies have shown that reaction time to auditory stimuli using Oddball test is longer compared to reaction time to visual stimuli [17, 18]. In this study, by considering this contradictory situation in the literature, it was investigated whether auditory and visual reaction times differ according to stimulus type. Reaction times to asynchronous auditory and visual oddball paradigm were compared using statistical techniques. In order to eliminate the effect of gender on reaction time, all participants were male. The study aimed to enlighten the reaction time studies to be conducted using the oddball paradigm.

The number of trials a subject completes in an experiment affects the stability of the experiment. Insufficient trials might not be enough to reflect the subject's general performance [13]. One of the important aspect in reaction time studies is the determination of the optimum number of trials [14]. In order to bring a different insight on this situation, the reaction times for the first ten trials in an experiment were compared with the reaction times for the last ten trials. The difference in the reaction times of healthy controls in two states shows that the performance of individuals during the task varies with the duration of the task. This study provides a contribution to the research on determining the optimum number of trials in a task.

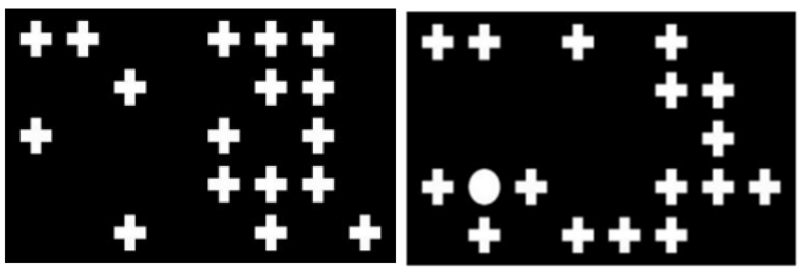
2. Materials and Methods

2.1. Participants

The study was conducted in a Faraday Cage room with light and sound isolation at the Erciyes University Clinical Research and Application Center. Participants were 19 healthy male students aged 18-23 years (21.6 ± 1.5) with normal hearing-visual function and no current neurological or psychiatric disorders. The hearing functions of the participants were checked using the Rinne and Weber tests. All volunteers were right-handed. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the institutions ethical review board by the Clinical Research Ethics Committee of Erciyes University (2022/312).

2.2. Experimental Setup

An asynchronous oddball paradigm used in this study comprising a total of 160 stimuli presented in a random sequence, including of 32 visual targets and 32 auditory targets. Asynchronous oddball paradigm measures the divided attention of the participants by presenting visual and auditory stimuli during an experimental session. Divided attention refers to the ability to respond to multiple stimuli at the same time. In visual stimuli, the standard stimuli were seventeen white plus shape ("+") placed in different areas of a black screen. An example of standard stimuli given Figure 1-a. The target stimuli consisted of sixteen white plus shape ("+") signs and one white circle of similar size and Figure 1-b shows an example of a standard stimulus. Each stimulus duration was 800 ms with an inter-stimulus interval of 300 ms. For auditory stimuli, the standard stimuli were 1000Hz, 70dB, and the target stimuli were 2000Hz, 70dB "beep" sounds. In the Oddball task, the participant was expected to ignore frequently appearing standard stimuli and press a button in response to less frequently appearing target stimuli.



(a) (b)

Figure 1: a) Oddball Visual Standard Stimulus b) Oddball Visual Target Stimulus

The Oddball task used in this study consist of two types of stimuli, visual and auditory. Participants were asked to press the right button when they saw visual target stimuli and the left button when they heard auditory target stimuli. Figure-2 shows a representative picture of the subject, who performed a recreation by pressing a button in front of the screen on which the stimuli were presented. In addition, the task was designed so that the target visual and auditory stimuli did not occur simultaneously. The stimulus system was developed by us using the JavaFX programming language in the NetBeans IDE. The time at which the participant pressed the button was automatically recorded in the system. The designed system automatically records the participants' button pressing data on the computer and provides an objective analysis of the reaction time to the stimulus. The correct and incorrect responses and as well as reaction times of the participants to the target stimuli were determined, and reaction times, which are an important parameter in attention measurement, were determined for each target stimulus.

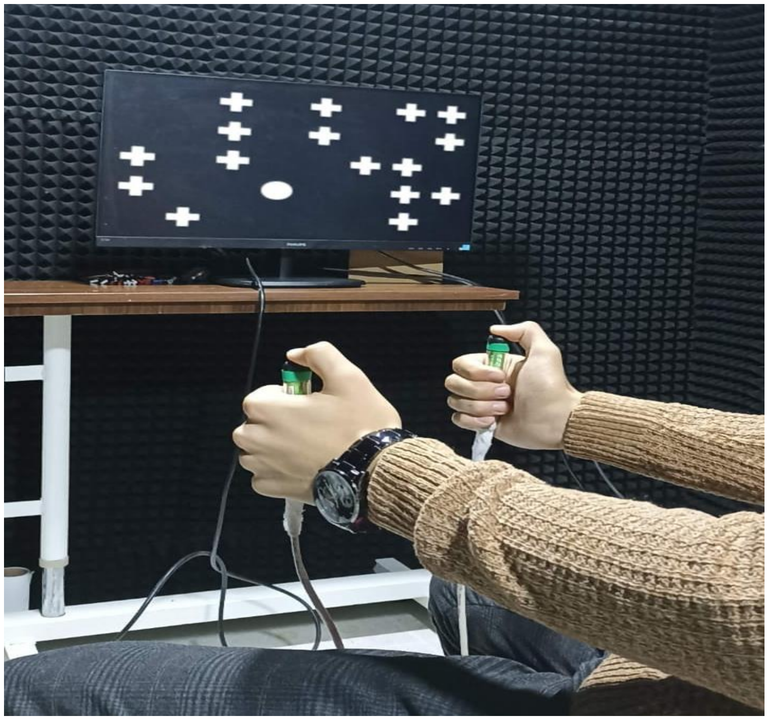


Figure 2: Asynchronous Oddball Experiment Setup. Participants reacted by pressing the right button on their hands when they saw the target stimulus as shown in the visual example. Participants responded by pressing the left button on their hands when they heard the auditory target stimulus.

2.3. Statistical Analysis

In the present study, we compared the reaction times to auditory and visual stimuli to investigate the effect of stimulus type on reaction time. The reaction times of the auditory and visual stimuli recorded by the software were categorized, and only the reaction time to each target stimulus to which the participants responded correctly were included. The average reaction time (RT_{average}) for each participant was determined by calculating the mean reaction time to the target stimuli throughout the task:

$$RT_{\text{average}} = \frac{\sum_{i=1}^{n} X_i}{n} \quad (1)$$

Here, n represents the number of correctly responded target stimuli, and X_i corresponds to the reaction time to each target stimulus. This calculation was performed separately for auditory and visual stimuli, and an auditory and a visual RT_{average} value was determined for each participant.

In addition to examining the effect of stimulus type on reaction time, the study also investigated the reaction times over the number of trials. For this purpose, the average reaction time to the first 10 trials and the average reaction time to the last 10 trials for each participant were calculated to observe changes in reaction time over time. The obtained features were evaluated through statistical analyses to search for differences in reaction times between different tasks. Data groups that were found to be normally distributed by Shapiro-Wilk test were compared by Two Sample Dependent t-Test. Wilcoxon Signed Ranks test was used for the comparison of non-normally distributed data.

3. Results

In the study, the number of correct responses to visual target stimuli, the number of correct responses to auditory target stimuli, the overall average reaction times of correct responses to visual stimuli, the overall average reaction times of correct responses to auditory stimuli, and the statistical analysis results are presented in Table 1.

Table 1: Comparative Analysis of Visual and Auditory Stimuli

	Visual		Auditory		Comparison of stimulus type	
	mean	standard deviation	mean	standard deviation	**t/Z**	**p**
Reaction Time (ms)	561	0,06	529	0,082	2,187	0, 042*
Number of Correct Responses	29,74	2,13	30,32	1,376	0,953	0,34**

Abbreviations: * Paired Sample t-Test; ** Wilcoxon Signed-Rank Test

As shown in Table-1, participants' reaction times to visual and auditory stimuli exhibit a significant difference. Reaction times to visual stimuli are significantly longer. There was no significant difference in the number of correct responses to either stimulus type.

Table 2 shows the response times for the first ten trials and the last ten trials for both stimulus types. Table 3 shows the results of the comparison of reaction times for the first 10 trials and the last 10 trials in an experimental setup.

Table 2: Reaction Times to the First and Last Ten Auditory and Visual Stimuli

	First 10 Visual Trials		Last 10 Visual Trials		First 10 Auditory Trials		Last 10 Auditory Trials	
	mean	standard deviation	mean	standard deviation	mean	standard deviation	mean	standard deviation
Reaction Time (ms)	546	0,061	566	0,069	481	0,084	550	0,083

Table 3: Statistical Analysis of Reaction Times to the First and Last Ten Auditory and Visual trials

	First 10 -Last10 Visual Trials		First 10 -Last10 Auditory Trials	
	t	p	t	p
Reaction Time (ms)	2,94	0,009	5,83	0,000

Figure 3 shows a boxplot of the reaction times to the first 10 and last 10 visual and auditory trials.

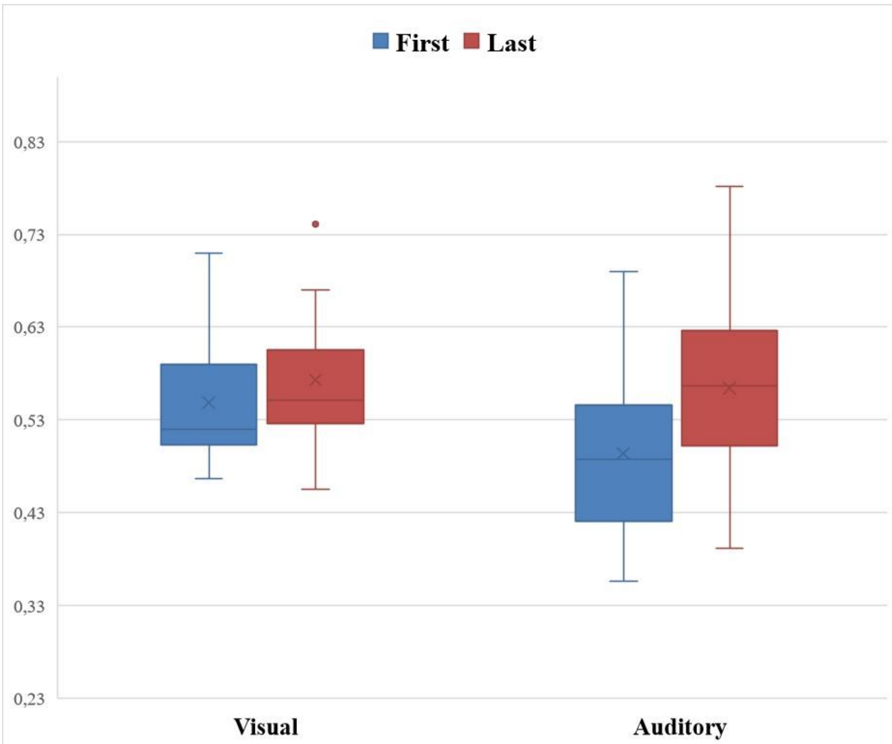


Figure 3: Reaction times to the first ten visual trials (blue), the last ten visual trials (red).

As can be seen in Table 2 and Table 3, the reaction time to the first ten trials and the last ten trials showed a significant difference in both visual and auditory stimuli. It was seen that the reaction time of the participants to the last 10 trials was prolonged.

4. Discussion and Conclusion

In this study, it was examined whether the reaction time to auditory and visual stimuli in the oddball paradigm differs according to the stimulus type, and the effect of the number of trials in a task on the performance of the individuals. Reaction time, defined as the time taken to respond to a stimulus, is an important parameter frequently used in the assessment of executive functions in various neurological and psychiatric disorders [7-12, 15-21].

The results of this study showed that the reaction time to visual stimuli was longer than the reaction time to auditory stimuli. This finding is consistent with the literature [1, 15, 22] . Ghuntla *et al.* [23] found that the reaction time to visual stimuli was longer in their study investigating the difference in reaction times to visual and auditory stimuli . On the other hand, some studies in the literature have shown that the reaction time to visual stimuli is shorter compared to auditory stimuli [17, 18]. These studies have an experimental setup where visual and auditory stimuli are presented at different times. Therefore, it is thought that this difference may be due to the tasks being applied at different times. In the current study, a simultaneous recording system was designed with randomly presented visual and auditory stimuli to ensure that responses to stimuli were collected simultaneously. This approach eliminated other factors affecting reaction time, providing a more objective analysis. Moreover, the developed tool provided reliable results by allowing the participants' reaction times to the stimuli to be recorded automatically in a precise manner. The simultaneous task design enabled a more accurate measurement and comparison of responses to these two stimuli.

In this study the effect of task duration on reaction time examined by statistically comparing the reaction times to the first ten trials and last ten trials. Increasing the number of trials throughout an experiment can lead to faster reaction times as the person becomes more familiar with the task. However, conducting too many trials can increase reaction time by causing fatigue. The effect of the number of trials, which is one of the factors affecting the experimental power in reaction time studies, on the performance of individuals was examined [24]. In this study, it was observed that reaction time increased towards the end of the approximately 3-minute task for both types of stimuli.

In conclusion, this study demonstrated that reaction time, known to be an important biomarker for the early diagnosis of various diseases, is affected by the type and number of trials. It was highlighted that these parameters should be considered in future reaction time studies.

Declarations

Ethical Approval: The study was approved by the Clinical Research Ethics Committee of Erciyes University (Ethics No: 2022/312).

Conflict of Interest: The authors declare that there is no conflict of interest in this study.

Financial Support and Acknowledgements: The study was supported by a grant from The Scientific and Technological Research Council of Turkey (TÜBİTAK) [Grant number:

121E502]. We also thank the Erciyes University Clinical Research and Application Center for providing laboratory and infrastructure support for our study.

References

[1] A. Jayaswal, "Comparison between auditory and visual simple reaction times and its relationship with gender in 1st year MBBS students of Jawaharlal Nehru Medical College, Bhagalpur, Bihar," *Int. J. Med. Res. Rev,* vol. 4, no. 7, pp. 1228-1232, 2016.

[2] L. H. Jakobsen, J. M. Sorensen, I. K. Rask, B. S. Jensen, and J. Kondrup, "Validation of reaction time as a measure of cognitive function and quality of life in healthy subjects and patients," *Nutrition,* vol. 27, no. 5, pp. 561-570, 2011.

[3] G. M. Clark, J. A. Lum, and M. T. Ullman, "A meta-analysis and meta-regression of serial reaction time task performance in Parkinson's disease," *Neuropsychology,* vol. 28, no. 6, p. 945, 2014.

[4] A. Prabu Kumar *et al.*, "How does cognitive function measured by the reaction time and critical flicker fusion frequency correlate with the academic performance of students?," *BMC medical education,* vol. 20, pp. 1-12, 2020.

[5] K. Prabhavathi, R. Hemamalini, C. Amalraj, K. Maruthy, and A. Saravanan, "A correlational study of visual and auditory reaction time with their academic performance among the first year medical students," *National Journal of Physiology, Pharmacy and Pharmacology,* vol. 7, no. 4, pp. 371-371, 2016.

[6] S. L. Karalunas, H. M. Geurts, K. Konrad, S. Bender, and J. T. Nigg, "Annual research review: Reaction time variability in ADHD and autism spectrum disorders: Measurement and mechanisms of a proposed trans-diagnostic phenotype," *Journal of Child Psychology and Psychiatry,* vol. 55, no. 6, pp. 685-710, 2014.

[7] D. Andriuta, M. Diouf, M. Roussel, and O. Godefroy, "Is reaction time slowing an early sign of Alzheimer's disease? A meta-analysis," *Dementia and Geriatric Cognitive Disorders,* vol. 47, no. 4-6, pp. 281-288, 2019.

[8] P. D. Maia and J. N. Kutz, "Reaction time impairments in decision-making networks as a diagnostic marker for traumatic brain injuries and neurological diseases," *Journal of computational neuroscience,* vol. 42, pp. 323-347, 2017.

[9] L. D. Medina *et al.*, "Reaction time and response inhibition in autosomal dominant Alzheimer's disease," *Brain and cognition,* vol. 147, p. 105656, 2021.

[10] A. S. Malik and H. U. Amin, *Designing EEG experiments for studying the brain: Design code and example datasets*. Academic Press, 2017.

[11] T. Batbat, A. Guven, and N. Dolu, "Olay İlintili Potansiyeller Üzerinden Dikkatin Hu Momentleri Yardımıyla Tespiti," *Academic Perspective Procedia,* vol. 2, no. 3, pp. 553-562, 2019.

[12] S. Balko *et al.*, "The influence of different caffeine doses on visual and audial reaction time with different delay from its consumption," *Science & Sports,* vol. 35, no. 6, pp. 358-363, 2020.

[13] C. R. James, J. A. Herman, J. S. Dufek, and B. T. Bates, "Number of trials necessary to achieve performance stability of selected ground reaction force variables during landing," *Journal of sports science & medicine,* vol. 6, no. 1, p. 126, 2007.

[14] J. Miller, "How Many participants? How many trials? Maximizing the power of reaction time studies," *Behavior Research Methods,* vol. 56, no. 3, pp. 2398-2421, 2024.

[15] J. Shelton and G. P. Kumar, "Comparison between auditory and visual simple reaction times," *Neuroscience and medicine,* vol. 1, no. 01, pp. 30-32, 2010.

[16] O. K. Wadoo, S. I. Sayeed, and M. Rouf, "Effect of Gender and Physical activity on Visual and Auditory reaction time in young Adults," *International Journal,* vol. 2, no. 2, p. 462, 2019.

[17] R. Verleger, "On the utility of P3 latency as an index of mental chronometry," *Psychophysiology,* vol. 34, no. 2, pp. 131-156, 1997.

[18] Y. Yagi, K. L. Coburn, K. M. Estes, and J. E. Arruda, "Effects of aerobic exercise and gender on visual and auditory P300, reaction time, and accuracy," *European journal of applied physiology and occupational physiology,* vol. 80, pp. 402-408, 1999.

[19] T. Batbat, A. Güven, and N. Dolu, "Evaluation of divided attention using different stimulation models in event-related potentials," *Medical & Biological Engineering & Computing,* vol. 57, pp. 2069-2079, 2019.

[20] V. Bari *et al.*, "From neurovascular coupling to neurovascular cascade: a study on neural, autonomic and vascular transients in attention," *Physiological measurement,* vol. 33, no. 8, p. 1379, 2012.

[21] A. Güven *et al.*, "Effects of methylphenidate on reaction time in children with attention deficit/hyperactivity disorder," *Archives of Neuropsychiatry,* vol. 56, no. 1, p. 27, 2019.

[22] M. Firdos, M. Nausheen, and Q. A. K. Ahmed, "Comparative study of visual and auditory reaction times on the basis of gender in first year medical students", 2021.

[23] T. P. Ghuntla, H. B. Mehta, P. A. Gokhale, and C. J. Shah, "A comparison and importance of auditory and visual reaction time in basketball players," *Saudi Journal of Sports Medicine,* vol. 14, no. 1, pp. 35-38, 2014.

[24] J. Dubois *et al.*, "Change in brain asymmetry reflects level of acute alcohol intoxication and impacts on inhibitory control," *Scientific Reports,* vol. 13, no. 1, p. 10278, 2023.