Serious Videogame for Evaluating and Analyzing Behavior in Individuals with Potential ADHD

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Abstract. Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental condition characterized by difficulties in maintaining attention, controlling impulses, and regulating behavior. Traditional diagnosis is based on a combination of questionnaires, clinical observation, and neuropsychological tests, such as the Test of Variables of Attention (TOVA), the MOXO Test, and the Conners' Scale. While these tools are useful, they are usually conducted in controlled environments and require the psychologist's subjective interpretation, which can make them somewhat boring, impractical, and sometimes inaccessible.

Keywords: ADHD, video game, neuroscience, behavioral analysis, physiological signals.

1 Introducción

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common neurodevelopmental disorders in childhood and can persist into adulthood, significantly affecting the quality of life of those who suffer from it. This disorder is characterized by difficulties in sustained attention, impulse control, and hyperactivity, which interfere with the academic, work, and social performance of individuals [1]. The main symptoms are grouped into three categories: inattention, hyperactivity, and impulsivity, with predominantly inattentive, hyperactive-impulsive, or combined presentations [2].

The diagnosis of ADHD is primarily based on clinical observation, structured interviews, and the application of objective tests, such as the Conners' Continuous Performance Test II and the MOXO d-Cpt test. These tools allow for the assessment of affected executive functions, such as sustained attention, impulse control, and response time. However, these methods are often static, repetitive, and unattractive to patients, especially in children and adolescent populations [3]. Furthermore, these tests lack dynamic stimuli that better represent the demands of the real environment.

In this context, the present research proposes an innovative alternative for the evaluation of ADHD, based on the dynamics of a video game conducted in Geometry Dash. This gamified approach not only maintains the user's interest during the evaluation but also allows for the analysis of cognitive and behavioral performance in an interactive

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and progressive environment. Through five levels specifically designed, the game evaluates key aspects such as sustained attention, impulsivity, frustration, and cognitive flexibility, providing an experience closer to today's digital reality and fostering greater patient engagement.

The relevance of this project lies in its ability to improve diagnostic accuracy through an attractive and accessible approach, overcoming the limitations of traditional tests. By combining gamification with clinical assessment, it is expected to facilitate the early detection of ADHD and optimize the customization of therapeutic interventions, creatively enhancing the tools available for healthcare professionals to evaluate and treat this disorder. This innovative method aims to make the assessment process more engaging and reflective of everyday challenges faced by individuals with ADHD, thereby improving the overall effectiveness of interventions and support strategies offered to them.

2 Literature Review

2.1 ADHD: Characteristics, Neurobiology, and Treatment Options

Attention Deficit Hyperactivity Disorder (ADHD) is characterized by difficulty maintaining attention, increased distractibility, poor impulse control, hyperactivity, emotional instability, and disorganized behavior. This neurodevelopmental disorder is essentially characterized by deficits in executive functions, which can be defined as the actions an individual uses to self-regulate and achieve goals. The main executive domains affected in this population include time management, organization, problem-solving, motivation, and emotion management [1]. ADHD encompasses three main groups of symptoms: inattention, hyperactivity, and impulsivity [2]. Attention Deficit Hyperactivity Disorder (ADHD) is the most common neurodevelopmental disorder in childhood, of genetic and multifactorial origin with a neurological substrate mainly affecting the frontal lobe and its connections with the basal ganglia [3].

Attention Deficit Hyperactivity Disorder (ADHD) is associated with dysregulation of the catecholaminergic pathways, specifically the neurotransmitters dopamine and norepinephrine. This alteration affects executive functions such as attention, impulse control, and motor activity regulation [4]. Pharmacological treatments for ADHD include stimulant and non-stimulant medications. Stimulants, such as methylphenidate and amphetamines, work by increasing the availability of dopamine and norepinephrine in the brain [5]. Methylphenidate inhibits the reuptake of these neurotransmitters, while amphetamines, in addition to inhibiting reuptake, promote their release into the synaptic space. These mechanisms help to improve attention and reduce hyperactivity and impulsivity in patients with ADHD. On the other hand, non-stimulant medications, such as atomoxetine, work by selectively inhibiting the reuptake of norepinephrine, increasing its availability in the brain. Although their efficacy may be lower compared to stimulants, they represent a therapeutic alternative, especially in cases where stimulants are not well tolerated or are contraindicated [6]. It is essential that ADHD treatment be individualized and supervised by healthcare professionals, considering the specific characteristics of each patient and regularly evaluating the efficacy and potential side effects of the medication.

Based on the types of symptoms, there are three types (presentations) of attention deficit hyperactivity disorder: predominantly inattentive presentation, predominantly hyperactive-impulsive presentation, and combined presentation (a combination of inattention and hyperactivity-impulsivity symptoms) [7]. Adults with ADHD may have difficulties with: managing their attention, completing long tasks unless they are interesting, staying organized, controlling their behavior, and/or symptoms of hyperactivity [8].

2.2 Assessing ADHD: Traditional Methods and a New Video Game-Based Approach

In patients with ADHD, if the following behaviors are constantly present for more than 6 months, it is necessary to give importance due to the relationship it has in the behavior of a person with ADHD. In the realm of inattention, we have: often avoids, dislikes, or is reluctant to engage in tasks that require mental effort over a long period of time, loses things necessary for tasks and activities, has trouble organizing tasks and activities, does not pay close attention to details or makes careless mistakes, appears not to listen when spoken to directly, does not follow instructions and/or fails to finish tasks; in the realm of hyperactivity, we have the following behaviors: fidgets nervously or taps with hands or feet, leaves the seat in situations where remaining seated is expected, cannot play or engage in leisure activities quietly, acts as if "driven by a motor", talks excessively, blurts out an answer before a question has been completed, has trouble waiting their turn and/or interrupts or intrudes on others' activities [9].

From these behaviors and symptoms, a diagnosis is made, the diagnosis of ADHD is essentially clinical and is based on the confirmation of the presence of symptoms through clinical observations, structured, semi-structured interviews, and objective tests. Sometimes, it is also important to interview a family member or person living with the individual experiencing the symptoms [10]. Some of the tests used for detection include the Conners' Continuous Performance Test II, which assesses attention problems and treatment utility. It is a commonly used tool in ADHD research and clinical evaluations for participants aged 6 years and older. The test is performed on a computer. The participant presses the spacebar or clicks the mouse button when a letter other than X appears on the screen. Letters appear on the screen at varying time intervals [11]. The d-Cpt MOXO test is a tool that objectively measures executive functions using the evaluation of attention, response time, impulsivity, and hyperactivity; its system of distractors allows assessing the patient's performance in various environments using letters and/or beeps, which are less stimulating for evaluating ADHD [12].

Compared to traditional tests such as the Conners' Continuous Performance Test II and the d-Cpt MOXO test, the proposed project based on the dynamics of the video game Geometry Dash represents a more innovative and attractive approach to evaluating ADHD. While conventional tools are limited to controlled, repetitive environments with simple stimuli (letters and beeps), the proposal integrates an interactive and gamified environment that evaluates the same metrics under more dynamic conditions closer to the reality of today's digital environment.

The design of the five levels of the video game allows a progressive and multifaceted evaluation of the executive functions affected by ADHD. Unlike traditional tests, where stimuli are static and monotonous, this approach introduces synchronized visual and auditory stimuli, increasing the level of complexity and variability at each stage. This evolution in difficulty not only allows for the assessment of sustained attention, impulsivity, and hyperactivity but also provides information on the patient's ability to adapt to changing situations and manage frustration.

3 Methodology

To address this challenge, we developed MindRush, a system based on a video game designed to assess attention, impulsivity, stress tolerance, frustration, and boredom response through the analysis of interactional, behavioral, physiological, and emotional data. Unlike traditional tests, MindRush offers an interactive and dynamic environment that engages the subject with a naturally controlled stimulus environment, allowing for a more objective, fun, and accessible evaluation. The game consists of five progressive levels, each designed to provoke specific behaviors which will make it possible to differentiate between a person suffering from ADHD and one who does not. Level 1: Induction, Level 2: Attention, Level 3: Stress and Frustration, Level 4: Advanced Attention, Level 5: Boredom. As participants play, their physiological signals such as heart rate variability, brain activity (EEG), skin conductivity, and pinky finger temperature are recorded. Additionally, qualitative (behavioral) data such as anxious movements or expressions and how they interact and perform in the video game are collected, noting their reaction times, concentration, and progress. At the end of each level, participants complete the Self-Assessment Manikin (SAM) questionnaire, which measures how they felt during the activity in terms of valence, arousal, and dominance.

3.1 Acquisition Protocol

Data acquisition in the MindRush experiment followed a structured protocol that included signing informed consent, placing biosensors (heart rate, EEG, thermal conductivity, and temperature), playing the video game, and collecting behavioral and physiological metrics in real-time. During the game, correct, impulsive, hyperreactive, and omitted jumps were evaluated, along with attempts and completion time. At the end of each level, the participant completed the Self-Assessment Manikin (SAM) questionnaire to assess their emotional experience. After the experiment concluded, the sensors were removed and disinfected, ensuring a proper closure. This approach allowed for a comprehensive evaluation of behavior, physiology, and emotions under different cognitive conditions (Fig 1).

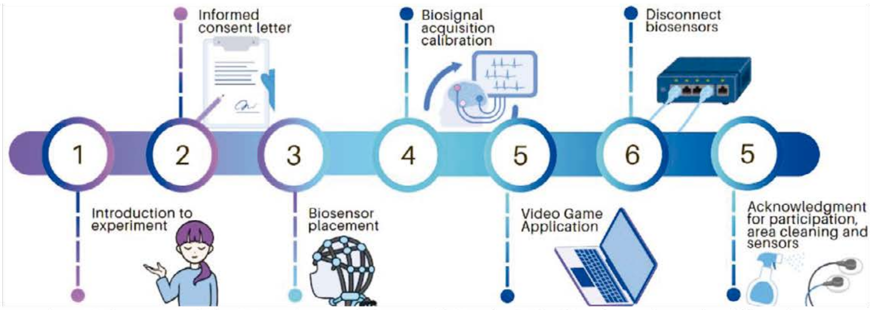

Fig. 1 Diagram of the Experimental Protocol for the MindRush Project, detailing the stages of the process with each participant. The sequence begins with an introduction to the experiment (1) and the delivery of the informed consent form (2). Then, the placement of biosensors (3) and the calibration of the physiological signal acquisition system (4) proceed. Once prepared, participants perform the video game tasks while behavioral and physiological metrics are recorded (5). Upon completion, the biosensors are disconnected (6), and participants are thanked for their participation, proceeding to clean the area and devices for the next evaluation (7).

3.2 Approaches to the Phases applied at each Level

The purpose for which the protocol was designed was to induce the subject into psychological and physiological states that would allow us to identify the presence or absence of ADHD. To achieve this, it was necessary to create a significant gap/bias in the data we would take from participants to classify them.

The planning and development of the protocol consisted of analyzing symptoms and looking for potential triggering stimuli to be applied in a controlled manner to generate the characteristic bias of ADHD. An effective way to generate this was by creating a progression of phases/levels with different intentions seeking specific and planned effects, where, depending on the type of level, different data and metrics would be taken into account. The game is primarily divided into two types of levels, stimulative and metric.

Stimulative levels were created to trigger a specific type of emotion or behavior that, while affecting most participants in the same way, will not affect all of them to the same extent, and reactions will vary from one user to another depending on the psychological characteristics of the subject. By subjecting the subject to different levels of stress, pressure, frustration, boredom, etc., we can observe and measure various aspects considered, which are physiological data, performance data and interaction with the video game, and emotional states.

Metric levels are those based on the dynamics of other tests like MOXO, where different types of reaction to the same stimulus are measured. The intention of this level is to measure impulsivity, hyperreactivity, attention, and the person's response time (Fig. 2).

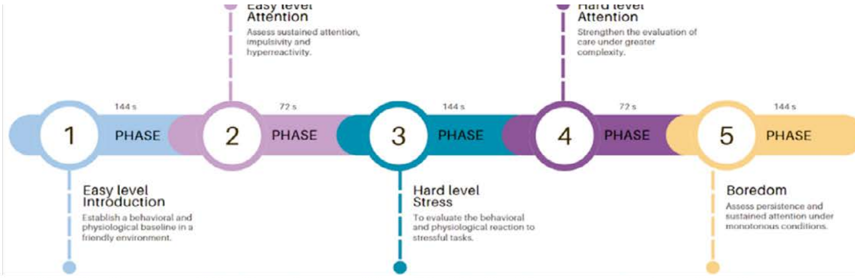

Fig. 2 . Diagram of the five phases of the MindRush video game, designed for the assessment of ADHD. Each phase presents a specific level of complexity and objective: (1) Introduction: establishes a behavioral and physiological baseline in a friendly environment (144 s); (2) Attention: measures sustained attention, impulsivity and hyperreactivity using specific visual stimuli (72 s); (3) Stress: assesses behavioral and physiological reaction to stressful and desynchronized tasks (144 s); (4) Advanced Attention: reinforces the assessment of attention under greater complexity and shorter response time (72 s); and (5) Boredom: analyzes persistence and sustained attention under monotonous conditions (144 s).

3.3 Description and Objectives of the Levels in MindRush

The progression of levels was created with a specific order to measure and compare basal states with states altered by stress, frustration, distraction, etc. Throughout all levels, physiological signals are monitored for analysis, and visual annotations by the applicator of anxious and hyperactive behaviors are made.

Level 1: Introduction Phase

The goal of this phase is to establish a baseline behavioral and physiological environment that allows for assessing the initial performance of the participant without generating much stress or frustration. The level design is based on precise synchronization between jumps, the rhythm of the music, and color changes, creating a fluid and intuitive experience for the player with the intention of being easy to pass. During this phase, the number of jumps made, the number of attempts required to complete the level, and the total completion time are recorded, providing a performance benchmark for later phases (Fig. 3).

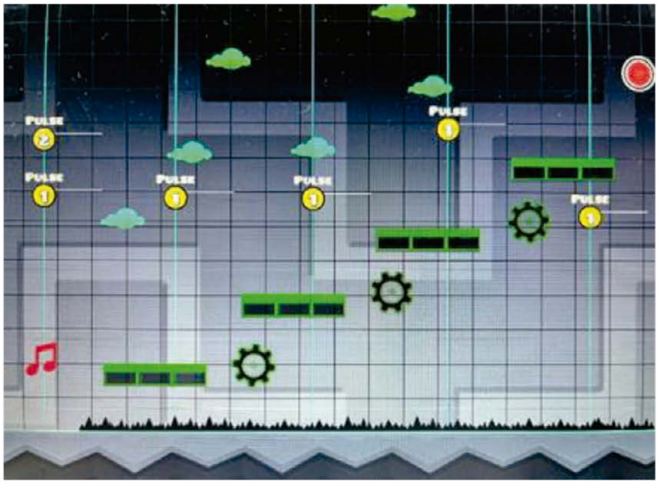

Fig. 3

Level 2: Attention Phase

The objective of this phase is to evaluate sustained attention, reaction time, impulsiveness, and hyperreactivity of the participant. The task involves jumping only at the appearance of a specific figure, ignoring the rest of the stimuli presented (Fig. 4). The level design aims to create a challenging but controlled environment, where correct responses require concentration and impulse control. During this phase, activation accuracy is recorded, differentiating whether the jump occurs on time or out of time, as well as impulsive jumps (jumping at an incorrect figure), hyperreactive jumps (repeated jumps after a correct stimulus), and omissions (not responding to the target stimulus). Work memory cues are also considered, assessing the participant's ability to remember and act according to instructions during the task. These data allow for identifying patterns of attentional behavior that will serve as a reference for later phases.

Fig. 4 . Visual instructions in the attentional evaluation phase in MindRush. Participants are instructed to only jump at the appearance of the green figure, while any other stimulus requires inhibiting the motor response. This task allows measuring sustained attention, impulsivity and hyper-reactivity in real time.

Level 3: Stress Phase

The goal of this phase is to evaluate the behavioral and physiological reaction of the participant to stressful tasks, challenging their ability to manage frustration and adapt to a challenging environment. The level design is based on the asynchrony between the music, color changes, and the location of obstacles, generating a misaligned environment that complicates anticipation of movements and increases task complexity. During this phase, the number of jumps made, the number of attempts required to complete the level, and the total completion time are recorded. This is to be compared with performance in other phases and to identify behavior patterns under stress, frustration, discomfort, and pressure (Fig. 5).

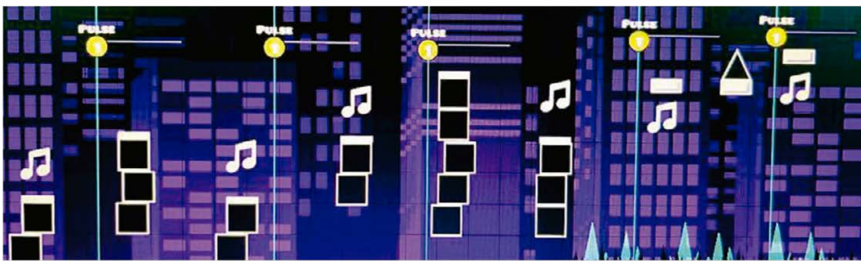

Fig. 5 Capture of Level 3 (Stress Phase) of the MindRush video game. The yellow markers indicate the color change, but in this phase the synchronization between the music, the visual stimuli and the timing of the jump is misaligned, the obstacles are irregularly designed to complement the purpose of the phase.

Level 4: Advanced Attention Phase

The objective of this phase is to reinforce the evaluation of attention in a more complex environment, considering the impact of cognitive fatigue after stressful tasks. The level design is similar to the initial attention phase but with more complex stimuli and shorter response times, demanding greater concentration and inhibitory control. During this phase, activation accuracy is recorded, including correct jumps (timely or delayed), impulsive activations (response to incorrect stimuli), hyperreactive jumps (repeated jumps after a correct stimulus), and omissions (lack of response to the target stimulus). These data help identify how difficulty and previous exposure to stress affect attentional performance and behavioral self-regulation of the participant (Fig. 6).

Fig. 6 Jump metrics in phases 2 and 4 of the MindRush video game, designed to assess sustained attention, impulsivity and hyper-reactivity. Green stripes represent correct stimuli, red stripes represent distractors and blue stripes represent rest intervals. The initial yellow stripe marks the instruction period. Stimuli and rests are presented at equal intervals, varying between 0.5, 0.75 and 1 second, assessing the participant's adaptation to different processing speeds. In

Phase 2, 13 correct stimuli are presented in 72 seconds, while in Phase 4, with greater complexity and shorter response time, 18 stimuli are presented in the same period. A jump is considered correct if it occurs during the green box, while if it is not jumped at that time but in the consecutive blue box, it is classified as a correct jump with delay. If the participant jumps in both the green and subsequent blue boxes, it is considered a hyper-reactive jump. A jump during a red box is classified as impulsive, and if after that impulsive jump the player jumps again in the subsequent blue box, the second jump is also considered hyper-reactive. Finally, omission is recorded if the participant does not jump in either the green or the following blue box. This classification allows the assessment of sustained attention, impulsivity and hyperactivity, providing a detailed view of the participant's cognitive and behavioral control.

Level 5: Boredom Phase

The goal of this phase is to evaluate the persistence and sustained attention of the participant under monotonous conditions, analyzing their ability to maintain focus and motivation in the absence of attractive stimuli. The level design includes an initial minute with relaxing music and a neutral background, followed by an empty environment without visual or auditory stimuli. During this stage, false and true obstacles are presented to assess the player's perseverance and cognitive flexibility in the absence of clear feedback. Metrics recorded include the number of attempts made, jumps performed, and strategy changes, providing key information on boredom tolerance and the participant's ability to regulate their behavior.

3.4 Instruments and Equipment for Data Acquisition

For the acquisition of the selected biosignals, four biosensors were used, selected for their previous use and the quality of results obtained; these can be seen in Table 1 and (Fig. 7), which describes the type of sensor, model, application in the study, and an image of them.

Table 1. Sensors

Sensor	Model	Application	Image
Sensor GSR	Grove GSR	Acquisition of skin conductance	Fig. #.3
Temperature Sensor	LM335	Acquisition of body temperature	Fig. #.4
Photoplethysm	Phototransistor and Photodiode	Acquisition of cardiac pulses	Fig. #.2
Single Channel EEG	INA-129	Acquisition of electro-encephalographic activity of the Fp1 channel.	Fig. #.5

GSR Sensor

A galvanic skin resistance sensor from Seed Studio®, model Grove GSR, was used. This sensor measures the body's resistance using two electrodes into which a small current (on the order of microamperes) is injected, and the resistance value varies depending on skin perspiration. The higher the perspiration, the lower the resistance. The electrodes are positioned on the ring and middle fingers of the right hand [13].

Temperature Sensor
A high-precision temperature sensor, model LM335 from ST Microelectronics®, was used. This sensor has a resolution of 10mV/1°K for body temperature measurements [13].

Photoplethysmography
The circuit detects heartbeats using an infrared LED and a photodetector, whose signal is filtered to eliminate noise, amplified to increase its intensity, and compared to an adjustable threshold using a TL084. When the signal exceeds the threshold, an LED is activated that blinks in rhythm with the pulse [13].

Single Channel EEG
A circuit developed by us was used for the capture of a single EEG channel, this circuit consists of four stages, which included a pre-amplification phase that converts micro-volts to millivolts, using the instrumental amplifier INA-129. The second phase consists of a third-order High-Pass filter of 1Hz to eliminate noises that are common in our work area; followed by a Low-Pass filter of 100Hz, to limit the frequencies obtained in electroencephalographic activity. Finally, an amplification phase that converts millivolts to volts, using the instrumental amplifier INA-129, and thus able to read the signal [13].

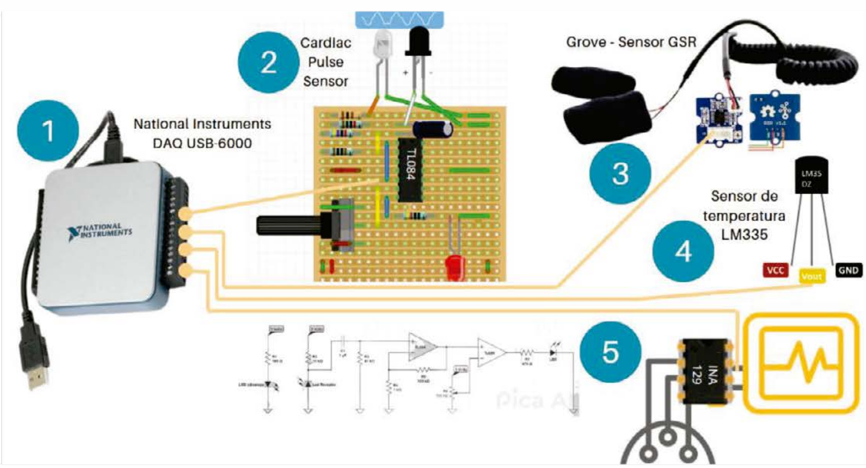

Fig. 7

The acquisition of these biosignals was carried out using a DAQ card, model USB-6000 from National Instruments®. This card provides both digital and analog inputs and outputs with a 32-bit counter. The biosignals for heart rate, skin conductance, body temperature, and EEG have approximate sampling frequencies of 100 Hz, 4 Hz, 2 Hz, and 80 Hz, respectively. Since the data acquisition card cannot acquire signals at different sampling frequencies, the highest necessary frequency from those sources was chosen for acquisition (fs = 250 Hz).

3.5 Using Forms for Subject Evaluation

Each time the participant completed a level, they rated their state using the Self-Assessment Manikin (SAM) system, which involves assigning a value (between 1 and 9) to each affective image based on three emotional dimensions: valence, arousal, and dominance (see Fig. 8).
This evaluation consists of three rows of drawings, each representing one of the previously mentioned emotional dimensions. Each participant can provide values for each emotional dimension according to the emotion they experience, with a score of 9 indicating the highest intensity for any given dimension.

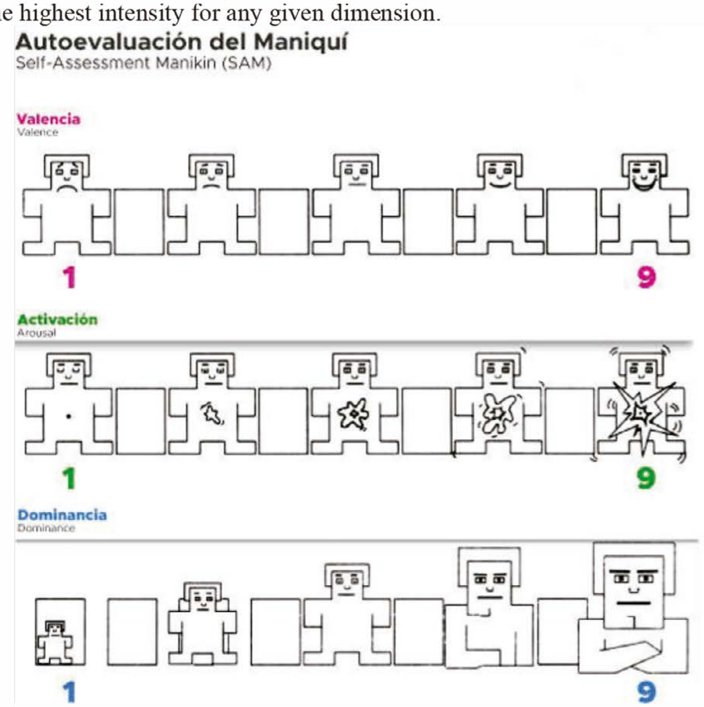

Fig. 8 SAM (Self-Assessment Manikin)

4 Results

A database was obtained consisting of 16 subjects (Fig. 9), with high-quality signals from the four previously mentioned sensors, ensuring the reliability of the data for processing. Currently, the data is in the analysis stage using a developing network designed to optimally classify participants based on their performance and physiological responses.

The protocol was practiced and refined through multiple trials, achieving an average duration of 30 minutes per subject. The participants' response was positive, showing interest and commitment during the activity, which facilitated data collection without interruptions or apathetic behaviors. Additionally, observing the performance in the game allowed for the identification of distinctive patterns in individuals with ADHD, highlighting differences in jump accuracy, reaction times, and behavior under stress and monotony conditions. These preliminary findings suggest that the dynamics of the video game are not only engaging but may also serve as an effective tool for detecting and evaluating characteristics associated with ADHD.

SUBJECT	Date	Pt	Age	Gender	Have you previously been diagnosed with ADHD or ADD by a specialist?	Do you consider yourself a Video Gamer?	Have you played Geometry Dash?	GROUP
1	thursday 20/02/25	0 / 6	20 years	Male	No	Yes	Yes	Control
2	thursday 20/02/25	2 / 6	21 years	Female	No	Yes	Yes	Control
3	thursday 20/02/25	3 / 6	22 years	Female	No	No	Yes	Control
4	thursday 20/02/25	5 / 6	21 years	Male	Yes	No	Yes	ADHD
5	thursday 20/02/25	6 / 6	21 years	Male	No	Yes	Yes	ADHD
6	thursday 20/02/25	2 / 6	21 years	Male	No	Yes	Yes	Control
7	thursday 20/02/25	5 / 6	22 years	Female	Yes	No	Yes	ADHD
8	thursday 20/02/25	6 / 6	20 years	Female	Yes	No	Yes	ADHD
9	thursday 20/02/25	2 / 6	19 years	Male	No	No	Yes	Control
10	thursday 20/02/25	4 / 6	19 years	Male	No	Yes	Yes	ADHD
11	thursday 20/02/25	2 / 6	19 years	Female	No	No	Yes	Control
12	thursday 20/02/25	3 / 6	20 years	Female	No	No	Yes	Control
13	friday 21/02/25	3 / 6	19 years	Female	No	No	No	Control
14	friday 21/02/25	0 / 6	21 years	Male	No	Yes	Yes	Control
15	friday 21/02/25	4 / 6	19 years	Female	No	No	Yes	ADHD
16	friday 21/02/25	3 / 6	20 years	Male	No	No	Yes	Control

Fig. 9 . Distribution of participants according to age, gender, previous ADHD diagnosis, affinity for video games and experience with Geometry Dash. The table shows the classification of subjects into control and ADHD groups, allowing a comparative analysis of the metrics obtained during the experiment.

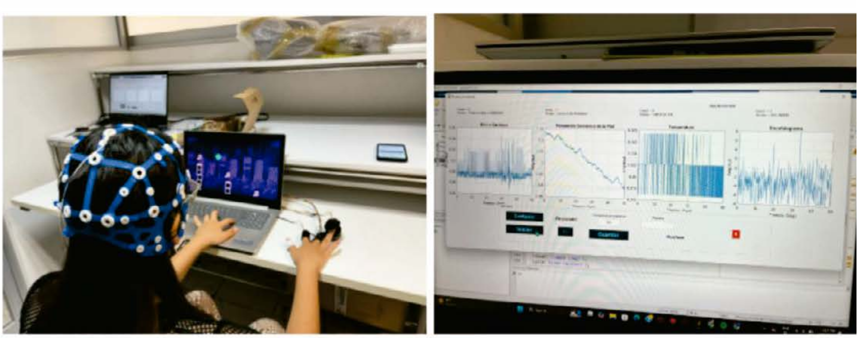

Fig. 10 Data acquisition process during the MindRush experiment. On the left, participant equipped with an electroencephalography (EEG) cap and galvanic skin response sensors while interacting with the video game. Right, real-time display of physiological signals recorded, including heart rate, galvanic skin response, body temperature, and encephalographic activity.

5 Conclusion

MindRush is a project with a promising outlook, ready to be optimized and applied in real-world settings. Although the final results are still under development, the methodological foundation, data collection, and technological integration achieved demonstrate its viability as an advanced assessment tool, paving the way for a more accurate, accessible, and personalized diagnosis and treatment.

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