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Identifying Brain Characteristics of Bright Students

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Abstract

Gifted students have different ways of learning. They are characterized by a fitful level of attention and intuitive reasoning. In order to distinguish gifted students from normal students, we conducted an experiment with 17 pupils, willing participants in this study. We collected different types of data (gender, age, performance, initial average in math and EEG mental states) in a web platform called NetMath intending for the learning of mathematics. We selected ten tasks divided into three difficulty levels (easy, medium and hard). Participants were invited to respond to top-level exercises on the four basic operations in decimals. Our first results confirmed that the student's performance has no relation with age. A younger 9-year-old student achieved a higher score than the group with an average of 68.18%. This student can be considered as a gifted one. The gifted students can be also characterized by a mean value of attention (around 60%). They also can be defined by slightly weaker values of their mental states of attention and workload in comparison with the weak pupils.

Keywords

NetMath Platform, Performance, Workload, Attention, Relaxation, Decimal Numbers

1. Introduction

Nowadays, the performance of learners in primary schools differs from one individual to another. We find more students who perform below the average than others whose performance exceeds the group average. The latter is often much more advanced than other students and is bored in class because the presented information is already obvious to them and too easy. We were talking about gifted, talented or high creativity students. According to Zettel (1979), general intelligence usually manifests in intelligent quotient (IQ). Gifted students have an IQ of 130 or above. These students are "endowed by nature with high intellectual capacity and have a native capacity for high potential intellectual attainment and scholastic achievement [1]". Usually, gifted students have a school achievement higher than their age. They have a different mode of operation. They rely on intuitive reasoning [2] and have a high speed of information transmission. Three main characteristics distinguish gifted students: critical, independent of though and judgment and persistent [3] [4]. Gifted, creative, and talented students have special educational needs: they may learn in some ways which are different from other students; they are more curious; and they think more abstractly. At the same time, gifted students present the risk of developing difficulties of adaptation, a lack of school motivation, anxious-depressive symptoms (such as frustration and boredom) and a lack of attention.

In literature, several studies have been conducted to identify and detect gifted students. Most studies focus on the measurement of intelligence quotient (IQ) with psychometric tests such as the Wechsler Intelligence Scale for Children (WISC) [5], the Wechsler Abbreviated Scale of Intelligence (WASI) [6], and Raven's progressive matrices [7]. However, to our knowledge, very few studies have been interested in establishing personal and biometric characteristics of these individuals. In order to answer this point, we propose in this paper to develop measures allowing both to examine the performance of talented students and to study the evolution of their biometric measurements resulting from electroencephalogram signal (EEG). More specifically, we are interested in studying the variation of three mental states extracted from EEG (attention, cognitive load and relaxation). These measures would establish some characteristics of this population.

The paper is organized as follows. In Section 2 we talk about related works in assessing and identifying gifted students. Section 3 describes our experimental environment designed to evaluate student's performance in mathematics, called NetMath. In Section 4, we describe the experiment conducted in a primary school. Finally, Section 5 shows our obtained results in term of gifted students achievement and EEG mental states variation.

2. Related Works

2.1. Gifted Students: A Definition

Historically, there are many definitions and conceptualizations of gifted and talented students [8] [9] [10] [11]. Some authors allege that the high intellectual potential is innate (genetically present) and others that it represents the result of training or development of abilities or capacities of the child. Intellectual assessment or intelligence quotient remains an important indicator of giftedness. Two essential models are used to define giftedness [12], the one of Renzulli [10] and the other of Sternberg [11]. According to Renzulli [10], there are two sorts of gifted students: the first type corresponds to those with high academic potential. The second type corresponds to those with high creative potential. It proposes three components of skills to characterize the behavior of gifted children (intelligence, creativity and implication). These components interact. Sternberg [11] described a model of five criteria (excellence in one area relative to other people, scarcity of the level reached against peers, potential to produce something, ability to demonstrate skills with a valid assessment, and relative value of the skill for society).

2.2. IQ and Giftedness

Although there is not a way to measure giftedness and intelligence, researchers agree that intellectual measurement or intelligence quotient measurement (IQ) can be considered as an intelligence measurement. IQ is a numerical value that reflects the overall intelligence of the person [13]. Currently, 2.28% of the population is gifted children [14]. These children have an IQ higher than 130 [15]. However, an IQ between 90 and 110 is considered as a normal child and presents 50% of population. Gifted students have a high IQ, differently treat stimuli, feel different things and think in a different way. To measure the IQ, neuropsychologists use psychometric tests such as the Wechsler test [5] [6] and the progressive matrices of Raven [7]. There are many forms and versions of Wechsler test such as WISC (Wechsler Intelligence Scale for Children) and WASI (Wechsler Abbreviated Scale of Intelligence) the abbreviated version for this test. For example, WISC V is consisting of 15 subtests. It is indicated for children between 6 and 16 year olds. It measures five cognitive functions (verbal comprehension, fluid reasoning, visuospatial skills, working memory and transmission speed). The test period is about one hour. In order to reduce this time, an abbreviated version of this term is also proposed called the WASI. This test is used to estimate IQ scores rapidly and efficiently when administration of full battery is neither feasible nor necessary. It takes about 30 minutes and measures four subsets of cognitive functions (block design, vocabulary, matrix reasoning, and similarities). These two latter tests require the knowledge of a psychologist. However, for research purposes, Raven Progressive Matrix could be also used to assess IQ. An average of 20 minutes is required to administrate these tools where we complete multiple-choice matrices. Three main forms of these matrices: Raven Standard Progressive Matrices, Raven Colored Matrices and Advanced Progressive Matrices.

2.3. Right Hemisphere, Mathematics and Giftedness

Both hemispheres of the brain (right/left) and their successful interaction play a crucial role in the complex process of mathematics [16]. For example, left hemisphere (LH) damage may result in difficulties with reading or writing numbers and the performance of basic arithmetic operations while damage to the right hemisphere (RH) disrupts spatial representation [17] [18]. Several psychophysiological studies support an important relationship between the specialized capacities of the right hemisphere and mathematical abilities. These studies indicated an enhanced processing reliance on the RH for the gifted studies [19]. Lui and colleagues [20] studied the relationship between electroencephalogram (EEG) band power, cognitive processing and intelligence in school-aged children. 47 individuals from an experimental class (24 gifted, 23 average) were selected and the main neural mechanism pertaining to high intelligence was investigated. The EEG was recorded and the relationship between different percentages of power bands (Delta, Theta, Alpha 1, Alpha 2, Beta 1 and Beta 2) and intelligence and cognitive ability were analyzed. The results suggest that Delta power activity of brighter individuals was more intensive than the one of normal individuals, and Alpha 2 and Beta 1 power activity of higher intelligence individuals were less than of normal individuals.

3. A Description of NetMath Platform

NetMath Platform[1] is a web application to support learning mathematics for primary and secondary students (from 3rd primary grade to 4th secondary grade). It contains a set of tasks and exercises in different topics of Math such probability, statistic, decimal numbers, fractions, etc. In our case, we focus on evaluating the topic of decimal numbers for 4th and 5th grade primary students. We are mainly interested in performing the four basic operations on decimal numbers (addition, subtraction, multiplication and division).

In order to evaluate students' performance and EEG traits in NetMath platform, we choose a total of 10 tasks from NetMath platform designed to 6th grade students. These tasks are divided into three levels of difficulty: easy, medium and hard as described below.

3.1. Easy Tasks

In these tasks, the student is asked to do one or two operations on decimals (adding or subtracting two numbers). An example of this task is presented in **Figure 1**.

3.2. Medium Tasks

In these tasks, the operations are presented in problems that are more complicated and where the student has to do more than one operation at same time. Therefore, we think that he has to be more careful in order to succeed in these tasks. **Figure 2** shows an illustration of these tasks.

3.3. Hard Tasks

Two difficult problems are presented to the students. The problems required a greater mental effort and the students have to think carefully in order to resolve these problems. **Figure 3** illustrates the problem of calculating the difference

[1] https://www.netmath.ca/fr-qc/

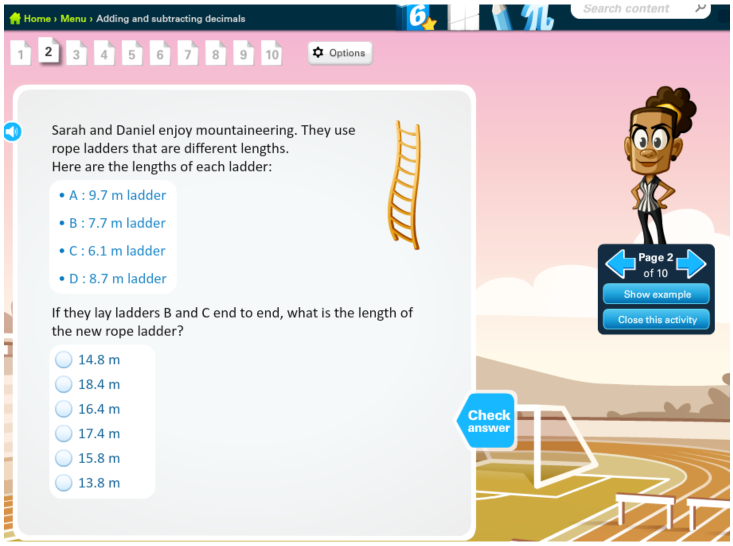

Figure 1. An example of an easy task extracted from NetMath platform.

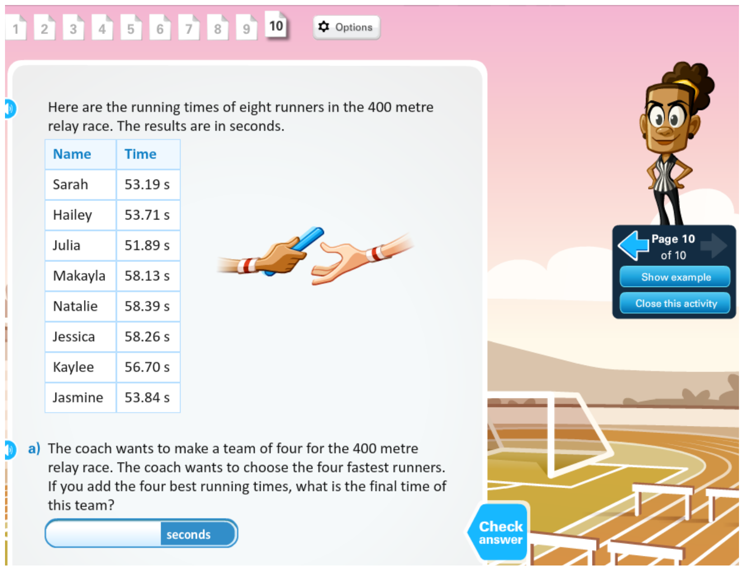

Figure 2. A task of a medium difficulty.

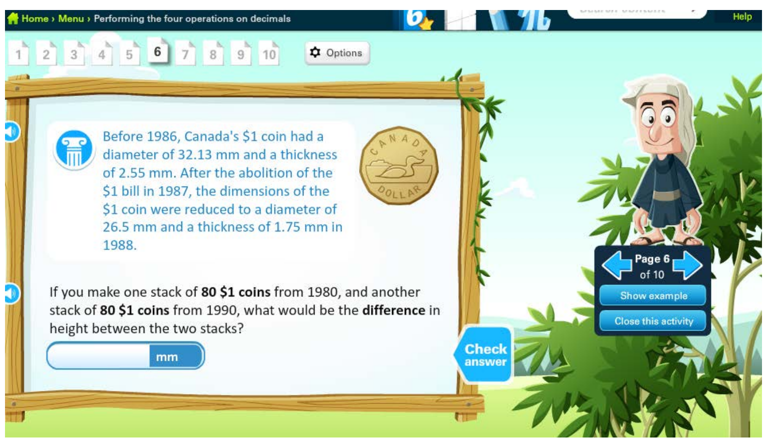

Figure 3. Example of a hard problem.

of the one-dollar money dimensions. It requires two multiplications and one subtraction.

4. Experiment

In order to detect bright and gifted students, we conducted an experiment where we asked elementary school students (4th and 5th grades) to resolve the selected tasks from NetMath environment described above. The proposed tasks were designed for higher-level students (6th grade). A consent form preceded the experiment where we obtained the agreement of each parent to let his/her child to participate in our study. The experiment was held at École Samuel de Champlain (Brossard, Canada) after the classes. 17 students (10 F, 7 M) voluntarily participated in this study with a compensation of 20$ each. Students are aged between 9 and 11 year (M = 10.05; SD = 0.42). We invite two children at the same time to do the experiment as we have two laptops and two EEG headsets.

We start the experiment by filling a short questionnaire about demographic data for each student (age, sex and math average obtained during the first step in school). Furthermore, we invite the student in login to the NetMath website and in completing the proposed tasks in ascending order (from easy to difficult). During the fulfilment of the tasks, we collect data from Neeuro Senzeband non-invasive EEG headset. This headset allows us to obtain EEG raw data from 4 channels and three mental states measures (Attention, Workload and Relaxation). This headset is heavy, easy to install and more suitable for use and experimentation with children. It collects EEG data from four sensors (two right and two left frontal lobes). Neeuro provides only an SDK for mobile phones. In order to save the EEG data in the student's computer, we started by creating a mobile application that is connected to the EEG headset through Bluetooth. This application collects in real time the EEG data, then, it sends them to the computer via Wi-Fi and the computer saves them to a CSV file. Figure 4 illustrates the EEG data acquisition process.

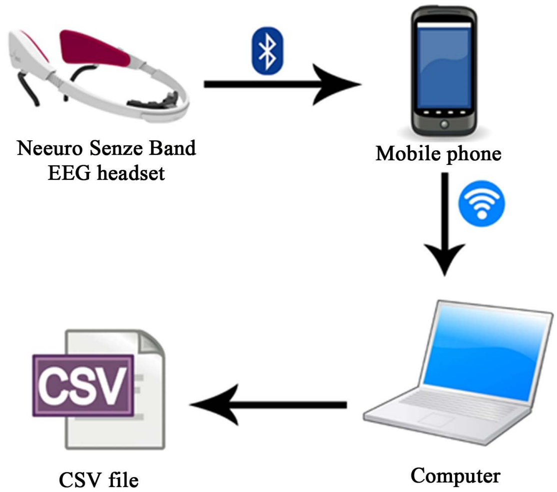

Figure 4. EEG acquisition process.

5. Results

In this part, we present the results obtained in NetMath platform for the 10 selected exercises. This part is divided in three subparts. The first part compares the performances obtained in these tasks and the initial averages in mathematics. This comparison lets us to obtain an indication of the strongest students (bright). The second part asks the question of the influence of age on performance. Finally, the third part studies the distribution of mental states according to the performance.

5.1. Performance and Initial Average

In order to detect the strongest students, we calculated for each student the obtained average (from 0% to 100%) in all the tasks extracted from NetMath platform. The average performance in this environment is 59.64%. However, the obtained group average in math in the first step class is 78% which is a little bit higher, due to the difficulty of the given tasks (tasks are designed for high level students). Thus, we can distinguish two groups: Group 1 with an average higher than the obtained group average in the first step or in NetMath platform and Group 2 with a lower average. **Table 1** presents the distribution of students according to the math first step and to our experiment (NetMath platform). We show statistics according to the total student's number, the mean, the standard deviation, the minimum and the maximum values.

From **Table 1**, we can see clearly that the performance in our experiment is lower than the initial performance (first step score) for all students. This result is very expected as the proposed tasks aims to detect the strongest students. We can also observe that the highest obtained performance is 90.9% comparing to an initial first step score of 97%. However, there is no difference between the students' distribution in the first step and the experiment (11 participants with a higher performance in the first step comparing to 10 participants with a higher performance in the NetMath platform). We also run an independent samples t-test to compare scores variation in both conditions (before and in the experiment). There was a significant difference in the scores ($t(23) = 2.84$; $p = 0.004 < 1\%$). This result supports the fact that there is a significant difference between the initial scores (obtained in the first step) and the experiment scores (obtained in NetMath platform). To confirm this result, we studied also the distribution of scores according the task difficulty. As we will describe further, our proposed tasks are divided to three levels of difficulty (easy, medium and hard). **Figure 5**

Table 1. Distribution of student's scores in the first step and in NetMath platform.

Performance	First Step					NetMath				
	N	Moy	SD	Min	Max	N	Moy	SD	Min	Max
Group 1	11	88.63	6.19	81	97	10	76.71	11.34	68.18	90.9
Group 2	6	68.66	8.01	57	73	7	35.25	20.41	10	57.14
Total	17	81.72	11.57	57	97	17	59.64	25.9	10	90.9

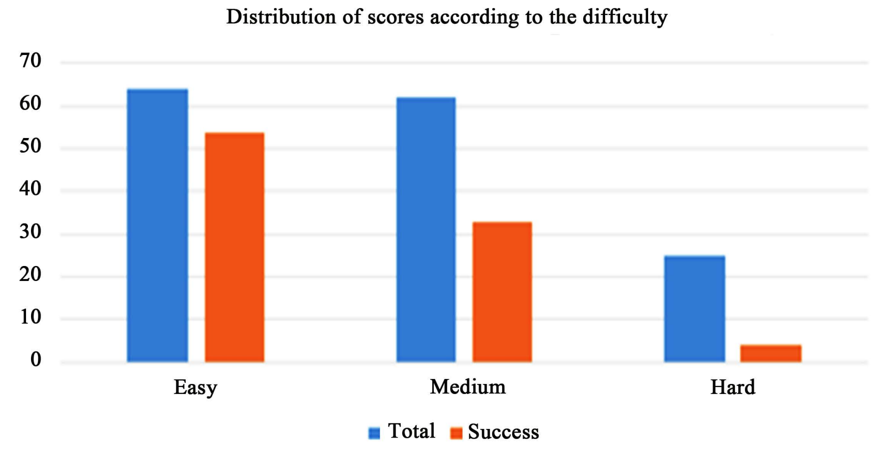

Figure 5. Distribution of student's scores according to the difficulty in our experiment.

presents this distribution. We can deduce that almost all students succeeded in resolving easy tasks (53.75 out of 64: 83.89%), more than half students accomplished medium tasks, and a very few number of students (only 2) success to solve hard tasks. So, we suspect that these students are very good at school. There is a large probability that they are gifted students. This finding will be studied and proved in our next work.

5.2. Performance and Age

In this part, we studied the influence of age on performance. We remember that our sample of students is composed of 3 ages (9, 10 and 11 years old). Table 2 shows the distribution of student's scores obtained in our experiment according to these three ranges of age.

From Table 2, we can see clearly that the age has not an influence on scores. For instance, a 9 year old student succeeds to obtain a score of 68.18% which is higher than the average obtained in the experiment (59.64%) and higher than the average of 10 year old students (63.72%) and 11 year old (26.78%). Moreover, two oldest students (11 year old) have poor performance comparing to all students. We can deduce therefore that the 9 year old student has a higher probability to be a gifted student.

5.3. EEG Mental States Distribution and Performance

This part discusses the variation of three mental states extracted from EEG senzeband according to student's performance. As students could be classified into two group: Group 1 with the highest performance (>59.64%) and Group 2 with the lowest performance (<59.64%), we present below two curves which indicates the EEG mental states distribution among each group.

From Figure 6 and Figure 7, we clearly can see that the mental states of workload and relaxation have similar variations. They are presented by linear curves where values are between 0% and 10%. However, for the attention curve, There is a significant difference between Group 1 and Group 2. We notice that

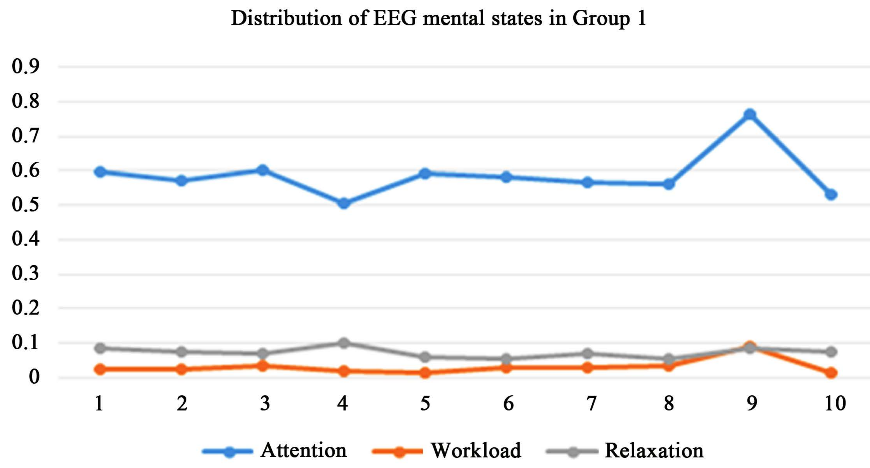

Figure 6. Variation of EEG mental states for bright students.

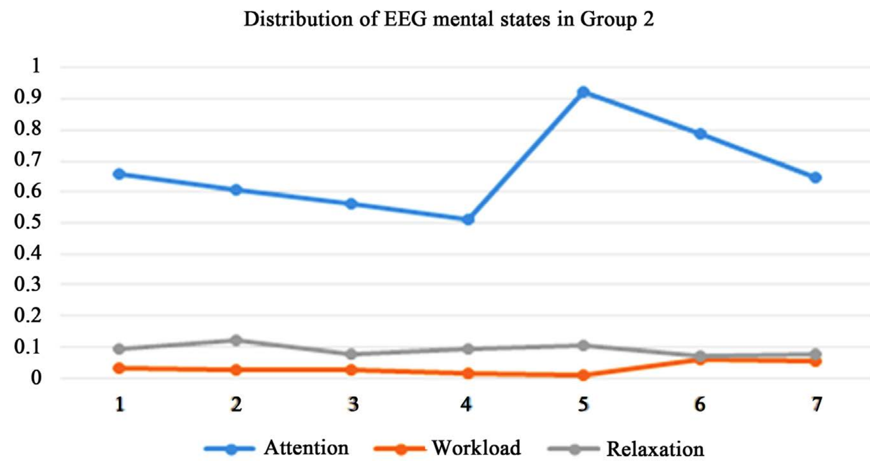

Figure 7. Variation of EEG mental states for weak students.

Table 2. Distribution of performance according to age.

Age	Performance				
	N	Moy	SD	Min	Max
9	1	68.18*	0	68.18	68.18
10	14	63.72*	25.2	10	90.9
11	2	26.78	2.52	25	28.57

* indicates that the average is higher than the student's average in our experiment (59.64%).

Group 1 (bright students) have a stable attention value of 60% (see **Figure 6**) and Group 2 have an instable value. It varies between 50% and 90%. So, we can characterize bright students with an average value of attention and weak students by fluctuated values of attention (very high or very low). To confirm this finding, we dressed also a comparison curve which presents the variation of four statistics (Moy, SD, Min and Max) extracted from these mental states for both groups (see **Figure 8**).

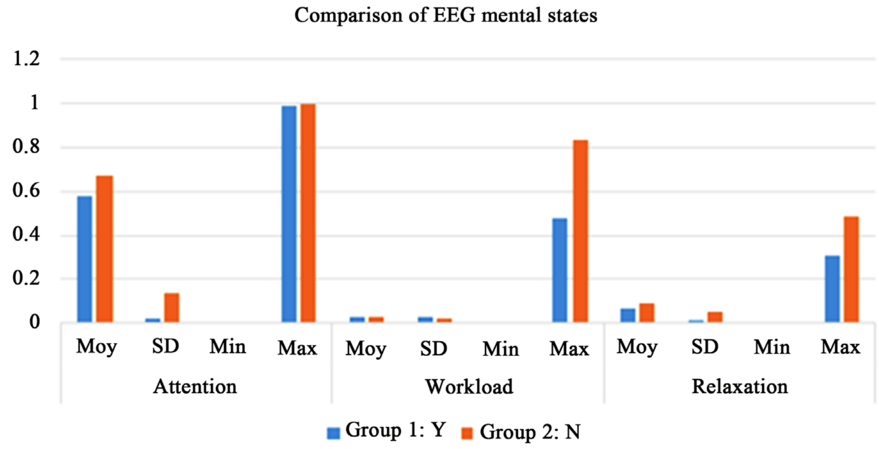

Figure 8. Variation of EEG mental states for bright and weak students.

Figure 8 confirms that Group 2 (weak students) have high values of attention and relaxation comparing to Group 1 (bright students).

6. Conclusion and Future Works

In this paper, we described a study aiming to distinguish high ability math students from average students. This study is based on the measure of the performance, age, and EEG mental states of attention, workload and relaxation. Our results show that bright and talented students succeed to answer top-level math exercises with a performance of 90%. We can also characterize bright students with an average value of attention (60%) and average students by fluctuated values of attention (very high or very low). Future work will focus on comparing the results extracted from Raven Progressive Matrices and EEG raw data. We will study tendencies in EEG variation for the right and left hemispheres and power bands (Alpha, Beta, Theta and Delta).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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