Research Article

Improvement of Attention in Subjects Diagnosed with Hyperkinetic Syndrome using BIOVIT Simulator

Cesar R Salas-Guerra*

Doctoral Program, Philosophy Department, Autonomous University of Barcelona Catalunya

***Corresponding Author**
Cesar R Salas-Guerra, PhD, DBA, Doctoral Program, Philosophy Department, Autonomous University of Barcelona Catalunya

Abstract
This study aimed to stimulate the brain's executive function through a series of tasks and rules based on dynamic perceptual stimuli using the Biotechnology Virtual Immersion Simulator (BIOVIT) and thus evaluate its usefulness to maintain and increase attention levels in subjects diagnosed with hyperkinetic syndrome. With a quantitative methodology framed in a longitudinal trend design, the cause of the exposure-outcome relationships was studied using the BIOVIT simulator. Exploratory analysis of oscillatory brain activity was measured using a graphical recording of brain electrical activity and attention levels. Data consisted of 77,566 observations from n = 18 separately studied participants. The findings established that the BIOVIT simulator maintained and increased the attention levels of the participants by 77.8%. Furthermore, the hypothesis was tested that virtual reality immersion technologies significantly affect attention levels in participants aged 8 to 12. The evidence shows that the BIOVIT simulator is an alternative to developing learning methodologies in vulnerable populations. The low implementation costs and the diversity of academic applications may allow schools in developing countries to solve this problem that afflicts thousands of children with attention deficit and hyperactivity disorder.

Keywords: Virtual Reality; User Experience; Attention; Hyperkinetic Syndrome; Brain Computer Interface

1. Introduction

Today human beings have developed new adaptive capacities based on information management through executive and cognitive functions. We can mention attention and memory as an ability to remember and carry out operations in the future through structured processes such as coding, interpretation, and storage [1, 2].

However, inadequate sensory processing regulations are identified as an additional dimension of the hyperkinetic syndrome [3]. Hyperkinetic syndrome or attention deficit with hyperactivity (ADHD) most commonly affects the child population [4]. There is substantial evidence linking hyperkinetic syndrome to various sensory processing dysfunction problems, presenting sensory modulation problems compared to others without (ADHD) [3].

Psychostimulant agents are described in some studies as a treatment to aid in patients' quality of life; though, ecological testing with virtual reality is a very encouraging option that benefits modulation of sensory signal processing and improves its performance because immersion in virtual reality allows the development of dynamic visual stimuli by optimally encoding the sensory information received and minimizes the distraction of incoming stimuli [4, 6, 7].

Within the paradigm that establishes virtual reality's potential to revolutionize education, , virtual reality environments may allow the user to immerse themselves in a simulation of everyday activities [4, 8]. This human-computer interface (HCI) requires a robust user experience (UX) design to track translational and rotational movements facilitating the development of dynamic perceptible stimuli [5]. One of them is visual and auditory information. These factors produce specific effects seen in the literature as beneficial for increasing and retaining attention naturally and frequently [8].

Therefore, this study aims to test the BIOVIT simulator that allows stimulating the executive function of the brain infusion into the real world through a series of tasks and rules based on dynamic perceptual stimuli by using virtual immersion biotechnology, thus managing to maintain and increase attention levels in subjects diagnosed with the hyperkinetic syndrome [5].

Several functions include the processing, propagation, and synchronization of information attributed to the brain's oscillating activity and making inferences about the environment to plan and meet goals successfully [6, 9].

2. Theoretical Framework: Information Processing Theory and the Neurophysiology of Learning

The information processing theory contributes to learning through stimuli used by attention, perception, and memory [10].

Recent literature establishes a relationship between the functions of the oscillatory activity of the brain, such as the processing, propagation, and synchronization of information with attention, with low-frequency oscillations being significant in the processes of perception of visual stimuli [9, 11].

These findings show that one of the qualities of attention is extracting the characteristics of a stimulus, increasing the brain activity involved in processing information and receptivity of active stimuli [1, 12]. Ecological testing with virtual reality is a very encouraging option that benefits sensory signal processing modulation and improves its performance because immersion in virtual reality allows the development of dynamic visual stimuli by optimally encoding the sensory information received (9) and minimizing the distraction of incoming stimuli [5, 7].

Therefore, new learning tools such as virtual immersion biotechnology composed of cognitive, affective, and physiological qualities would help students perceive, respond, and interact in different real-life situations [13].

Consequently, this theoretical approach demonstrates the importance of attention in storing information's coding and interpretation processes, and short-term memory develops sufficient semantic recovery resources [14]. With this premise, the following hypothesis was formulated, which will be verified in the study. H1: Virtual immersion biotechnology is beneficial for retaining and improving attention among children with hyperkinetic syndrome.

3. Research Methodology
This studio consists of a quantitative approach and longitudinal trend design, which seeks to identify the possible cause in the exposure-result ratio using the virtual immersion biotechnology simulator (BIOVIT) and exploratory analysis of brain electrical activity and attention levels. The data will be collected and analyzed according to the ethical protocols applicable to this study. Below is explained in detail the methodology used and the protocols implemented.

3.1 Participants
This study evaluated 77,566 observations from 18 students from 8 to 12 years of age diagnosed with the hyperkinetic syndrome. Recruitment was carried out incidentally by disseminating the live voice project through information exposed in the respective associations of support for relatives of patients with hyperkinetic syndrome in two schools in the north of Minas Gerais, Brazil.

Participation was voluntary, unpaid, and with the prerequisite of reading and approving the research project's information sheet and the signature of their respective informed consent. The sample was an intentional pseudorandom selected through the inclusion and exclusion criteria, the parents' respective authorities, and the individual academic institutions' ethics committee under current scientific recommendations [15]. The inclusion criteria are described in appendix 1.

3.2 Data Security
The data generated in the study were stored in a digital repository using information encryption processes, thus complying with the policies of integrity, traceability, and adequate preservation during the time established by the systematic generation of periodic backups, which will be stored for a current period of five years [16].

A copy of this will be returned to the subject after the study is completed, ensuring that it is not disseminated by mistake or without care. Similarly, the program (Software) used in the patient data recording process was archived for the time established in the protocol.

3.3 Potential Research Risk
Invasive among the risks or discomfort that may arise from volunteers' participation in the study, it is imperative to establish the difference between non-invasive and invasive brain electrical activation studies. The first is an s electroencephalogram, a neurophysiological examination that uses electrodes overlaid on the scalp to record activity in the cerebral cortex.

The Second, electrocorticography, is a neurophysiological examination that uses electrodes placed directly on the brain's exposed surface to record activity in the cerebral cortex through craniotomies or in the operating room during surgery. Therefore, EEG is recognized as a safe and non-invasive method for neuroeducation applications based on electronic data generation devices.

4. Methodological Procedure
This section describes the methodological procedure used for data collection and analysis, with a brief integrative review that includes empirical and technical literature. Therefore, it can provide a complete understanding of how the research was conducted in the field. This procedure included the following steps: 1) the brain electrical activity register, 2) virtual immersion biotechnology simulator (BIOVIT), 3) ecological validation of virtual immersion biotechnology test (BIOVIT), and 4) human computer-interface environment.

4.1 First Phase Research: The Brain Electrical Activity Register
Within this macro-physiological data recording process, the participants were instructed to keep calm and collaborate with the monopolar electroencephalogram; the specifications and characteristics of the EGG used in the study are described below: (Table 1) [7].

This device consists of an external cranial adapter located on the left side of the forehead called in the electrodeposition nomenclature as the left hemisphere's Fp1 frontopolar region; the data collection device has algorithms called eSense™ which measure attention and meditation levels [17, 18]. These algorithms develop dynamic oscillation processes and spectra by adapting natural fluctuations based on each participant's trends using visual, audible, and tactile stimuli from the BIOVIT virtual immersion simulator. The eSense algorithm™ set a measurement scale for attention and meditation consisting of low performance

(1-39), normal or base performance (40-60), and superior performance (61-100).

4.2 Second Phase Research: Virtual Immersion Biotechnology Simulator (BIOVIT)

Recent literature emphasizes the need for a new generation of tests led by functions that allow the stimulation of the executive brain system in the real world and the possibility of tasks adapting according to the study population [19]. The conceptual incorporation of the MET mandates test with the use of a virtual immersion biotechnology simulator (BIOVIT) offered the possibility of obtaining a detailed record of the individual performance of each participant, combining the rigor and control of tests with fixed stimuli performed in the laboratory, to simulations that reflect dynamic stimuli in real-life situations [19, 20].

The BIOVIT tool allowed to stimulate the brain's executive function infusion into the real world through a series of tasks and rules based on dynamic perceptual stimuli by using virtual immersion technology, and this tool is composed of two dimensions: resource use and time use. In the test's execution, participants were asked to meet the objectives that require problem-solving and decision-making within the virtual immersion environment [5, 21].

Several previous studies have provided sufficient evidence of the efficiency of virtual reality content and video games in evaluating executive functions [5]. Recently, virtual reality content and video games have been studied separately. The user experience (UX) between the traditional spaces and the new virtual reality environments allows study participants to satisfactorily meet the objectives [22]. The efficiency of the design (UX) in these new environments is due to the degree of spatial tracking in the user interface that does not depend only on the relative sensory orientation or the orientation senses but on the immersive experience through the degrees of freedom in the rotation-translation movements through tracking and depth sensors. (Figure 1).
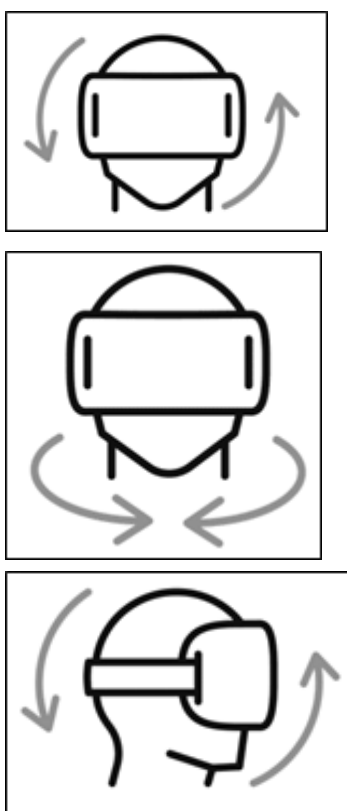

Figure 1: Three-degree-of-freedom (3DoF)

Note: Three-degree-of-freedom (3DoF) tracking tracks rotational movements. It is the simplest form of monitoring and relies entirely on the sensors (accelerometers, gyros, and magnetometers) built into mobile phones that use virtual reality headsets to measure movement.

4.3 Third Phase Research: Ecological Validation of Virtual Immersion Biotechnology Test (BIOVIT)

Ecological assessment is called a "function-based approach" (Serino & Repetto, 2018), which involves direct observation of behavior that includes daily life tasks. This validation process establishes the importance of likelihood as a replicability principle within behaviors of interest based on direct observation [19, 23].

Of the existence of outdated technologies and static stimuli related to the traditional use of laboratory tests, all this needs to include the contexts of affection and motivation required in evaluating real-world activities [24]. Indeed, virtual immersion technology has been identified as suitable for developing ecologically valid environments, as 3D objects in spatial computing are presented consistently and accurately [5].

Therefore, the BIOVIT test was used as part of a new generation of video-based virtual immersion tools, which proved ready to motivate and challenge the participant, providing easy access to experimentation based on "fun" and a sense of commitment and self-efficacy, supporting the brain to acquire the new and complex skill [22, 25].

4.4 Four Phases of Research: Human Computer-Interface Environment

Through a human-computer interface (HCI), the MET test could be adapted with a usability design that helps users perform their tasks smoothly [26]. It has also made it possible to combine and develop new techniques, such as using haptic devices adapted to virtual immersion simulators and collecting brain activity simultaneously with the test's execution in real time.

Considering the MET's conceptual framework within the requirements of the study, it was established the need for the participant in the virtual immersion process to use a haptic device that helps in the acquisition of skills in specific tasks of the execution of the test; in addition to having proven in previous studies, its valuable contribution to learning [20, 25].

The haptic device used with the virtual reality simulator was a steering wheel that will contribute to developing a level of commitment generating emotion due to different degrees of pressure since, in some studies, it has been identified that these devices used together with virtual reality simulators contribute to the proper use of the hands to perform specific tasks [21, 27].

Therefore, the haptic device and the virtual environment selected for this test were the virtual simulator Real Feel Racing which has tree-degree-of-freedom (3DoF) tracking, which tracks rotational movements based on sensors (accelerometers, gyroscopes, and magnetometers) built into the mobile device [28, 29].

This virtual immersion simulator consists of eight racetracks, which the participant can select. This simulator consists of four models of race cars identified with different colors. The participant selects the panoramic view within the immersion environment, among which they can choose the perspective mode, foreground, background, and third plane (Figure 2).

Figure 2: Real Feel Racing Virtual Simulator

4.4.1 Task and Rules Guideline
This test was based on a guideline that was explained to each participant in their native.

Language and Included
Task Section: in this section, the participant was asked to select the track, the car color, and the panoramic view. Besides, he was asked to finish the race in the shortest time possible while avoiding accidents that could delay it (Figure 3).

Figure 3: BIOVIT Task imagen

Rules Section: in this section, the participant was asked not to leave the race before the time necessary to complete the evaluation, nor to exceed the time required to complete the evaluation, and finally, not remove the VR goggles before the time required to complete the evaluation (Figure 4).

Figure 4: BIOVIT Rules imagen

5. Measurement Research Model

The data were analyzed with the Minitab version 18.1 program for MS Windows 10, where descriptive and inferential statistics were performed, and a new measurement scale was designed. To comply with the assumptions of normality, the Anderson-Darling test was performed using the hypothesis test to search for normalcy.

5.1 First Phase Data Analysis: Hypothesis Test for Normality Search

Before performing the hypothesis test, the assumption of normality is verified:

H_o Data follow a normal distribution
H_1 Data do not follow a normal distribution

Given the test results with *p-values* of .005 in AD, the null hypothesis is rejected. Therefore, according to the nature of this type of data, the data collected do not follow a normal distribution. (Table 2)

5.2 Second Phase Data Analysis: Central Trend Descriptive Tests

The essential characteristics of the study data are described below. They provide a simple summary of the sample and measurements (Table 3).

5.3 Third Phase Data Analysis: Creation of the Measurement Model

The attention growth analysis model was created based on a non-stationary time series. The respective preliminary tests were carried out with the linear model, exponential growth, quadratic, and S curve; to determine which model best fits the data of this research.

The data obtained in the MAPE (mean absolute percentage error), MAD (absolute deviation of the mean), and MSD (squared deviation of the mean) tests were compared. These tests allowed us to observe that the quadratic model has a more significant data fit since the results obtained were lower than the other models, thus confirming what the literature review mentions.

The selected model includes a non-stationary time series showing the growth trend. The quadratic model estimation uses the following function:

$$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + e_t$$

Where Y_t is the value of attention in time, β_0 is the constant, β_{1-2} the coefficients, t time unit value and e_t the error term. Therefore, if $\beta_1, \beta_2 > 0, Y_t$ observation is monotonous increasing, if $\beta_1, \beta_2 < 0, Y_t$ is monotonous decreasing. In the same way if $\beta_1 > 0$ y $\beta_2 < 0, Y_t$ is concave down, and if $\beta_1 < 0$ y $\beta_2, > Y_t$ its shape is concave upwards. Complete analysis in appendix 2.

5.4 Four-Phase Data Analysis: Time Measurement Scale

The selected time scale (t) was in minutes and seconds as the collection process using the BIOVIT tool was performed on a minute and second scale that was the maximum time that lasted the respective tests $t = 5.37$. (Table 4)

5.5 Five-Phase Data Analysis: New Measurement Scale Design
EFGA Degrees of the Care Frequency Scale

Considering that the scale assigned by the eSense algorithm™ for attention and meditation is: low performance (*1-39*), average or base performance (*40-60*), superior performance (*61-100*), and since a scale that fits the study variables has not been found in the literature review, a scale called "Attention Grade Frequency Scale - EFGA" was designed for this study, which consists of the following function:

$$f_{biovit} = M_o / Mape \; x \; 100$$

Where f is the value of the composite scale of attention as a function of the stimulation of the virtual immersion technology tool (BIOVIT). M_o are repeated values more frequently within the observations. MAPE is the absolute percentage error medium. Thus, the higher the scale result, the better the care process.

5.5.1 Internal Validation and Reliability Estimation

Cronbach's Alpha test and Pearson's Correlation were used to perform the Internal validation of the EFGA degree of attention frequency scale, seeking to evaluate the internal uniformity of the scale, as well as the strength and direction of the relationship between elements; the results yielded $\alpha = .959$ and $r = .922$; therefore, the EFGA will be kept as a scale within this investigation (Table 5).

5.5.2 Six-Phase Data Analysis: Mann-Whitney Hypothesis Test

The previous growth trend test results presented minimum scores in the mean absolute percentage error MAPE, which validated the model's fit and precision from the growth of the repeated values more frequently (M_o) within the observations.

The nonparametric Mann-Whitney test was performed to validate and determine if the two groups' medians differ significantly, since the higher the attention growth, the lower the mean absolute percentage error. Therefore, the first hypothesis test was performed separately with the first fourteen participants, n = 14. The hypotheses of the Mann-Whitney test are described below:

H_o $n_1 - n_2 = 0$
H_1 $n_1 - n_2 > 0$

Given that the p-value = .001 is less than the significance level of 0.05, we rejected the null hypothesis. We concluded that the level of care was maintained and grew considerably using the BIOVIT tool (Table 6).

The second Mann-Whitney hypothesis test was performed, which is described below:

H_o $n_1 - n_2 = 0$
H_1 $n_1 - n_2 < 0$

Given that the *p-value* = .002 is less than the 0.05 level of significance, we reject the null hypothesis and conclude that the level of attention decreased considerably with the BIOVIT tool (Table 7).

5.6 Discussion and Conclusions

Comparing the theoretical model and the results of the tests carried out; we can conclude that the BIOVIT tool maintained and increased the participants' attention levels by 77.8%. Consistent

with the hypothesis test results, it was possible to conclude that the BIOVIT tool has a statistically significant effect on the retention and increase of attention in children aged 8 to 12 years diagnosed with hyperkinetic syndrome.

Therefore, BIOVIT is an alternative for developing biocybernetics learning methodologies in vulnerable populations. The low implementation costs and the diversity of academic applications can allow educational centers in developing countries to solve this problem that afflicts thousands of children with attention deficit and hyperactivity disorder.

Finally, due to the type of study population, which has characteristics and treatments, in addition to the financial resources that an international investigation contemplates, certain limitations were identified about longitudinal follow-up that could allow observing changes in the attentional processes of the daily life of the participant, as well as integration tests in traditional academic environments with the use of virtual immersion technology.

References

1. Grandi, F., & Tirapu-Ustárroz, J. (2017). Neuropsicología de la memoria prospectiva basada en el evento. Rev Neurol, 65(5), 226-33.
2. Fombuena, N. G. (2016). Normalización y validación de un test de memoria en envejecimiento normal, deterioro cognitivo leve y enfermedad de Alzheimer. In Universitat Ramon Llull.
3. Navarra, R. L., & Waterhouse, B. D. (2019). Considering noradrenergically mediated facilitation of sensory signal processing as a component of psychostimulant-induced performance enhancement. Brain Research, 1709, 67-80.
4. Rubiales, J., Bakker, L., Russo, D. P., & González, R. (2014). Memoria verbal y estrategias de recuperación en niños con trastorno por déficit de atención e hiperactividad.
5. Parsons, T. D., Carlew, A. R., Magtoto, J., & Stonecipher, K. (2017). The potential of function-led virtual environments for ecologically valid measures of executive function in experimental and clinical neuropsychology. Neuropsychological rehabilitation, 27(5), 777-807.
6. Młynarski, W. F., & Hermundstad, A. M. (2018). Adaptive coding for dynamic sensory inference. Elife, 7, e32055.
7. Yuste, R., Goering, S., Arcas, B. A. Y., Bi, G., Carmena, J. M., Carter, A., ... & Wolpaw, J. (2017). Four ethical priorities for neurotechnologies and AI. Nature, 551(7679), 159-163.
8. Marian, V., Hayakawa, S., Lam, T. Q., & Schroeder, S. R. (2018). Language experience changes audiovisual perception. Brain sciences, 8(5), 85.
9. Kissinger, S. T., Pak, A., Tang, Y., Masmanidis, S. C., & Chubykin, A. A. (2018). Oscillatory encoding of visual stimulus familiarity. Journal of Neuroscience, 38(27), 6223-6240.
10. Moos, D. (2015). Information Processing Theory in Context. In Educational Psychology (Educational Psychology).
11. Einstein, M. C., Polack, P. O., Tran, D. T., & Golshani, P. (2017). Visually evoked 3–5 Hz membrane potential oscillations reduce the responsiveness of visual cortex neurons in awake behaving mice. Journal of Neuroscience, 37(20), 5084-5098.
12. Ruiz-Contreras, A., & Cansino, S. (2005). Neurofisiología de la interacción entre la atención y la memoria episódica: revisión de estudios en modalidad visual. Revista de neurología, 41(12), 733-743.
13. Freiberg Hoffmann, A., & Fernández Liporace, M. M. (2015). Estilos de aprendizaje en estudiantes universitarios ingresantes y avanzados de Buenos Aires. Liberabit, 21(1), 71-79.
14. Luna-Lario, P., Peña, J., & Ojeda, N. (2017). Comparación de la escala de memoria de wechsler-iii y el test de aprendizaje verbal españa-complutense en el daño cerebral adquirido: Validez de constructo y validez ecológica. Rev Neurol, 64(8), 353-61.
15. Hueso, A., & Josep Cascant, M. (2012). Metodología técnicas cuantitativas de investigación.
16. de Educación, C. D. M. C. (2013). Orden 2091/2013, de 27 de junio, por la que se autoriza la creación de la Escuela de Doctorado de la Universidad Carlos III de Madrid.
17. Morillo, L. E. (2008). Analisis visual del electroencefalograma. R. Gomez, B. Hernandez, U. Rojas, O. Santacruz, & R. Uribe, Psiquiatria Clinica: diagnóstico en niños, adolescentes y adultos 3ra. edición (pág. Cap 17). Bogota, Colombia.: Editorial médica Panamericana.
18. Nasir, T. B., Lalin, M. A. M., Niaz, K., Karim, M. R., & Rahman, M. A. (2021, January). EEG based human assistance rover for domestic application. In 2021 2nd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST) (pp. 461-466). IEEE.
19. Pallavicini, F., Pepe, A., & Minissi, M. E. (2019). Taking neuropsychological test to the next level: Commercial virtual reality video games for the assessment of executive functions. In Universal Access in Human-Computer Interaction. Multimodality and Assistive Environments: 13th International Conference, UAHCI 2019, Held as Part of the 21st HCI International Conference, HCII 2019, Orlando, FL, USA, July 26–31, 2019, Proceedings, Part II 21 (pp. 133-149). Springer International Publishing.
20. Shallice, T. I. M., & Burgess, P. W. (1991). Deficits in strategy application following frontal lobe damage in man. Brain, 114(2), 727-741.
21. Mäkinen, H., Haavisto, E., Havola, S., & Koivisto, J. M. (2022). User experiences of virtual reality technologies for healthcare in learning: An integrative review. Behaviour & Information Technology, 41(1), 1-17.
22. Serino, S., & Repetto, C. (2018). New trends in episodic memory assessment: immersive 360 ecological videos. Frontiers in psychology, 1878.
23. Heart Stroke Foundation. (2019). Multiple Errands Test (MET) - Stroke Engine.
24. Parsons, T. D. (2015). Virtual reality for enhanced ecological validity and experimental control in the clinical, affective and social neurosciences. Frontiers in human neuroscience, 9, 660.
25. Prasad, R., Muniyandi, M., Manoharan, G., & Chandramohan, S. M. (2018). Face and construct validity of a novel virtual reality–based bimanual laparoscopic force-skills trainer

with haptics feedback. Surgical Innovation, 25(5), 499-514.

26. Hassanien, A. E., & Azar, A. T. (2015). BCI: Current Trends and Applications. Spring, 74(416), 416.

27. Girod, S., Schvartzman, S. C., Gaudilliere, D., Salisbury, K., & Silva, R. (2016). Haptic feedback improves surgeons' user experience and fracture reduction in facial trauma simulation. Journal of Rehabilitation Research & Development, 53(5).

28. Bonetti, F., Warnaby, G., & Quinn, L. (2018). Augmented reality and virtual reality in physical and online retailing: A review, synthesis and research agenda. Augmented reality and virtual reality: Empowering human, place and business, 119-132.

29. Pak, J., & Maoz, U. (2019). Compact 3 DOF driving simulator using immersive virtual reality. arXiv preprint arXiv:1909.05833.

Appendix 1 Inclusion and exclusion criteria

Participants met the following inclusion criteria as follows:

1. Residents in Montes Claros, State of Minas Gerais, Republic of Brazil.
2. Have a clinical diagnosis of attention deficit and hyperactivity.
3. Do not receive psychostimulant medicine within 24 hours before the test.
4. His first language must be Portuguese.
5. Age ranges from 8 to 12 years.
6. Fundamental teaching schooling.
7. Hearing and vision physical conditions should be adequate to participate in the test, using if necessary, corrective prosthetic measures, such as using glasses, hearing aids, or any other device.
8. Sufficient ability to see, listen, and use either of its two limbs to use the virtual immersion simulator.
9. The following factors were considered for exclusion criteria:
10. Lack of will or inability of the participant to collaborate appropriately in the study.
11. Any central nervous system pathology may affect cognition such as Parkinson's disease, Huntington's disease, brain tumour, hydrocephalus, progressive supranuclear epilepsy, subdural hematoma, multiple sclerosis, hand history of cerebral infarction.
12. A major depressive episode or dysthymic disorder, according to DSM-V criteria.
13. Unstable or clinically significant cardiovascular disease in the previous six months may impact mental abilities in the clinician's opinion.
14. Be patient with diabetes with insulin dependence level.
15. Any situation that, in the opinion of the principal investigator, is unsuitable for the study.

Variable	M_o	Mape	EFGA	QUADRATIC TREND ANALYSIS	eSense™
MOC1-3	88	13. 53	6.50		>61 Superior
MOC2-4	100	17. 50	5.71		>61 Superior

MOC0-3	100	17. 87	5.61	Gráfica de análisis de tendencia de MOC0-3 Modelo de tendencia cuadrática Yt = 86.088 - 0.000508×t + 0.000000×t^2	>61 Superior
MOC2-1	100	22. 04	4.53	Gráfica de análisis de tendencia de MOC2-1 Modelo de tendencia cuadrática Yt = 67.339 + 0.000805×t - 0.000000×t^2	>61 Superior
MOC1-8	41	22.22	1.84	Gráfica de análisis de tendencia de MOC1-8 Modelo de tendencia cuadrática Yt = 48.400 - 0.000205×t + 0.000000×t^2	>40 Normal
MOC2-5	63	24.00	2.62	Gráfica de análisis de tendencia de MOC2-5 Modelo de tendencia cuadrática Yt = 59.033 + 0.000135×t - 0.000000×t^2	>61 Superior

MOC1-5	51	25.12	2.03			>40 Normal
MOC2-3	50	25. 22	1.98			>40 Normal
MOC0-4	61	29. 39	2.07			>61 Superior
MOC1-1	47	32. 51	1.44			>40 Normal

MOC1-7	57	34.20	1.66		>40 Normal
MOC1-2	37	35. 78	1.03		<39 Bass
MOC1-6	53	36. 97	1.43		>40 Normal
MOC0-2	53	48. 22	1.09		>40 Nor-mal

Quadratic Trend Analysis 2

Variable	M_o	MAPE	EFGA	QUADRATIC TREND ANALYSIS	eSense™
MOC1-4	30	48. 28	0.62		<39 Bass
MOC2-2	47	54. 21	0.86		>40 Normal
MOC0-1	41	73. 27	0.55		>40 Normal
MOC2-6	30	77. 34	0.38		<39 Bass

Appendix 3 Tables and Figures

Table 1: EEG Monopolar NeuroSky Specifications

Specifications	NeuroSky EEG	Diagram
Weight:	90g	
Top sensor dimensions:	225mm x width:155mm x depth: 92mm	
Lower sensor dimensions:	225mm x width:155mm x depth:165mm	
Force Range:	30mw to 50mw - 6dBm RF max power	
Frequency:	2,420 - 2.471GHz RF	
Data Range:	250kbit/s RF	
Range:	10m RF	
Packet Loss:	5% via Wireless	
Uart baudrate:	57,600 baud	
Maximum input signal:	1mV pk range signal	
Hardware Range Filter:	3Hz to 100hz	
ADC Resolution:	12bits	
Sample range:	512Hz	
Esense calculation range:	1Hz	

Table 2: Anderson-Darling Test Results

Variables	Average	Des.Est.	Observations	And.Darling	P-value
MOC0-1	45.233	15.062	77566	300.082	.005
MOC0-2	48.179	21.226	77566	531.850	.005
MOC0-3	77.642	15.217	77566	988. 968	.005
MOC0-4	58.862	18.083	77566	405.. 306	.005
MOC1-1	47.218	13.702	77566	223.. 417	.005
MOC1-2	43.284	16.593	77566	1021. 765	.005
MOC1-3	78.769	13.137	77566	945.077	.005
MOC1-4	43.080	17.258	77566	402.820	.005
MOC1-5	48.602	14.321	77566	392. 797	.005
MOC1-6	56.832	21.716	77566	408.. 314	.005
MOC1-7	51.642	17.421	77566	396. 607	.005
MOC1-8	42.252	10.371	77566	512. 637	.005
MOC2-1	73.134	17.820	77566	556.. 770	.005
MOC2-2	54.353	20.798	77566	682.. 612	.005
MOC2-3	46.945	12.966	77566	298.004	.005
MOC2-4	72.466	14.850	77566	459.. 790	.005
MOC2-5	59.452	15.008	77566	398.853	.005
MOC2-6	40.626	16.167	77566	274.. 991	.005

Table 3: Descriptive statistics of experimental conditions

Variable	Observations	Average	Variance	Desv.Est.	M_o
MOC0-1	77566	45.233	226.849	15.062	41
MOC0-2	77566	48.179	450.533	21.226	53
MOC0-3	77566	77.642	231.546	15.217	100
MOC0-4	77566	58.862	327.000	18.083	61
MOC1-1	77566	47.218	187.747	13.702	47

MOC1-2	77566	43.284	275.318	16.593	37
MOC1-3	77566	78.769	172.584	13.137	88
MOC1-4	77566	43.080	297.848	17.258	30
MOC1-5	77566	48.602	205.092	14.321	51
MOC1-6	77566	56.832	471.580	21.716	53
MOC1-7	77566	51.642	303.492	17.421	57
MOC1-8	77566	42.252	107.561	10.371	41
MOC2-1	77566	73.134	317.549	17.820	100
MOC2-2	77566	54.353	432.568	20.798	47
MOC2-3	77566	46.945	168.117	12.966	50
MOC2-4	77566	72.466	220.522	14.850	100
MOC2-5	77566	59.452	225.239	15.008	63
MOC2-6	77566	40.626	261.385	16.167	30

Table 4: Attention growth analysis

Variable	M_o	MAPE	Mad	Msd	BIOVITt
MOC0-1	41	73.270	11.678	221.284	5.14
MOC0-2	53	48.216	14.719	304.994	5.37
MOC0-3	100	17.865	12.529	222.564	3.52
MOC0-4	61	29.386	14.666	322.506	3.09
MOC1-1	47	32.512	10.998	186.171	3.13
MOC1-2	37	35.782	12.154	232.832	3.09
MOC1-3	88	13.530	9.600	139.165	3.17
MOC1-4	30	48.280	13.512	297.418	5.28
MOC1-5	51	25.124	10.484	174.809	3.26
MOC1-6	53	36.967	14.060	303.367	3.43
MOC1-7	57	34.203	14.258	286.215	5.09
MOC1-8	41	22.224	8.264	98.226	4.04
MOC2-1	100	22.039	12.723	269.204	3.36
MOC2-2	47	54.210	15.829	396.084	3.25
MOC2-3	50	25.217	10.177	159.141	3.25
MOC2-4	100	17.500	11.716	199.137	3.22
MOC2-5	63	24.003	11.611	222.764	2.32
MOC2-6	30	77. 343	11.759	204.672	3

Table 5: Normal-superior EFGA attention scale

Variable	M_o	Mape	EFGA
MOC1-3	88	13. 53	6.50
MOC2-4	100	17. 50	5.71
MOC0-3	100	17. 87	5.61
MOC2-1	100	22. 04	4.53
MOC1-8	41	22.22	1.84
MOC2-5	63	24.00	2.62
MOC1-5	51	25.12	2.03
MOC2-3	50	25. 22	1.98
MOC0-4	61	29. 39	2.07
MOC1-1	47	32. 51	1.44
MOC1-7	57	34.20	1.66

Table 6: Low EFGA attention scale

Variable	M_o	MAPE	EFGA
MOC2-2	47	54. 21	0.86
MOC1-4	30	48.28	0.62
MOC0-1	41	73. 27	0.55
MOC2-6	30	77. 34	0.38

Table 7: First Mann-Whitney hypothesis test

Variable	M_o	MAPE	N.Trust.	IC Inf.	p-value
MOC1-3	88	13.53	95.32%	23.13	.001
MOC2-4	100	17.50	95.32%	23.13	.001
MOC0-3	100	17.87	95.32%	23.13	.001
MOC2-1	100	22.04	95.32%	23.13	.001
MOC1-8	41	22.22	95.32%	23.13	.001
MOC2-5	63	24.00	95.32%	23.13	.001
MOC1-5	51	25.12	95.32%	23.13	.001
MOC2-3	50	25.22	95.32%	23.13	.001
MOC0-4	61	29.39	95.32%	23.13	.001
MOC1-1	47	32.51	95.32%	23.13	.001
MOC1-7	57	34.20	95.32%	23.13	.001
MOC1-2	37	35.78	95.32%	23.13	.001
MOC1-6	53	36.97	95.32%	23.13	.001
MOC0-2	53	48.22	95.32%	23.13	.001

Table 8: Second Mann-Whitney hypothesis test

Variable	M_o	MAPE	N.Trust.	IC Inf.	p-value
MOC1-4	30	48.28	95.37%	-7.21	.002
MOC2-2	47	54.21	95.37%	-7.21	.002
MOC0-1	41	73.27	95.37%	-7.21	.002
MOC2-6	30	77.34	95.37%	-7.21	.002