26th International Congress of Mechanical Engineering
COBEM 2021
ABCM Associação Brasileira de Engenharia e Ciências Mecânicas
November 22-26, 2021, Virtual Congress, Brazil

COBEM2021-1416
CUSTOMIZATION OF A SYSTEM FOR REACTIVE AGILITY TESTS WITH COGNITIVE DEMAND

Eloi Antonio Triaca*
Dávila Moreira Lopes Silva**
Lucas Damasceno de Araújo Batista*
Jonas Medeiros de Azevedo Barbosa*
Jefferson Igor Duarte da Silva***
Arnaldo Luis Mortatti*
Adilson José de Oliveira*

*Federal University of Rio Grande do Norte, Lagoa Nova Campus, ZIP CODE 59078-970, Natal, RN, Brazil.
eloiat3@gmail.com, lucasdabatista@gmail.com, jmpnd@hotmail.com, amortatti@gmail.com, adilson@ct.ufrn.br
** University of São Paulo, São Carlos School of Engineering, ZIP CODE 13566-590, São Carlos, SP, Brazil.
davilamlopes@gmail.com
*** Federal Institute of Science, Technology and Education of Rio Grande do Norte, Ipanguaçu Campus, ZIP CODE 59508-000, Ipanguaçu, RN, Brazil.
jefferson.igorbr@gmail.com

Abstract. *The performance of athletes is directly related to how quickly their decision-making process is done. This capacity consists, mainly, in the ability to regulate, coordinate, and sequence thoughts and actions according to pre-established goals. One way to assess this cognitive capacity involves the application of the Reactive Agility with the Cognitive Demand (RACD) test, in which participants have to make decisions based on visual stimulus while executing a physical task. Thus, the cognitive demand is evaluated through the analysis of the rate of correct decisions and the amount of time the participants required for making their actions. The accuracy of the RADC test can be improved with the aid of a customized automation system, which needs to be capable to connect transducers and actuators. This paper describes the RACD test automation developed to assess the decision-making capacity of athletes. The designed system can identify the movement of an athlete in a predetermined position with the support of a photoelectric presence transducer and, then, presents to her/him a visual signal that indicates the action that he/she needs to go. A computer code based on the visual interface was developed to acquire data from the transducer and produce the visual stimulus, which can be: monochromatic arrows indicating three possible directions; colored arrows (blue, red, or green) also indicating three possible directions; or a combination of both types above-mentioned. These different configurations are levels of the cognitive demand: in the first one, the direction of the arrows coincides with the direction the athletes should move to; in the second configuration, the signal colors indicate the correct direction and the direction of the arrows do not necessarily coincide with it; and in the final configuration, both situations are presented to the assessed athlete. Moreover, the manufacturing of a functional prototype including transducer and electronic components was performed. After the completion of the automation, RACD tests were applied to athletes aimed at verifying the functional behavior of the developed device. In addition to this application, the product development can be directly applied to the automation, the monitoring, and the control of other sports-related systems and in other engineering applications.*

Keywords: *reactive agility, cognitive demand, automation, software design, product design.*

1. INTRODUCTION

Football is considered one of the sports with the greatest degree of indeterminism and unpredictability (Garganta and Gréhaigne, 1999). For each context of the game, the player must observe, process and evaluate situations at the same time, as well as choose the appropriate technical and tactical solutions for each game circumstance, that is, players are constantly making decisions (Greco, 2006). The decision-making capacity consists of the ability to regulate, coordinate, and sequence thoughts and actions in accordance with predetermined goals (Pereira, 2019; Sheppard and Young, 2006).

Thus, decision-making is dependent on executive brain function, specifically the inhibitory control of the prefrontal cortex. Inhibitory control corresponds to the individual's ability to control attention, to have discipline and self-control, to inhibit pre-existing thoughts and behaviours, in addition to resisting to interference from distractors (Diamond, 2013). The main instrument for analysing inhibitory control is the Stroop test, which aims to assess selective attention (the ability to respond to certain stimuli in the environment while ignoring others) (Salgado-Pineda *et al*., 2002; Scarpina and Tagini, 2017). This ability seems to be very important in decision-making in team sports, where the athlete must decide at all times for the best “play” during the match.

However, the traditional Stroop test does not seem to be the most suitable test to differentiate athletes with better or worse decision-making during a match, since athletes are performing actions that involve the physical and cognitive components within the field and the Traditional Stroop test is exclusively a cognitive test.

Thus, the use of instruments that assess inhibitory control in an ecological way, that is evaluating this variable within the characteristics inherent to football, can be more accurate in discriminating athletes in decision-making during a football match.

The Reactive Agility Test with Cognitive Demand (RACD) is a procedure applied to evaluate and compare the physical and cognitive performance of individuals. Usually, in reactive agility tests, a visual stimulus is presented to the participants, and, based on it, they have to make a decision (perceptual-cognitive ability) and a specific physical action (perceptual-motor skill), that is associated with a visual instruction (Lopes *et al.*, 2016). Then, the results are assessed according to two criteria: the number of correct decisions that the individuals make and the amount of time they demand to complete the test assignments (Farrow, Young and Bruce, 2005; Gabbett, Kelly and Sheppard, 2008; Pojskic *et al.,* 2018; Sheppard *et al.,* 2006; Young and Willey, 2009). In order to incorporate the cognitive demand evaluation of the individuals, two kinds of visual commands are featured: congruent signals (monochromatic arrows indicating the direction that must be followed) and incongruent signals (coloured arrows, which each colour indicating a different direction). During the test, the participants have to sprint and move in the correct direction, which is indicated just at the moment that a certain position is reached. The direction instructions can be manually presented by a referee or by an automated system. In the first case, the time demanded to present the visual stimulus to the individual needs to be recorded (Young and Willey, 2009). In the other case, the application of an automated system composed by transducers, actuators, and computers provides a more reliable and accurate data to the test (Farrow, Young and Bruce, 2005; Pojskic *et al.*, 2018; Matlák, Rácz and Tihanyi, 2017).

Moreover, tests that are done to evaluate athletic performance can be present different procedures and characteristics, depending of several factors such as: which types of signal needs to be displayed; how these signals should be presented to the assessed athletes; which decisions and actions the athletes will have to take; how the athletes will be evaluate; what types of transducers must be used to automate the test. Therefore, an automated system for the RACD test needs to be customized to fulfil specific requirements of the test for which it is designed. For instance, sport-oriented tests are found in the scientific literature. A methodology for assessing the reactive agility of netball players was developed by Farrow, Young and Bruce (2005) and Gabbett, Kelly and Sheppard (2008) developed a procedure for evaluating the reactive agility and the change of direction speed of rugby league players.

Aiming to perform accurate and customized RACD tests, the Research Group in Physiology of Growth and Motor Development (GEPEFIC), from the Department of Physical Education at the Federal University of Rio Grande do Norte (UFRN), demanded from Manufacturing Lab (LABMAN) of the Department of Mechanical Engineering in the same university, the development of an automated and customized system for such application.

Therefore, this study had as its main objective to customize the automation of a RACD test applied for the evaluation of the performance of athletes. Due to the cognitive demand assessment and the customized design, the developed system exhibits specific characteristics that are not displayed by other reactive agility test systems, in particular with regard to the types of command signal that are used. To develop the system, the following specific objectives were established: (a) the choice of presence transducer; (b) the construction of data acquisition, processing and transmission system, that will be applied for the signal emitted by the transducer; (c) the development of a power supply system for support voltage to the electronic components; (d) the manufacturing of a protective case to assembly the transducer and electronic components; (e) the implementation of computer code capable of producing and presenting the visual instructions. Moreover, the system was designed to fulfil some specifications, such as the usage of open-source technologies and the portability.

It should be noted that the technologies applied in the RACD system such as photoelectric detection and automated procedures can be employed in other physical and cognitive tests and in sport related tracking and monitoring systems (Sun et al., 2015; Ho et al., 2019). Furthermore, in the engineering context, the system has the same development chain of any automation product and it can be transferred directly to system automation, monitoring and control activities. For instance, similar concepts can be applied to automate activities such as packing and inspection in mass production lines, obstacle identification for floor-state identification, healthcare monitoring, alarm detection and water level detection (Jeong *et al.,* 2013; M. Lee and S. Lee, 2011; Ha *et al.,* 2019; Banjanovic-Mehmedovic, Zukic and Mehmedovic, 2019; Tabada, Loretero and Lasta, 2020).

2. METHODOLOGY

The set up for the RADC test and its stages are shown in Figure 1.

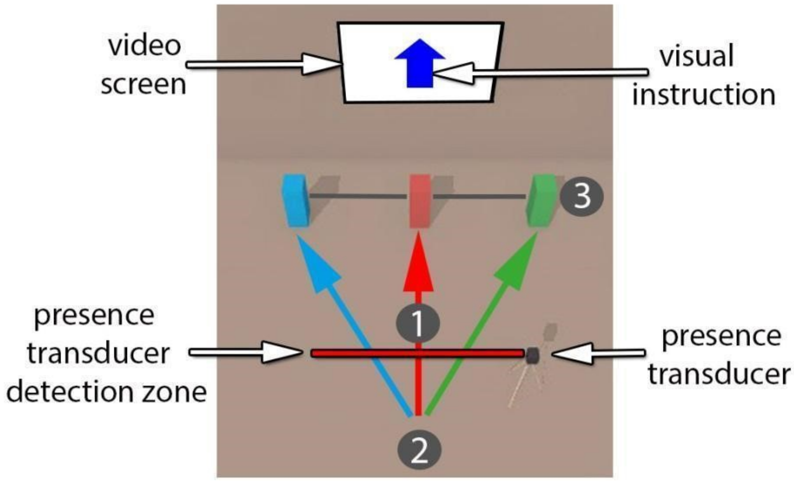

Figure 1 - Schematic drawing of the proposed set up for the RADC test

According to Figure 1, as required by GEPEFIC, the RADC test stages are defined in four steps: (a) at the beginning, the athlete must start in position "1" in front of the presence transducer detection zone; (b) in the next step, the athlete runs backwards until he reaches position "2", passing through the transducer and, then, he runs forward, passing again by the transducer sensing area; (c) at the same moment of the first passage, a signal is projected on a video screen and, based on it, the athlete has to run until he reaches position "3" in the direction indicated by the visual instruction (which can be congruent or incongruent); (d) after reaching this position, the athlete returns to position "2". Then, this cycle repeats continuously for a predefined number of times and in the end, the total test time is retained for analysis.

The visual signal needs to be chosen randomly according to three possible settings: (a) a monochromatic arrow in three possible directions (left, right or forward); (b) a coloured arrow (blue, green or red) in the same three directions; (c) and a combination of both described signals.

In the first configuration, the direction indicated by the arrow has to be followed (congruent stimulus). In the second case, the stimulus is incongruent, and the athlete must follow the direction indicated by the colour (each colour is associated with one specific direction) even if the arrow is oriented to another direction. This is a strategy to complicate the decision-making and to assess the inhibitory control, i.e., the ability to control attention, keep discipline and self-control, inhibit pre-existing thoughts and behaviours, and resist interference from distractors (Diamond, 2013). In the third possible setting, the visual signal is the combination of the monochromatic and coloured signals, and the selection criterion (the arrow orientation of the arrow colour) is informed to the athlete at the beginning of the test.

In order to develop the RACD test setup in accordance with the aforementioned requirements, the work was executed according to the steps presented in Figure 2.

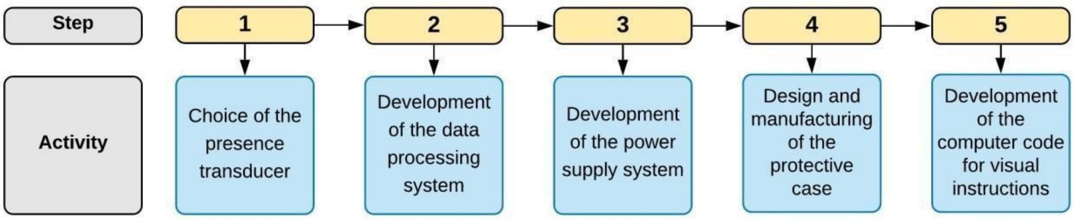

Figure 2 - Sequence of steps aimed at development of the RADC test.

As shown in Figure 2, the five steps to achieve the project specific objectives are: (a) choice of the appropriate presence transducer; (b) conception and the programming of a data processing system for the signals emitted by the transducer; (c) development of a power supply system for the electronic components; (d) design and manufacturing of a protecting case to accommodate the components; (e) and development of a computer code associated with a graphical user interface which is responsible for generating and presenting the visual stimulus.

Thus, the first step of this work was the selection of the type of presence transducer to be used. The main requirement for this selection was the maximum transducer detection length range, which needs to be longer than 1 m, due to the need to leave some space to allow the athletes to run. Other factors were taken into account in this step: the transducer response time (the time required to detect the presence); the ease of its installation; and its suitability for the connection to software and hardware.

The second step of development involved the processing of the electric response emitted by the transducer, with the aid of a universal board associated with a microcontroller. This device was selected to fulfil the following requisites: (a) the disposal of an analog input port to allow the transducer response signal acquisition; (b) a signal output port capable of being connected to a computer using a USB-A (Universal Serial Bus, or universal port) cable; (c) and the capability of operating at a minimum sampling frequency of 200 Hz. This value was chosen so that the system is capable to detect little variations of the athlete movements and that the system does not demand high computer processing capacity and data storage as well. The universal board dimensions were also considered for the selection, since, as the system is designed to be portable, the case which will allocate the transducer and the other electronic components should have the smallest possible volume. Once the microcontroller is defined, its programming was implemented. It involved the definition of the sampling frequency, the input signal processing procedure and the output data generation. A challenge for the system programming was the passage recognition. Due to the spacing between the athletes' legs and arms, the transducer can detect two passages rather than only one. Therefore, the computer code needs to be able to identify this case, producing an output signal that indicates only one passage. Besides that, the microcontroller was programmed so that: there are no breakdowns due to processing errors (such as bugs, infinite loops, and the microcontroller memory overflow), which frequently occur and can impair the system operation and its enforcement in the RACD tests; possible noises and oscillations in the input signal do not have an impact in the output signal, which could cause flaws in the visual stimulus production (e.g., the signal displays at an incorrect time) and in the test execution.

The third step involved the development of a power supply system for the transducer and the universal board, i.e., a system that connects these elements to a power supply. The electronic circuit was designed, and, after that, its connections were mounted on a universal printed circuit board (universal PCB). In this regard, a requisite for determining the power supply is the required voltage for energizing the presence transducer and board connected to the microcontroller. This process was defined in conformity with the components' technical specifications.

In the fourth development step, the protective case was designed and manufactured. The purpose of this structure is to accommodate the electronic components (the presence transducer, the board with microcontroller, the power supply system, and the connection wires). In addition, the protective case also needs to have: (a) internal structures for assembling the printed circuit board and the board with microcontroller; (b) a slot for passing the USB-A transmission cable; (c) a geometry (shape and maximum dimensions) that enables the portability of the device and its mounting on a tripod. The last requisite is important since it allows that the distances between the positions 1, 2, and 3, indicated in Figure 1, can be adjusted during the RADC test execution. The protective case was designed with the aid of the software Creo Parametric 4.0 and manufactured by Fused Deposition Modelling (FDM) process (additive manufacturing) with filament Acrylonitrile Butadiene Styrene (ABS).

In the final step, a computer code responsible for generating and presenting the visual instructions was developed. Furthermore, this computer code was also written to: (a) establish serial communication with the microcontroller output data; and (b) process this signal. As described in Figure 1, the visual stimulus shall be presented at the same moment that the evaluated athlete passes in front of the presence transducer sensing area when he/she moves to position "2". Thus, the computer code needs to identify the movement direction (whether the athlete is going forward or backward) in the data processing. After the development of the computer code, functional tests were carried out to assess the effectiveness of the system for automating the tests. This procedure enabled the detection of possible execution and installation failures and the adjustment of parameters that were applied in the signal acquisition and processing systems design.

3. RESULTS AND DISCUSSION

In order to facilitate the understanding, the section Results and Discussions is presented following the same phases that the section Methodology. Therefore, the first point refers to the choice of the presence transducer. Two types of transducer (in terms of the operating principle) were considered: the photoelectric transducers (based on the emission/reception of photoelectric beams) and the ultrasonic transducers (based on the emission/reception of ultrasonic waves). For this work, a photoelectric transducer was chosen accordingly to a product catalogue from Rockwell Automation Inc. (2016). The main benefit of the photoelectric transducer is the immediate response time since it is proportional to the speed of light. For the ultrasonic transducer, the response time is proportional to the speed of sound and, therefore, slower than the photoelectric transducer. Also, according to S. Lee and M. Lee (2011), another drawback is that the ultrasonic transducers present a wide beam angle, which restricts the differentiation of objects.

After defining the transducer operating principle, its setup time needed to be defined. The most common configurations are: diffuse (the emitter and the receiver are in located in the same device), retro-reflective (although the emitter and receiver are in the same device, it is necessary to install a reflecting mirror) and through-beam (the emitter and the receiver are located in two different devices) (Mazzaropi, 2007). For the retro-reflective and through-beam types, the alignment of two devices (the emitter/receiver and the reflecting mirror, for retro-reflective transducers; the emitter and the receiver devices, for the through-beam transducers) is required. The selection of these configurations can lead to a more difficult installation: since the system was designed to be portable (as shown in Figure 1), thus, at each repositioning of the system, the devices need to be realigned. Besides, it is important to emphasize that the system device has to be mounted over different grounds (floor, grass, earth and sand), and, in consequence, the transducer alignment is hampered. For this reason, a diffuse photoelectric presence transducer was chosen for this application. Based on the above-mentioned characteristics and the requisites listed in the methodology, the BA2M-DDTD-P diffuse photoelectric presence transducer (Autonics Corporation, BA Series) was selected. This device presents a maximum sensing distance of 2 meters and can be energized with a voltage between 12 and 24 V (Autonics Corporation, 2018).

In order to achieve the requisites determined in the second development step, the Arduino Nano module, which contains the ATMega328P microcontroller, was employed. This board was selected to satisfy the operational specifications of the system. The Arduino Nano module presents as main specifications: 8 analog input pins; 14 digital input/output pins (6 of them provide PWM output); operating voltage of 5 V; input voltage between 6 and 20 V (a voltage between 7 and 12 V is recommended); clock speed of 16 MHz (it measures the number of cycles that the central processing unit - CPU - can complete a processing cycle); and the availability of the USB Mini-B port for data output (Arduino, 2020). The data transmission between the module and the computer was done with the aid of a cable with USB Mini-B and USB-A connectors. The clock speed is related to the module maximum sampling frequency. However, the sampling frequency is lower than the clock speed, due to the analogical-digital conversion, that is executed inside the module; and also due to the amount of information that is processed inside the microcontroller. Besides the operational specification, the Arduino Nano module was selected due to its smallest dimensions in comparison with other Arduino models. The purpose of this was the size reduction of the protective case, which eases its installation and portability.

The microcontroller was programmed in the Arduino integrated development environment (IDE). In the computer code, an output signal that indicates the passage of the athlete is produced only after the acquisition of five input signals indicating the presence (Triaca, 2020). These signals are acquired at a sampling rate of 200 Hz. In operational tests, oscillations and noises in the emitted signal were observed. Due to these signal instabilities, the signal needs to be filtered, since they could lead to errors in the presence detection and, consequently, in the microcontroller output signal. Besides that, the microcontroller was configured in a manner that it is reset to a known condition (initial condition) if any failure or unexpected situation occurs. Concerning the problem of detection of two passages in one run (which can occur due to the passage of two distinct human body members), a delay time was added between acquired signals when the microcontroller detects a passage. Therefore, in the first passage of an arm or a leg, the system stops to acquire the signal emitted by the transducer for an amount of time, recognizing just one passage. Based on functional tests, the delay time was 500 ms.

The power supply system uses two batteries of 9V connected in series in such way that the presence transducer is energized with a voltage of 18V and the module is energized with half voltage (9V). The batteries were connected to the transducer and to the Arduino Nano module with the aid of an electric circuit. This circuit was mounted on a universal PCB.

The protective case design and manufactured device are shown in Figures 3 and 4, respectively.

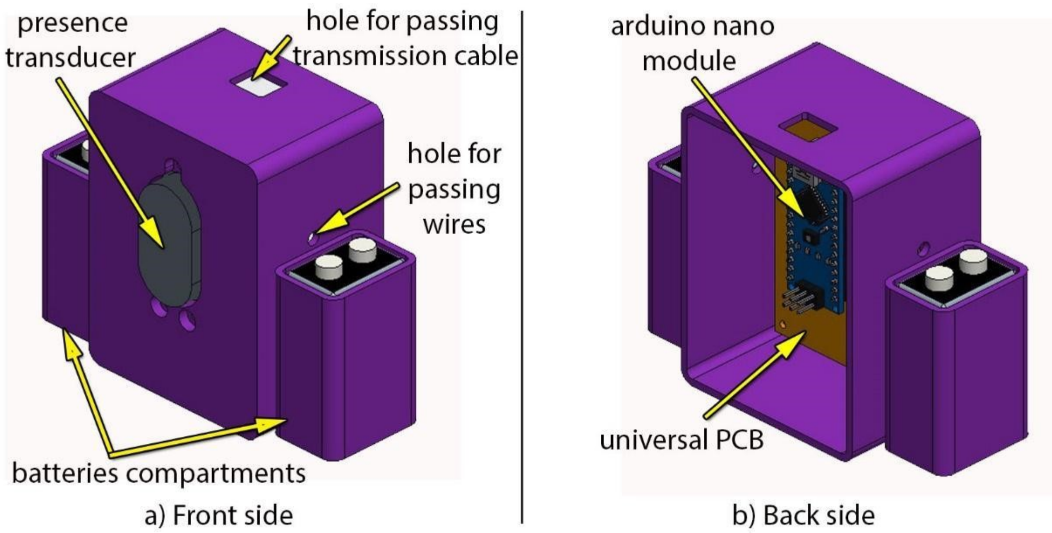

Figure 3 - Design of the protective case for the transducer and electronic components

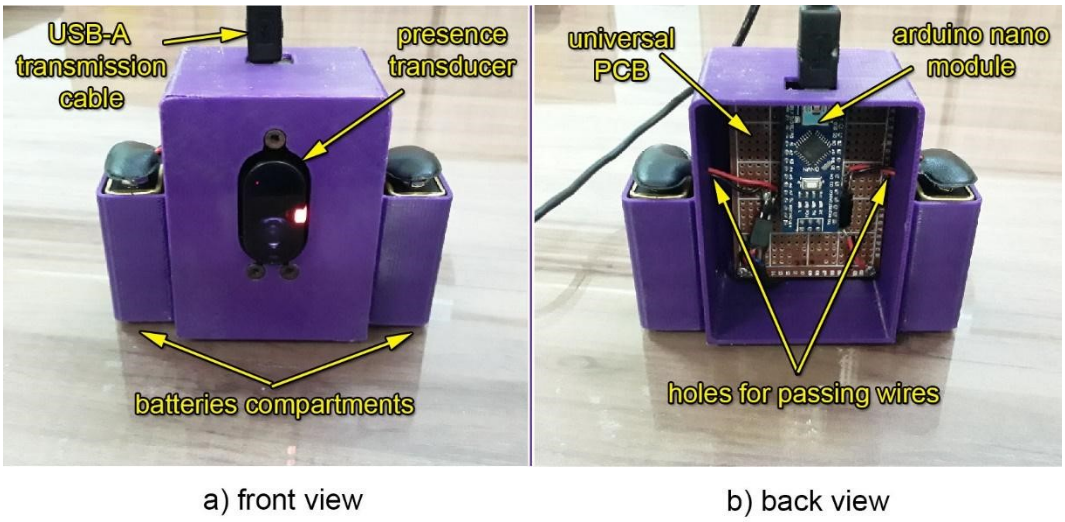

Figure 4 - Presence transducer and electronic components mounted inside the protective case associated with batteries mounted outside

According to Figures 3 and 4, the transducer, the module, and the universal PCB are accommodated internally, whereas the batteries are disposed externally to the protective case. This setup was chosen to ease the replacement of the batteries, which is needed after their discharge. The transducer and the universal PCB were mounted inside the case with the aid of screws (diameter of 2.778 and length of 19.05 mm). In addition, the designed protecting case displays: (a) a rectangular hole for passing a USB-A transmission cable; (b) a wall thickness of 2 mm; (c) the two small holes for passing wires that connect the batteries to the universal PCB. The maximum dimensions of the designed device are length of 106.33 mm, width of 47 mm and height of 80 mm. Such dimensions, in conjunction with the geometry of the case (as displayed in the Figures 3 and 4), also allowed an easy mounting of the protecting case to the tripod and, in consequence, its portability. To manufacture the device, the enclosures of the electronic components and the batteries were produced separately and, afterward, they were bonded. This procedure is associated with the limitation of the FDM process since it still does not allow the manufacturing of parts with tight tolerances for the adjustments.

In the last development step, the Processing IDE was employed to write a computer code for visual instructions (Triaca 2020). This IDE is suitable for the generation of simple graphical and visual representations. Figure 5 shows the initial user menu and graphical interface of the computer code.

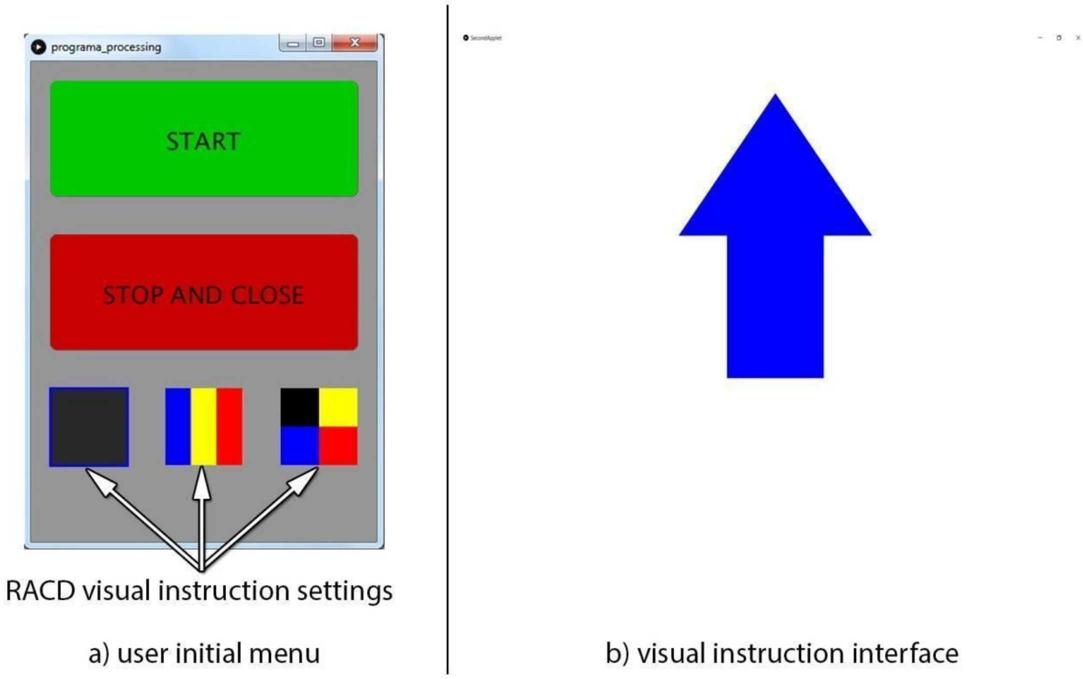

Figure 5 - Graphical interface of the computer code for visual instructions

Figure 5 indicates that the computer code consists of two interfaces: the first (on the left side) presents to the user the possibilities of choosing the visual signal properties, of starting the signal presentation, and of stopping it; the second window (on the right side) displays the visual instructions. The data acquisition, which is transmitted to the computer, was done through the establishment of serial communication. In order to solve the problem of identifying the direction of the movement of the athlete (forward or backward), the following solution was adopted: a variable was created to count the number of passages; since the athlete passes through the transducer sensing area two times in each run, the direction indication is exhibited when the passage counting is an odd number. The choice for odd numbers was due to RADC test procedure: the athlete places himself/herself, initially, in front of the presence transducer detection zone; next, the individual has to run backwards, passing through the transducer detection; at the moment that this first passage is registered, the visual instruction is displayed, and, then, the athlete starts to sprint for the test. Then, the signal is presented only when the individual reaches the position where he/she started the sprint.

With the aid of the functional tests, the computer code and system operations parameters were adjusted, such as the microcontroller sampling frequency, the delay time, the size of the visual signal and the presence transducer placement (related to the height from the ground and the distance between the transducer and the screen with the visual instructions). Therefore, the operational tests confirmed the suitability of the designed system for the execution of RACD tests in the conditions demanded by GEPEFIC.

4. CONCLUSIONS

This paper presented the development of a system that allows the automation and the customization of a reactive agility test with cognitive demand (RADC) test, which had its viability assessed with the aid of functional tests. The designed system fulfils the demands of GEPEFIC for an automated, accurate test capable of assessing the reactive agility and cognitive demand of individuals, which differs from common reactive agility tests. Moreover, the system construction and programming employed open-source and low-cost technology, such as the usage of an Arduino Nano board, the Arduino IDE and the Processing IDE. Based on the requisites of the five development steps (choice of the presence transducer, development of the data processing system, development of the power supply system, design and manufacturing of the protective case, and development of the computer code for visual instructions), the conclusions about these activities are that:

• The selection of a diffuse photoelectric presence transducer has proven suitable for identifying the passage of athletes at a distance shorter than 2 m;

• The selection of a diffuse photoelectric presence transducer has proven suitable for identifying the passage of athletes at a distance shorter than 2 m;

• The system designed with microcontroller was able to: acquire the transducer output data; process it, eliminating signal noises and oscillations; and transmit it with the aid of a USB cable; The power supply of the electronic components involved the employment of two batteries of 9V with the aid of an electric circuit mounted on a universal PCB;

• A protective case for the transducer and electronic components was designed and quickly manufactured, due to the application of additive manufacturing (Fused Deposition Modelling – FDM) process. Due to its small dimensions, the designed system is portable and the distances that are used in the RACD test setup can be adjusted;

• A computer code with a graphical user interface was developed, allowing the user to choose three kinds of visual stimulus settings for the RADC test. Besides, the computer code is capable of processing the acquired data and produces the visual signals randomly.

5. REFERENCES

Autonics Corporation., 2018. *Instruction Manual, Photoelectric Sensor, BA Series*.

Arduino. *Arduino Nano (web publications)*. Arduino, *https://store.arduino.cc/usa/arduino-nano*. Accessed 6 March 2020.

Banjanovic-Mehmedovic, L., Zukic, M., and Mehmedovic, F., 2019. “Alarm detection and monitoring in industrial environment using hybrid wireless sensor network.” *SN Applied Sciences,* Vol. 1, N. 263.

Diamond, A., 2013. “Executive functions”. *Annual Review of Psychology,* Vol. 64, pp. 135-168.

Farrow, D., Young, W., and Bruce, L., 2005. “The development of a test of reactive agility for netball: a new methodology”. *Journal of Science and Medicine in Sport*, Vol. 8, N. 1, pp. 52-60.

Gabbett, T.J., Kelly J.N., and Sheppard, J.M., 2008. “Speed, change of direction speed, and reactive agility of rugby league players”. *Journal of Strength and Conditioning Research*, Vol. 22, N. 1, pp. 174-181.

Garganta, J., and Gréhaigne J.F., 1999. “Systemic approach of the football game: trend or necessity?” (in Portuguese). *Movimento*, Vol. 5, pp. 40-50.

Greco, P., 2006. “Tactical-technical knowledge: pendulum axis of tactical (creative) action in collective sports games” (in Portuguese). *Revista Brasileira de Educação Física*, Vol. 20, N. 5, pp. 210–212.

Ha, S., Park, S., Lim, H., Baek, S.H., Kim, D.K., and Yoon, S.-H., 2019. "The placement position optimization of a biosensor array for wearable healthcare systems". *Journal of Mechanical Science and Technology,* Vol. 33, pp. 3237–3244.

Ho, C.-S., Lin, K.-C., Hung, M.-H., Chang, C.-Y, and Chen, K.-C., 2019. "System design and application for evaluation of digging agility in college male volleyball players". *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology,* Vol. 233, N. 3, pp. 424-431

Jeong, Y.-M., Kim, Y-S., Kim, S.-S., and Yang, S.-Y., 2013. "Construction of an automation system for the inspection and packing processes of a screw/bolt production line". *Journal of Mechanical Science and Technology,* Vol. 27, pp. 1825–1834.

Lee, M., and Lee, S., 2011. "Design and analysis of an infrared range sensor system for floor-state estimation". *Journal of Mechanical Science and Technology,* Vol. 25, pp. 1043-1050.

Lopes, M.C., Magalhães, R.T., Diniz, L.B.F., Moreira, J.P.A., and Albuquerque, M.R., 2016. "The influence of technical skills on decision making of novice volleyball players". *Revista Brasileira de Cineantropometria e Desempenho Humano*, Vol. 18, N. 3, pp. 362-370.

Matlák, J., Rácz, L., and Tihanyi, J., 2017. "Assessment of repeated reactive agility performance in amateur soccer players". *Science & Sports,* Vol. 32, N. 4, pp. 235-238.

Mazzaroppi, M., 2007. *Movement and Presence Sensors (in Portuguese)*. Bachelor Thesis, Undergraduate Program in Electrical Engineering, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil, 2007.

Pereira, D.C., 2019. *The impact of physical and cognitive demands on the cognitive control and its relationship with the physical performance of cycling athletes (in Portuguese).* Master's Thesis, Graduate Program in Physical Education, Federal University of Rio Grande do Norte, Natal, Brazil

Pojskic, H., Åslin, E., Krolo, A., Jukic, I., Uljevic, O., Spasic, M., and Sekulic, D., 2018. "Importance of Reactive Agility and Change of Direction Speed in Differentiating Performance Levels in Junior Soccer Players: Reliability and Validity of Newly Developed Soccer-Specific Tests". *Frontiers of Psychology*, Vol. 9, pp. 1-11.

Rockwell Automation Inc., 2016. *Presence Sensing brochure*. Rockwell Automation Inc., USA.

Salgado-Pineda, P., Vendrell, P., Bargalló, N., Falcón, C., and Junque C., 2002. "Functional magnetic resonance in the evaluation of the activity of the anterior cingulate cortex using stroop's paradigm". *Revista de Neurología* Vol. 34, N. 7, pp. 607-611.

Scarpina, F., and Tagini, S., 2017. "The stroop color and word test". *Frontiers of Psychology,* Vol. 8, N. 557.

Sheppard, J.M., and Young, W.B., 2006. "Agility literature review: Classifications, training and testing". *Journal of Sports Sciences,* Vol. 24, N. 9, pp. 919-932.

Sheppard, J.M., Young, W.B., Doyle, T.L., Sheppard, T.A., and Newton, R.U., 2006. "An evaluation of a new test of reactive agility and its relationship to sprint speed and change of direction speed". *Journal of Science and Medicine in Sport,* Vol. 9, N. 4, pp. 342-349.

Sun, Q., Chong, W., Chengqiang, Y., and Zhao, Y., 2015. "Photoelectric detection algorithm for football bounce rate measurement based on horizontal displacement compensation". *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology,* Vol. 230, N. 2, pp. 90-99.

Tabada, M. T., Loretero, M. E., and Lasta, F.F., 2020. "Investigation on the performance of a multi-wire water level detection system using contact sensing for river water monitoring." *SN Applied Sciences,* Vol. 2, N. 77.

Triaca E.A., 2020. *RACD test automation (web publications)*. GitHub repository, *https://github.com/eloiantonio/RACD_test_automation*. Accessed 26 June 2020.

Young, W.B., and Willey, B., 2009, "Analysis of a reactive agility field test". *Journal of Science and Medicine in Sport*, Vol. 13, N. 3, pp. 376-378.

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.