Reality monitoring measurement using Balls Control Test (BCT) Software

Medición de la realidad mediante el software Balls Control Test (BCT)

Pedro Carlos Martínez-Suárez[1,6,7*] Pablo Andrés Buestán-Andrade[2] Andrés Alexis Ramírez-Coronel[3] Javier Bernardo Cabrera-Mejía[2] Esteban Torracchi-Carrasco[4] María Gabriela Carpio-Carpio[5]

[1]Laboratorio de Psicometría, Psicología Comparada y Etología (LABPPCE), Cuenca, Ecuador.
[2]Real Time Simulation Laboratory of the Centre for Research, Innovation and Technology Transfer, Catholic University of Cuenca, Cuenca, Ecuador.
[3]PhD in Epidemiology and Biostatistics, CES University, Medellín, Colombia.
[4]Centre for Research, Innovation and Technology Transfer, Catholic University of Cuenca, Cuenca, Ecuador.
[5]Department of Operations of CREA, Cuenca, Ecuador.
[6]Vice rector of Research and Innovation, Society Outreach and Graduate Studies, Catholic University of Cuenca, Ecuador.
[7]HBR Health and Behavior Research Group, Cuenca, Ecuador.
*Correspondence: PC. Martínez Suárez Email: pmartinezs@ucacue.edu.ec o pecarmas@gmail.com

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Abstract

The monitoring of reality is a cognitive function involved in the discrimination of the stimulating source (internal or external). To measure this process, verbal paradigm tasks are used without considering that recent neuroimaging discoveries give a central role in source discrimination by stimulating basal ganglia and prefrontal motor cortex. For this purpose, a game was devised using a system of objects of different shapes whose number is variable in addition to their speed and size, with the particularity that the subject can control only one of them, and the rest are under the control of the program. Thus, the subject must find out which figure is under his control employing the directionals. The methodology used is based on the paradigm of object-oriented programming; each geometric figure is created through the concept of class so that properties such as shape, figure, dimensions, and behavior of objects are unique to each one. The main contribution is to have a precise non-verbal measure of the monitoring of reality, the time of discrimination of the source stimulated, as well as the errors made in the task and thus, matching these variables with other intervening variables to have a better knowledge of the nature of the process, to determine the role of motor feedback and in future research to have a cognitive marker that can be tested as an early predictor of schizophrenic spectrum disorders. These aspects are discussed at the end of the article.

Keywords: reality monitoring, schizophrenic spectrum disorders, cognitive markers, source monitoring.

Resumen

La monitorización de la realidad es una función cognitiva implicada en la discriminación de la fuente estimulante (interna o externa). Para medir este proceso se utilizan tareas de paradigma verbal sin tener en cuenta que los recientes descubrimientos de neuroimagen otorgan un papel central en la discriminación de la fuente mediante la estimulación de los ganglios basales y el córtex motor prefrontal. Para ello, se ideó un juego con un sistema de objetos de diferentes formas cuyo número es variable además de su velocidad y tamaño, con la particularidad de que el sujeto sólo puede controlar uno de ellos, y el resto están bajo el control del programa. Así, el sujeto debe averiguar qué figura está bajo su control empleando las direccionales. La metodología utilizada se basa en el paradigma de la programación orientada a objetos; cada figura geométrica se crea mediante el concepto de clase, de manera que propiedades como la forma, la figura, las dimensiones y el comportamiento de los objetos son únicos para cada uno. La principal aportación es disponer de una medida no verbal precisa del seguimiento de la realidad, del tiempo de discriminación de la fuente estimulada, así como de los errores cometidos en la tarea y así, emparejar estas variables con otras variables intervinientes para tener un mejor conocimiento de la naturaleza del proceso, determinar el papel de la retroalimentación motora y en futuras investigaciones disponer de un marcador cognitivo que pueda ser probado como predictor precoz de los trastornos del espectro esquizofrénico. Estos aspectos se discuten al final del artículo.

Palabras clave: monitorización de la realidad, trastornos del espectro esquizofrénico, marcadores cognitivos, monitorización de la fuente.

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Introduction

Reality Monitoring is a cognitive process that allows differentiating between the information of internal and external origin[1]. That is to say, it also allows to deciding between our actions and those induced by external agents[2]. From this construct, the neuropsychological model that explains the main symptoms of schizophrenia has been generated[3]. Although Johnson and Raye's[1] work focuses on the information source memory, Frith's model focuses on reality monitoring itself but not on its memorization, that is, at the time when the individual decides the origin of the stimulating source, including his actions. According to the model, there are two ways of action in the reality monitoring process which give rise to three types of disconnection[3]:

1) Goals fail at the time of generating actions: negative characteristics (lack of action).

2) Goals fail when inhibiting actions elicited by stimuli (indicates inhibitory action): positive characteristics (incoherent action).

3) Voluntary intentions fail at the time of generating action: Parkinsonism.

In Frith's model[3] three neuro-anatomical structures play the main role, the pre-frontal cortex (inhibitory role), the hippocampus (involved in the central aspect of stimulating discrimination) and the basal ganglia (in charge of the motor program).

According to recent studies[4], the model has absolute validity. By using functional magnetic resonance, the connection between reality monitoring and self or hetero action generation through the verbal task has been established; although the mentioned study establishes other anatomical structures involved, it rather expands on what was described by Frith[3]. Following Sugimori[4] and Gonsalves et al.[5], who conducted a study using photographs and identified the precuneus as the area of greatest activity when the participants distinguished between images incorrectly named as seen (perceived) versus those correctly named as imagined. We refer to the temporal-parietal area, just in front of the parietal-occipital fissure. In several studies, it has been found that the prefrontal cortex (PFC), a lateral-medial structure[6], takes place in the correct attribution of self-generated information[4,7,8]. Sugimori[4] work finds that "brain activity during word encoding predicted whether people later mistakenly responded "heard" when presented with imagined ítems", and associates reality monitoring with semantic processing in both Broca's and Wernicke's areas. It also refers to the need for more studies with normal population.

From the paradigm introduced by Johnson and Raye[1], verbal tasks are proposed in the studies, and these cognitive functions are linked in most of them to a decoding or a semantic coding task, as well as too self-referential language[6]. However, having demonstrated the relationship with the mental activity of generating, or not, information; the present study suggests the possibility of creating a task, with a visual and motor component, that could be introduced in future research to determine the difference between the semantic and sensory-motor role for monitoring reality in a more precise manner.

Balls control test (BCT)

Two programs have been developed in the Real-Time Simulation and Psychometrics Laboratories, which belong to the Research, Innovation and Technology Transfer Center (CIITT) of The Catholic University of Cuenca. Their objective is to measure the reaction times and errors of two people in a reality monitoring task, based on Johnson and Raye paradigm (1) and the previously described Frith and Done (2) neuropsychological-cognitive model.

The programs have been developed at a very high level, object-oriented and free software programming language (POO) "Python", which advantages are: ease of use, easy code interpretation, accessibility to a large user base, web repositories, libraries and extensions. One of the mentioned features is the wide variety of libraries that can be added; three of them have been included. They allow using random values in a series of numbers, objects, words, etc., obtaining the current time of the PC or based on a web server, and "Pygame", which is the most important for making these tools allowing the insert of graphic interfaces as well as user-machine interaction with the keyboard. The two programs are interrelated but have different characteristics as explained below:

Balls control test (User 1)

The most important part of the program is the "class", which has been developed in Python (a POO language that allows creating classes and objects). In this part of the program development, all the essential features for objects creation, such as geometric figures dimensions, screen limits, movement speed, color, and tracing initial points are found. Consequently, there are texts and keys that, depending on the user's selection, create objects and modify the mentioned geometrical figures performance. The program operation is as follows:

When the program starts, the main menu appears, allowing the user to choose between one or another option. After the choice, the program creates 9 geometrical figures that will randomly move around the screen; depending on the chosen option, the figures can be circles, triangles, rhombus or squares, with equal or different dimensions, and similar or different colors. A final geometric figure with an extra characteristic is then added. This object can be controlled by the user with the arrow keys which will change its random movement; all 10 geometrical figures have an assigned number. In the end, two counters are created, the first one starts counting when the "Start" button is pressed. When the user thinks he knows which geometric figure can be controlled, he can press the space bar and pause the random movement. Now, a second counter is activated, until a number from the numerical keypad is chosen; it will show the user's selected option. If it is the correct option, the program will end and return to the main menu; if not, it will restart and wait until the user clicks "Start" again. In either case, the information on counts and errors is stored in a database.

It is important to specify the characteristics presented in the main menu:

- "Start": 10 gray circles with a 20-pixel radius, are created.

- "Change shape": Geometric figures with 10 different colors, shapes, and dimensions, are created.

- Change color": 10 circles with different colors and 20-pixel radius, are created.

- Change Size": 10 gray circles with different dimensions, are created.

- Change Speed": 10 gray circles, with 20 pixel-radius, and different movement speeds, are created.

Balls control test (User 2)

Communication between user 1 and user 2 was possible by using The Message Queue Telemetry Transport (MQTT) protocol. Python has a library for creating MQTT server and subscribers. The second program operation is as follows: When the first program starts, the number of the geometric figure that are subject to be controlled is sent to the topic "POO", and the program Balls control test (User 2) stores this information to make the comparison when in the PC2 keyboard the number that user 2 thinks is the geometric figure being controlled by user 1, is pressed. If it is the correct option, the program will end and return to the main menu; otherwise, it will restart and wait until user1 clicks "Start" again on PC 1. In either case, the information on counts and errors is stored in a database. Here there is a single counter which starts when user 1 clicks "Start". The two programs are closely related but they are independent, as no user can modify the parameters of either program.

Methodology

Software Implementation

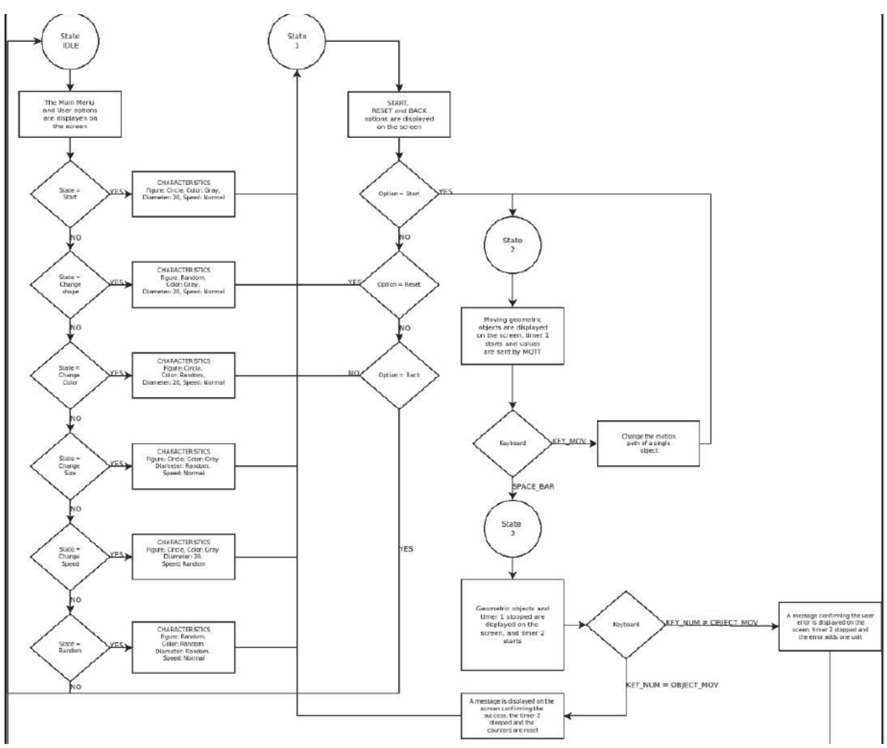
Balls Control Test was developed in the object-oriented programming language (POO) "Python." This tool was used because it has features that make it a functional, elegant, and straightforward style. BCT has been programmed in Windows 10 using Sublime Text 3, a very sophisticated text editor that allows programming in multiple languages. Balls Control Test is a multiplatform software, so it is also compatible with macOS and Linux.

Additional Tools

The main idea of BCT is to be a system that allows the interaction of a set of geometric bodies that are related in certain qualities, but with different behaviors. Python, being a POO language, provides mechanisms that make it possible to create this software, using additional tools; "pygame" and "paho-mqtt" are some of them. Pygame is a set of functions, modules, classes, etc., intended for the creation of 2D video games. With this library you can create the user interface, as well as the geometrical figures to be projected on the screen. BCT works in two different computers. The communication between computers is done through the Message Queue Telemetry Transport (MQTT) protocol. "Paho-mqtt" provides a class to Python so that IOT (Internet of Things) applications connect to this MQTT intermediary to publish and subscribe to topics. Finally, it is necessary to link to this set of tools a message agent (broker) that works through the MQTT protocol. Mosquitto is a broker suitable for IOT messaging such as low power sensors, mobile devices, computers, or microcontrollers. All programs, libraries, and information are open source.

Main program

Fig. 1 Flow chart BCT (User 1). Elaboration: The authors



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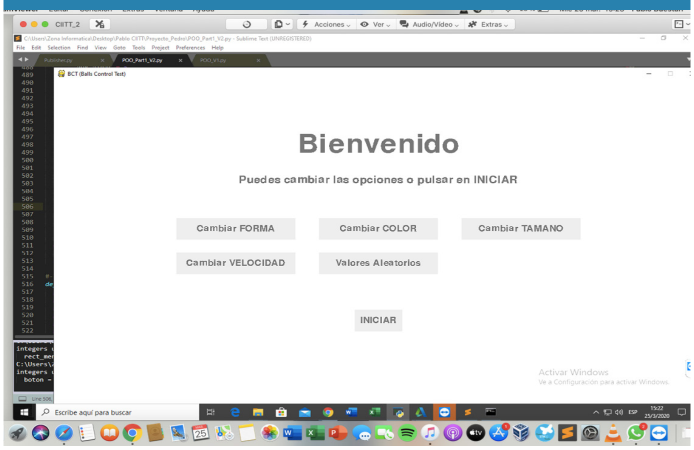
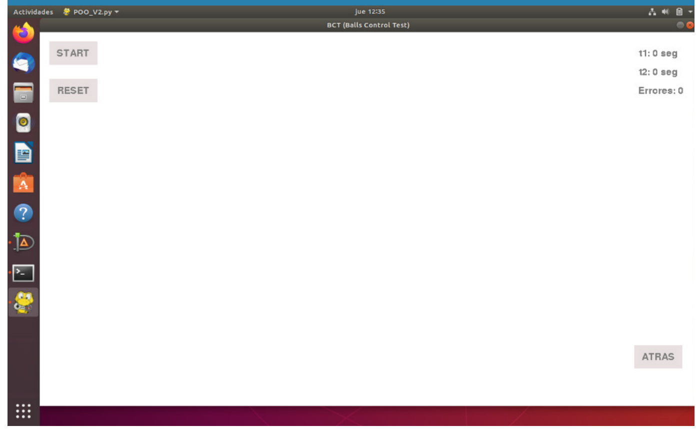
The flow chart of the BCT program (User 1) is illustrated in Fig. 1. The main feature of BCT is the class that is created according to the option that the user has chosen. Internally this class (object) consists of the default properties that have been included to build the objects: diameter, length, width, colors, shapes, limits, and speeds. The peculiarity is in the final element that is constructed; this last object can be controlled by the keyboard direction keys, which will generate a change in the random path of the geometric figure. In figure 2, the main user interface can be seen; here, the user can choose between the options presented to the user for different tests to be performed.

Fig. 2 Start Menu BCT (User 1). Elaboration: The authors



If the user selects "Start," the following properties are generated: 10 grey circles with a radius of 20 pixels are created, a maximum speed of 3 pixels in each movement, and a random number between 0 and 9 is added. "Change shape" generates a set of equal figures that can be circles, squares, rhombuses, or triangles. If circles were randomly chosen, they would have the characteristics of the "Start" option; if they are squares, ten grey squares are created with their sides equal to 20 pixels, with a maximum speed of 3 pixels in each movement and a random number between 0 and 9 is added. If they were randomly chosen triangles, then ten equilateral grey triangles with sides equal to 20 pixels are created, with a maximum speed of 3 pixels in each movement and a random number between 0 and 9 is added; finally, if the objects created turned out to be rhombuses, then ten grey rhombuses with sides equal to 20 pixels are created, with a maximum speed of 3 pixels in each movement and a random number between 0 and 9 is added. When selecting in "Change color," the properties that are generated are the same as choosing in "Start"; the difference is that each circle has a different color. "Resize" creates loops with the qualities of "Start"; the divergence lies in the radius of the figure, which can be: 20 pixels, 40 pixels, or 60 pixels. "Change speed" the only thing it does, unlike "Start" is to change the movement of the objects with a maximum speed between 3, 5, and 7 pixels. Finally, "Random Values" generates geometric figures with different characteristics; they can be any geometric figure, with different speed, size, color, and shape mentioned above. Once the objects have been created, the screen that is generated is displayed in figure 3.

Fig. 3 Control menu BCT (User 1). Elaboration: The authors



The next step is the initialization of the test. Once the geometrical figures have been created, the user interface is as shown in figure 3. The user is offered three options: "Start," "Reset," and "Back," and three variables are presented: t1, t2, and errors. When "Start" is selected, the t1 counter starts and the ten objects are displayed all over the screen; these move around the environment, and it must be remembered that in one of them, its trajectory can be altered with the direction keys. Once the space bar has been pressed, the objects and the t1 counter stop, and the t2 counter starts. At this point, the user can select with the numerical keyboard the number of the purpose he thinks he has been controlling. If it is correct, a message is displayed and confirms the success; otherwise, an erroneous selection message is displayed, and again the BCT control menu in figure 3 is displayed with the difference that in the error variable a unit has been added. In any of the two events, the values of t1, t2, and errors are stored in a database. At any time, "Reset" can be pressed; the objects disappear, and the t1, t2, and error variables are reset. With the option "Back," you return to the start menu (figure 2). In figure 4, you can see the different options that the user can choose.

Fig. 4 Test BCT possibilities (User 1). Elaboration: The authors

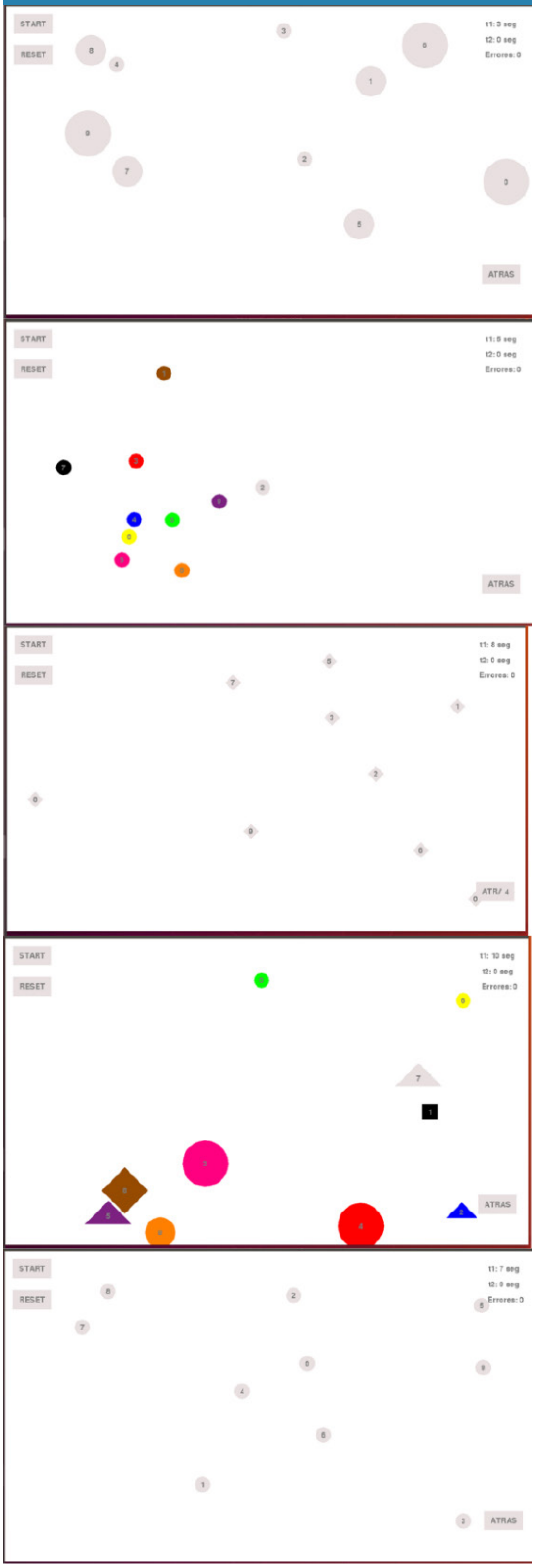
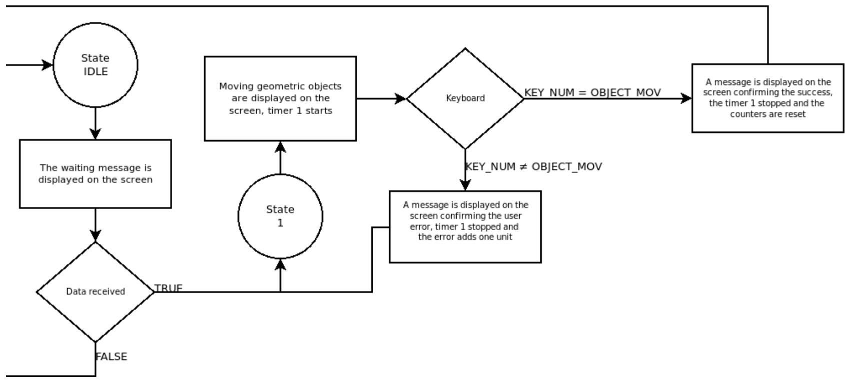


Fig. 5 Flow chart BCT (User 2). Elaboration: The authors



The flow chart of the BCT program (User 2) is illustrated in Fig. 5. When the first program is initialized the number of the geometrical figure that can be controlled is sent to the topic "POO," and the Balls control test program (User 2) saves this information for comparison when on PC 2 the number is pressed on the keyboard which user 2 believes to be the geometrical figure that user one is controlling. If the choice is correct, the program will end and return to the main menu; otherwise, it will restart and wait until the user one presses "Start" again on PC 1. In either of these two cases, the information of counters and errors is stored in a database. Here you have a single shelf, which is started when user one presses "Start." The two programs are very related but independent since no user can modify the parameters of either program.

Discussion

Undoubtedly, the function of monitoring reality is born linked to the paradigm of memory of words self-generated or generated by the experimenter[9-11] and the neuropsychological-cognitive model of Frith and Done (2). However, the old paradigm based on verbal tasks needs to be contrasted with tests that contemplate the importance of motor feedback in this cognitive function[12-14]. The assumption of a fundamental role for CPF and basal ganglia in monitoring reality as a neuroimaging finding is relatively recent but consolidated[15-18]. The fundamental contribution of the present work is precisely to dissociate the function of exclusively verbal tasks and to be able to measure more directly the viso-motor role in the discrimination of the stimulating source. The improvement in the understanding of the phenomenon of reality monitoring also represents an important advance in the very understanding of the delusional phenomenon in schizophrenia and other psychotic disorders, which also facilitates a better understanding of neurophysiopathology and therefore generates a greater impetus for pharmacological advances[19-22].

Similar programs can be developed for alternative devices (cell phone app, tablet, i-pad, or other devices) based on this initiative. Since it has been seen the importance of damage in introspective skills such as source discrimination stimulated to determine the outbreak and prognosis of functional development in schizophrenia[23], it will be necessary to perform neuroimaging studies with this software that also allows establishing different levels of difficulty to be studied evolutionarily which will establish its potential as a marker or early predictor of schizophrenic spectrum disorders. The development of software in cognitive neuropsychology has received a great boost in recent years[24] since the goal is the neurocognitive rehabilitation of patients. Furthermore, brain plasticity and cognitive functions can be improved throughout life[25]. One of the most important cognitive markers of schizophrenia is precisely the monitoring of reality associated with alterations in the medial prefrontal cortex[17]. Likewise, especially in recent years, computer programs aimed at the cognitive rehabilitation of these functions are effective (18,26,27,28,29,30).

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Conflict of interest

The authors declare no conflicts of interest.

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