A behavioral box for tactile tasks discrimination

José Wanderson Oliveira Silva[1] and Luiz Marcos Garcia Gonçalves[1]

[1]**Universidade Federal do Rio Grande do Norte**
Av. Salgado Filho, 3000, 59.078-970, Natal, Brazil
jose.wanderson.ct.ufrn@gmail.com, lmarcos@dca.ufrn.br

Abstract: Among the studies done with rodents, the behavioral ones stand out. To perform these studies, the behavioral boxes are commonly used. These are devices in which the rodents perform some task to receive a reward. These animals are considered excellent subjects for studying the tactile sensory system, since they use their whiskers to locate and discriminate objects. In this work the goal is studying the sensory system of rodents in tasks in which the animals must discriminate the width of an aperture, using only their whiskers to receive a reward. We aim to develop an automated open-hardware behavioral box to perform task of tactile discrimination in rodents. For such, we designed the box using a three-dimensional modeling software and its control is implemented with Arduino, which was tested in a computer model trhough physical simulation. All used components are low cost and can be found or developed in Brazil. The present study provides an important tool for the study of the tactile sensory system, that makes possible other laboratories to build their own behavior box for tactile studies.

Keywords: Rodents, Somatosensory; Sensory Integration; Behavioral Box.

1 Introduction

Rodents are the animal model most used in experimentation today due to a series of characteristics, such as: small size, short reproductive cycle, numerous offspring, precocity, easy handling, varied nutrition and adaptation to captivity [3]. Among the various procedures performed with rodents, we highlight the behavioral studies of operant conditioning, which consists of a learning process in which the animal's behavior is modified by a reward or punishment. In order to carry out these studies, training apparatus known as operant conditioning boxes (OCB) are commonly used. There are many types of OCB, and the operation of each box aims to study some characteristic of the animals' behavior. For example, the mazes in T and Y [25], aim at decision making; the elevated plus maze aims to study anxiety characteristics [26], the open field aims to study both spatial and anxiety characteristics. Actually, a series of learning and discrimination tasks can be studied by way of training in an OCB.

1.1 Simple and Conditional Discrimination

Operant conditioning is a method developed for learning of new behavior, normally tested with the above mentioned laboratory animals using OCB. The learning takes place through the use of stimuli (auditory, visual, tactile or taste) and through environmental consequences (reinforcements and punishments). Since its creation, it has been used in several areas of knowledge. In Neuroscience, for example, its use opens the door to a wide range of new knowledge through tasks that emulate behaviors.

The materialization of this contingency study and the proof of the learning method were developed based on the work of Skinner, a Behaviorist Psychologist who developed an environment, called the Skinner box, composed of a lever, a feeder and an electric shock generating grid. In this environment, two types of contingencies could be observed. When the lever is presented, the individual performs the behavior of pressing it, then he will receive the reward (reinforcement). If, when the lever is presented, the individual performs the behavior of going to the back of the box, he will soon receive a small electric shock (punishment). Experimental paradigms measuring response time often assess how the sequence of the information process of perception, decision making and action is organized [31]. For the development of behavioral tasks that include the evaluation of these processes, different experimental models have been developed throughout history, such as configuration, single rule and multiple rule models [32]. These were developed through the establishment of conditional discriminations. Unlike respondent conditioning, in which a stimulus elicits a response, in operant conditioning stimuli have the function of creating context for a new response to occur.

1.2 OCB FOR TACTILE DISCRIMINATION TASKS

The OCB developed by Krupa and colleagues [5], presents a mechanism that allows animals to discriminate the gap between two bars using only their vibrissae. The animal has to associate the wide or narrow opening with the position (right or left side of the box) where and receives a drop of water as a reward. This OCB was used in several experiments of tactile discrimination such as the study published by title the Brain-to-Brain Interface for Real-Time Sharing of Sensorimotor Information [28], in that study of Brain-brain interfaces were used to help mice to collaborate with each other the others. When a second mouse was unable to choose the correct lever, the first mouse noticed (not getting a second reward), and produced a round of task-related neuron firings that made the second mouse more likely to choose the correct lever. The mice were rewarded when the actions were performed by the "decoding mouse", which conformed to the input signals and when the signals were transmitted by the "coding mouse", which resulted in the desired action. However, the development of this box is almost 20 years old, and for its construction, electronic components and actuators that have already been technologically outdated were used. As a result, the operation of the box was a complex procedure, involving controller boards connected to a dedicated PC, an air compressor for actuating the actuators, a PCB with numerous components affixed to a frame of more than 1 m². In addition, this system used many imported components very rare to be found in Brazil.

With the popularization of micro-controllers and integrated platforms like Arduino and Raspberry it is possible to miniaturize many control systems. The Arduino is a micro controlled board built with the objective of being a device that was both inexpensive, functional and easy to program, thus being accessible to students and amateur designers. In addition, the concept of free hardware was adopted, which means that anyone can assemble, modify, improve and customize the Arduino, starting from the same basic hardware. Thus, it was created a board composed by an Atmel microontroller, input / output circuits and that can be easily connected to a computer and programmed via IDE (Integrated Development Environment, or Integrated Development Environment) using a language based on C / C ++, without the need for extra equipment in addition to a USB cable. Once programmed, the micro-controller can be used independently, that is, you can put it to control from the opening and closing of a gate to a robot, the lights in your house, the temperature of the air conditioning, you can use it it as a measuring device or any other project. In the developed project, the Arduino will be the hardware responsible for the automation and control of the behavioral box operating processes, being he specifically responsible for controlling the opening and closing of the sliding door, controlling the reward release of the nose pokes and controlling the sensors.

However, the OCB developed by Krupa uses electronic components and actuators that have already been technologically outdated, which makes the operation and maintenance of the box a difficult task. Aiming to overcome these technological difficulties, this work aims to develop a portable, low-cost device that uses components present in the Brazilian market and that allows rodents to train tactile discrimination with the same efficiency as the In addition, with the use of technology of micro-controllers and servo motors, it will be possible to design more complex experiments such as, for example, small variations in the opening of the bars, as well as to facilitate the programming of the OCB, by Krupa [5]. In this work we present an automated open-hardware OCB model to be used in tactile discrimination experiments.

2. Methodology

Figure 1 shows the behavioral platform generally used in neurosciences studies, which consists of a large main chamber connected to a small discrimination chamber by a narrow 7.5 cm passage. The discrimination chamber is separated from the main chamber by a sliding door controlled by the Rack system. The rack system consists of an upper and lower rack coupled to the upper end of the sliding doors, in addition to having the door bearing base connected to the motor-gear coupling base, where the servo motor is fixed promoting the rotation of the pulley that gives movement to the sliding door opening and closing rack system.

On the front wall of the main chamber are two mechanisms for the rodent to insert the nose, called nose pokes (Figure 1) that allow the rat to signal whether the opening is wide or narrow. Within each of these nose pokes there is a 2 mm diameter tube that a small water supply hose is inserted as a reward for correct discrimination. Directly in front of each nose poke is a small metal plate that covers completely when closed, thus preventing access to the nose poke (not shown in Figure 1).

Each time the sensor is activated when the animal places its nose, it has an infrared sensor that detects whenever a mouse has inserted its nose into the nasal cavity. When breaking the beam of light, it is sending a signal to the Arduino that controls the behavioral experiment. The discrimination chamber contains a third nose poke located in the middle of the front wall (see figures 1, 2) which also has an infrared sensor attached to its side, which detects when something has entered the discrimination compartment. In the same compartment it has two bars, made of plastic by 3D printing, responsible for delimiting an opening between them. Both bars are controlled by a mechanism called scotch yoke, which, through the rotation of the servo motor coupled to the internal system, transforms the angular movement of the internal pulley of the component into a linear movement, thus favoring the movements of the bar coming and going.

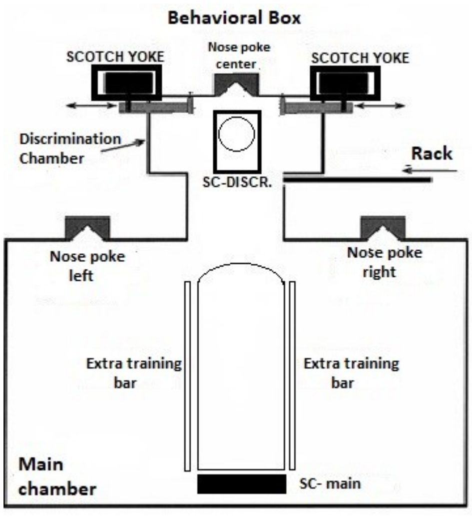

Fig. 1 - Schematic diagram of the structural behavior box.

In the upper part of the developed box, we have mechanisms for capturing the activities performed inside the equipment, called camera supports. These supports are made of acrylic and are located in each chamber, which are strategically positioned to capture all behavior performed inside the box. At the base of the developed behavioral apparatus we have a structure with a rectangular shape being constructed of acrylic, the base cover to which the walls of the box are connected has a rectangular shape and is also constructed of acrylic. The set of cylindrical bars, called a grid, must cover an area of 696 cm, the grid is made up of 32 aluminum cylindrical bars 25 cm long and 3 mm in diameter. The tray is built-in, being easy to insert, constructed of acrylic. The device can be placed inside a soundproof and lightproof insulation box.

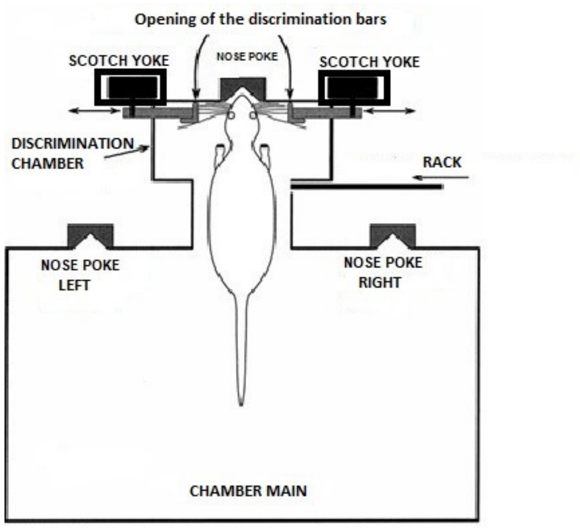

Fig. 2 - Schematic diagram of the Structural behavior box showing the rodent.

All aspects of the training were fully automated and controlled by an Arduino, requiring no intervention by an experimenter. Operation will be controlled by the Arduino IDE programming software. After the behavioral device is closed in a lightproof isolation box, it will be illuminated with infrared light. The behavior of each mouse can be monitored using infrared-sensitive video cameras (placed above the discrimination chamber and the main camera), thereby eliminating any need to obscure the vision of the mice. In a way, the construction of equipment consisting of several simple replacement mechanisms provides significant relevance in the handling and operation of the device. Modularity is a system characteristic that allows extra components to be added, related to a given mechanism.

Thus, offering extra features such as: two bars to insert forced training in the main chamber, a pair of reward nose pokes, the possibility of taking the device to environments outside the laboratory and even the adaptation of a small camera to the device.

The modular components can be combined with each other in an almost unlimited way. In this way, the ideas of obtaining multiple functionalities become reality. Reliability and expandability ensure that the built-in modulator systems can be used over a long period.

3 STRUCTURAL ASSEMBLY

The box basis has dimensions of 66.0 cm x 45.5 cm x 5.5 cm being constructed of wood, the base cover has dimensions 66.0 cm x 45.5 cm x 1.0 cm being constructed of acrylic, the set of bars (grid) must cover an area of 29 cm x 24 cm, and the grid is composed of aluminum cylindrical bars 25 cm long and 3 mm in diameter, with 0.8 cm spacing from one bar to another. the drawer or tray has dimensions 29.0 cm x 42.2 cm x 1.8 cm and is constructed of aluminum.

3.1 – HARDWARE AND SOFTWARE

For the development of control processes, an arduino mega 2560 micro-controller board (manufactured in Italy by Arduino) and its arduino IDE programming software were used to control the actuators and sensors present in the system. It has a nema pitch 23-56 mm 2.8 A - high torque kh42jm2b087 (manufactured in japan by Servo Co. Ltd, Indonesia), an infrared sensor hd-ds25cm-3mm (manufactured by Omron in China), a TowerPRO MG995 servo motor (manufactured by TowerPro in Taiwan) , walls and base made of acrylic, syringe pump, nose poke, security lock of the camera support and rack top system all made of ABS plastic (Acrylonitrile-Butadiene-Styrene) by 3D printing, Scotch Yoke built part with acrylic and the other part with ABS, camera holder made of acrylic and B/W cameras (manufactured by Panasonic in Suzhou, China).

The use of computer graphics tools for the conception and development of an automated behavioral box, makes this task more efficient and also allows the quick verification of different schemes of adequacy to the project, seeking the most adequate solution to the problem under study. The Sketchup program was originally developed by the @last Software, which is from an American Company based in Boulder, Colorado, and was acquired by Google, as announced on March 14, 2006. In 2012 Trimble Navigation acquired the program. Sketchup is available in two versions: the professional version, pro, and the free version, make, (for private, non-commercial use), available on windows and IOS platforms, in addition to a web version that runs directly in the browser.

3.2 – MECHANISMS - READY COMMERCIAL MODULES

The Scotch Yoke is a mechanism that converts the linear movement of a cursor into rotational movement or vice versa. the pin is directly coupled to a sliding fork with a slot that engages a pin in the rotating part (figure 3). these mechanisms are commonly used in control valve actuators in high pressure oil and gas pipelines, as well as in various internal combustion engines, hot air engines and steam engines. This mecanism is also used in testing machines to simulate vibrations with simple harmonic movements. In the work developed, the scotch yoke set will be used to move the bars of the discrimination chamber, where the animal will be taken to identify the opening of the bars. The purpose of this mechanism is to control the opening of discrimination bars. the assembly will be connected by an MG995 servo motor in the center of the circular pulley.

When the crank, which is a mechanical part consisting of an arm perpendicular to an axis, is connected to its end, the rotation movement begins, the received rotation movement will be transmitted by the axis and transforms it, through a tie rod, in a linear reciprocating motion when it is rotating clockwise, the scotch yoke will be receiving the moment of forward displacement. The Nose Poke is another mechanism consisting of a response device with light beam detection to signal when the animal positions the snout in the hole. The opening where the animal places the nose is 2.50 cm in diameter and 2.286 cm deep with a 1.03 cm diameter through-hole.

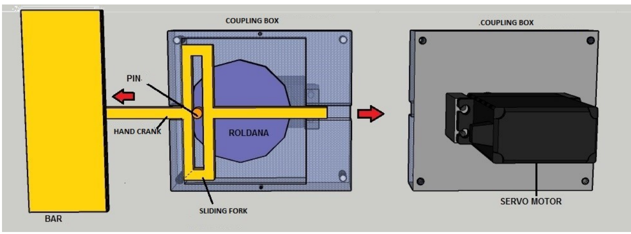

Fig. 3 – Scotch yoke.

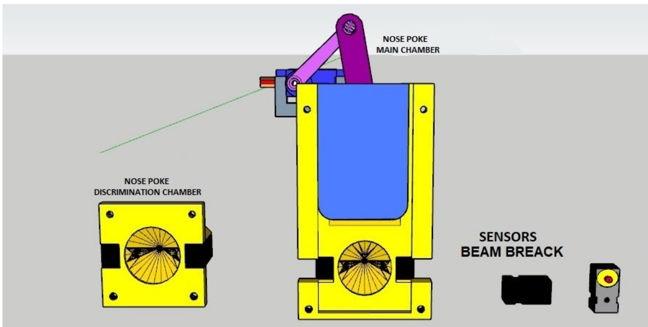

Fig. 4 – Nose Poke and IR Sensors.

A syringe pump is a type of device used for procedures that require precise volume control. the pump will be used to release the reward, 50 micro-liters of water for each hit in the tasks. the mechanism consists of a stepper motor Nema model jk42hs48-1804, which will be responsible for rotating a helical cylindrical piece that presses and loosens the syringe attached to the set. the syringe is attached to the syringe coupling piece by two fixing mechanisms that act as a limiter on the location from which we place it. after being placed, the syringe is completely filled with water with the pressurizer supported on its end, where the engine is finally connected to its base, thus leaving the system ready for operation. The rack is a straight-shaped mechanical device that helps to perform linear movements. The developed model is made in 3D printing with ABS plastic material, the upper rack with dimensions (18.8cm x 0.5cm x 0.5cm), the lower part has (6 cm x 0.5cm x 0.5cm) has as an objective to assist the movement of the sliding door and fix them in itself. As shown (Figure 6). Finally, cameras (Figure 7) will be used to record each experiment. For this, using the model mentioned in Figure 9, supports were developed to facilitate the coupling of the cameras, improve the adjustment, positioning and security of capturing the records in each area of the box. in the main chamber the support has a degree of freedom for angular adjustment, whereas for the discrimination chamber the support is fixed without the need for angular adjustment.

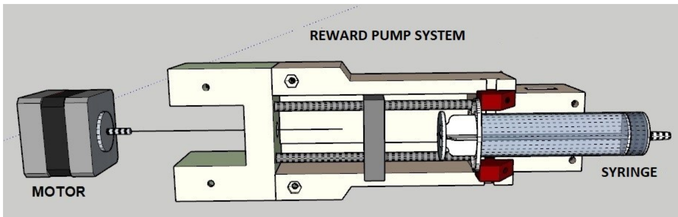

Fig. 5 – Syringe pump.

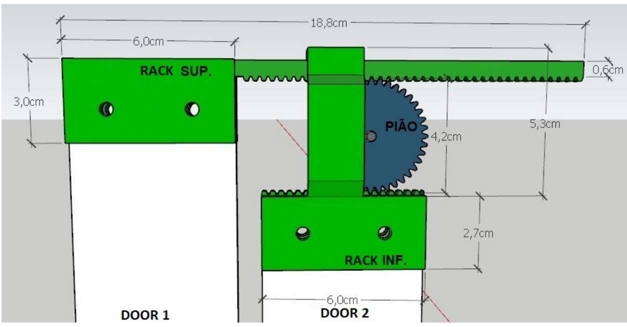

Fig. 6 – Rack.

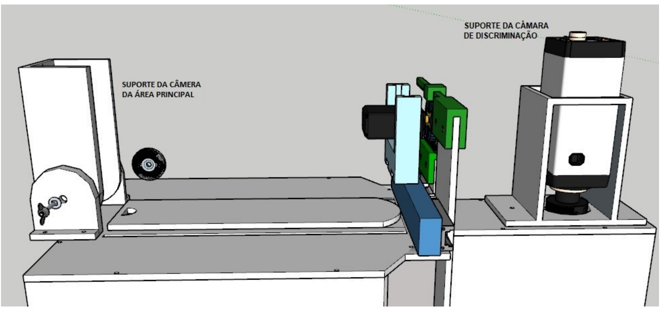

Fig. 7 – Cameras and brackets.

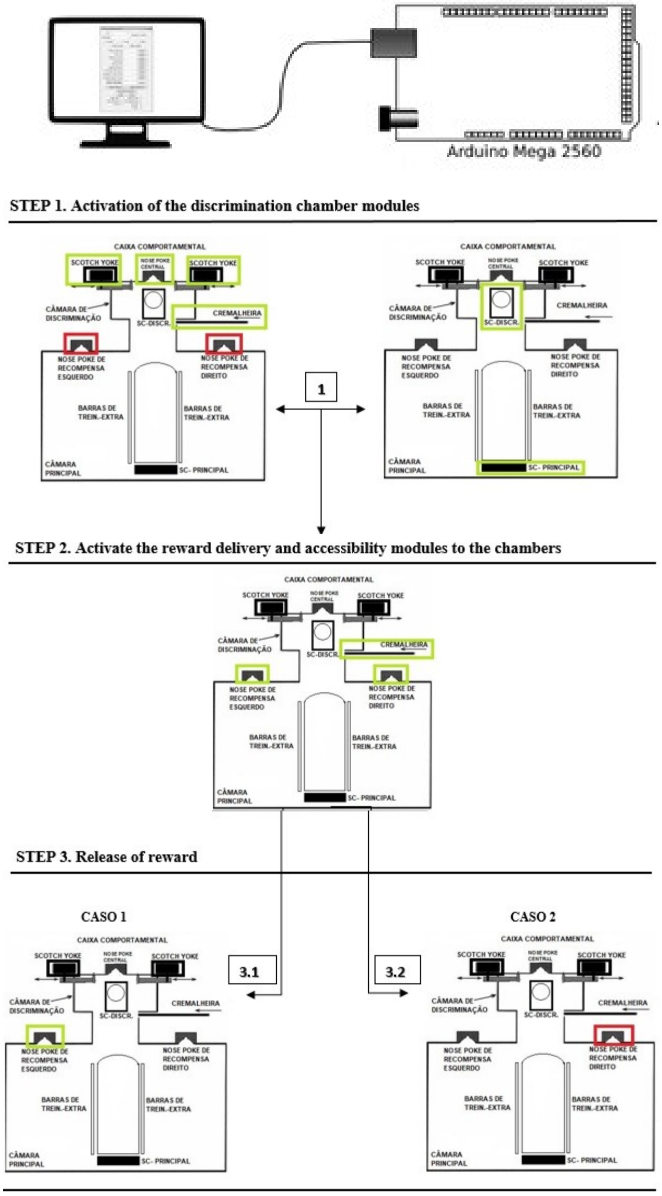

Fig. 8 – Control of the box plant through actuators.

A microcontroller is a single chip computer that is manufactured specifically for embedded system control applications. They also have input and output ports so that digital data can be read or emitted by the micro-controller [34]. Some devices have digital and/or analog converters and the converter outputs can be used to control a plant through an actuator, illustrated in Figure 8. In step 1, the Arduino hardware will activate the scotch yoke module, which will open the discrimination bars, then the rack module will open the sliding doors, leaving the central nose poke activated. In step 2, the arduino will activate the reward nose poke, where the rack module will close the sliding doors. After the occurrence of these first events, two situations will be created: Situation 1- If the nose poke is correct: a beam of light will be broken (infrared sensor), occurring the activation of the syringe pump module, and the release of the mini servo for the reward access bar when receiving a reward. Situation 2- If the nose poke is wrong: The mini servant does not release the access bar for the reward, and the reward is not released. In step 3, the arduino will activate the scotch yoke module, with the rack module passing the command to the central nose poke activating it.

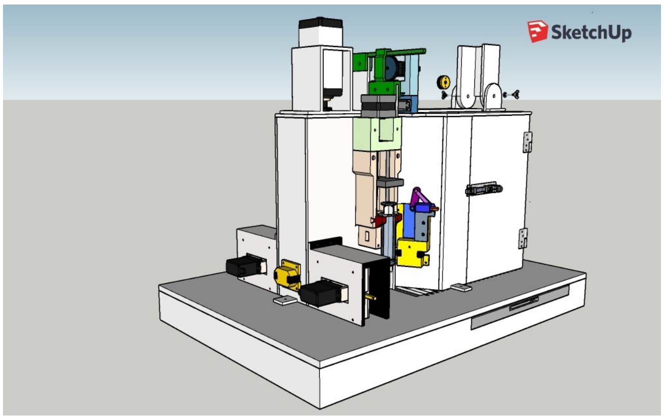

Figure 9 – Control of the box plant through actuators.

4. OCB CONSTRUCTION AND VALIDATION

The device works fully integrated with the Arduino functionalities, which will be the brain of the device. The mechanisms for moving the bars, releasing and delivering the reward, opening sliding doors, work in an integrated manner and together they collaborate so that the training to be carried out can be successful. The training filming steps result simultaneously from the process performed in the training of each animal. The reward nose pokes are integrated with the syringe pumps, which were designed to act precisely in the release of the reward, as shown in Figure 8.

The movement of the discrimination bars is linked to the scotch yoke which will act in determining the space of a narrow (62 mm; left column) or wide (68 mm; right column) opening. The sliding door is controlled by the rack top system, which will release the mouse access from the main chamber to the discrimination chamber. The full box is shown in figure 9.

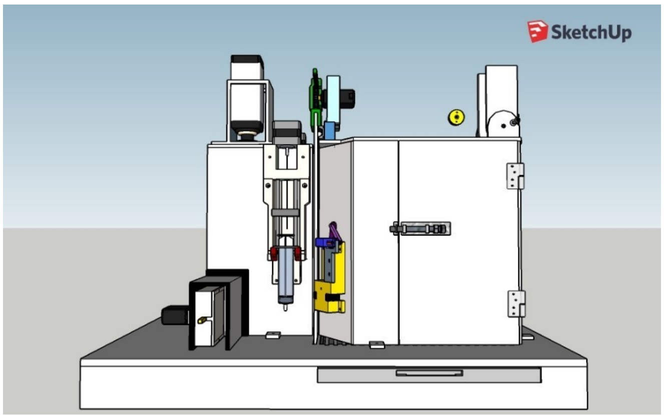

Figure 10 - Complete Automated Behavior Box (Side View)

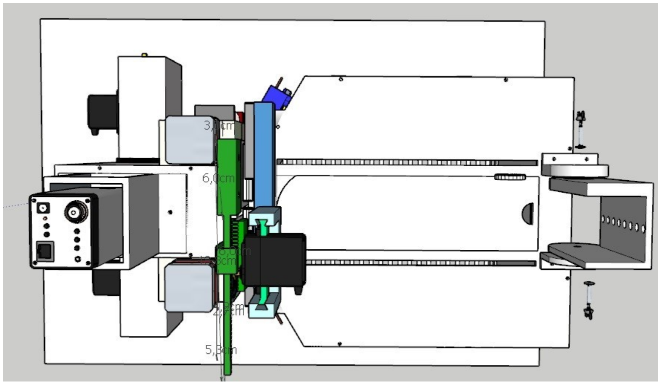

Figure 11 - Complete Automated Behavioral Box (top view).

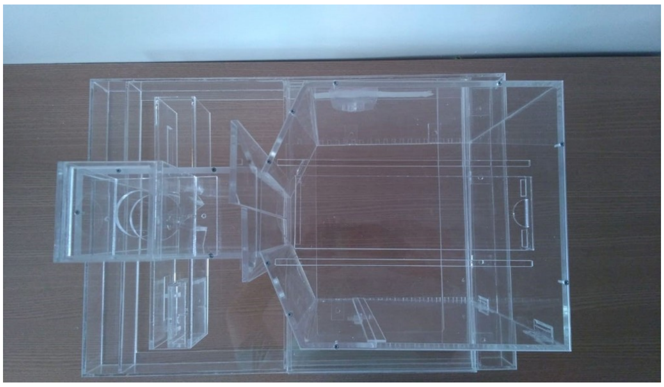

Figure 11 - Complete Automated Behavioral Box (top view).

In addition, the equipment in its upper part has two spacings, as shown in Figure 10 and 11, which allow the insertion of solid bars that provide the realization of different training sessions to what it has as main training the sketch shown in Figure 8.

Figure 12 shows the acrilic parts of the constructed OCB, which has been integrated with the above mentioned hardware and software. No further experiments have been done as the goal of this work is to show the design and construction phases.

5. CONCLUSION

To date, basically, we have constructed and assembled all of the structural parts of the device (acrylic and 3d printing parts). Further work will be done through the application of the several trainings as specified in the work, with an amount of rodents varying from 8 to 12 rodents, in order to fully validate it.

The behavioral study device developed is an important tool for the study of the tactile sensory system. The work developed here allows other laboratories to enjoy this accessible and easily developed tool. All the developed material will be made available in a collaborative multi-user platform.

References

1. SHIGLEY, Joseph Edward, Tradução de CARVALHO, Edival Ponciano de. Elementos de máquinas. Rio de Janeiro: LTC – Livros Técnicos e Científicos Editora S.A. 1984.
2. SHIGLEY, J.E., MISCHKE, C.R., BUDYNAS, R.G., Projeto de Engenharia mecânica, 7a edição, Bookman.
3. ANDRADE, A., PINTO, SC., and OLIVEIRA, RS., orgs. Animais de Laboratório: criação e experimentação [online]. Rio de Janeiro: Editora FIOCRUZ, 2002. 388 p. ISBN: 85-7541-015-6. Available from SciELO Books .
4. Arakelian, Vigen, Le Baron, Jean-Paul, Mkrtchyan, Manuk, 2015/11/17, Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics - Design of Scotch yoke mechanisms with improved driving dynamics, DO - 10.1177/1464419315614431
5. David J. Krupa, Matthew S. Matell, Amy J. Brisben, Laura M. Oliveira, and Miguel A. L. Nicolelis - Behavioral Properties of the Trigeminal Somatosensory System in Rats Performing Whisker-Dependent Tactile Discriminations
6. Martin GH. Kinematics and dynamics of machines.United States: Waveland Press, 2002.
7. Arduino. Wikipedia,2018. Disponível em: https://pt.wikipedia.org/wiki/Arduino. Acesso em: 15 de outubro de 2018.
8. Arduino. Arduino,2018. Disponível em: https://www.arduino.cc/. Acesso em: 15 de outubro de 2018.
9. Modelos de Arduino. Sgnrobotica,2018. Disponível em: https://www.sgnrobotica.com/single-post/2017/08/24/Qual-a-diferen%C3%A7a-entre-os-modelos-de-Arduino-Qual-deles-devo-escolher. Acesso em: 15 de outubro de 2018.

10. SketchUp. Sketchup,2018. Disponível em: https://www.sketchup.com/pt-BR. Acesso em: 15 de outubro de 2018.
11. SketchUp. Wikipedia,2018. Disponível em: https://pt.wikipedia.org/wiki/SketchUp. Acesso em: 15 de outubro de 2018.
12. Motor Mg995. Towerpro,2018. Disponível em: https://www.towerpro.com.tw/product/mg995/. Acesso em: 15 de outubro de 2018.
13. Motor de passo. Filipeflop,2018. Disponível em: https://www.filipeflop.com/produto/motor-de-passo-nema-17-18a-48mm/. Acesso em: 17 de outubro de 2018.
14. Motor JKM-JK42HS48-1804-48. Tmart,2018. Disponível em: https://pt.tmart.com/JKM-JK42HS48-1804-48mm-1-8A-Two-Phase-Hybrid-Stepper-Motor_p350489.html. Acesso em: 17 de outubro de 2018.
15. Micro servo sg90. Filipeflop,2018. Disponível em: https://www.filipeflop.com/produto/micro-servo-9g-sg90-towerpro/. Acesso em: 17 de outubro de 2018.
16. Scotch yoke. Mekanizmalar,2018. Disponível em: http://www.mekanizmalar.com/scotch_yoke.html. Acesso em: 17 de outubro de 2018.
17.]Datasheet sensor. Verical,2018. Disponível em: https://www.verical.com/datasheet/adafruit-misc-sensors-2167-2128562.pdf. Acesso em: 17 de outubro de 2018.
18. Nose poke. Wiktionary,2018. Disponível em: https://en.wiktionary.org/wiki/nose_poke. Acesso em: 25 de outubro de 2018.
19. Datasheet break Beam sensors. Adafruit.,2018. Disponível em: https://cdn-learn.adafruit.com/downloads/pdf/ir-breakbeam-sensors.pdf. Acesso em: 25 de outubro de 2018.
20. Bomba de infusão. Nursing,2018. Disponível em: https://www.nursing.com.br/bomba-de-infusao-continua/. Acesso em: 25 de outubro de 2018.
21. Elementos de Maquinas. Essel,2018. Disponível em: http://essel.com.br/cursos/material/01/ElementosMaquinas/37elem.pdf. Acesso em: 25 de outubro de 2018.
22. Câmera WVBP332 B&H. bhphotovideo,2018. Disponível em: https://www.bhphotovideo.com/c/product/422708-REG/Panasonic_WVBP332_WV_BP332_1_3_B_W_CCD.html. Acesso em: 28 de outubro de 2018.
23. Manual Câmera WVBP332 B&H. bhphotovideo,2018. Disponível em: https://panasonic.cn/support/download/manual/files/WV-BP330%E3%80%81332%E3%80%81334.pdf. Acesso em: 28 de outubro de 2018.
24. Suporte SketchUp. Sketchup,2018. Disponível em: http://sketchup.google.com/support/bin/answer.py?hl=en&answer=161784. Acesso em: 30 de outubro de 2018.
25. Handley, S. L., & Mithani, S. (1984). Effects of alpha-adrenoceptor agonists and antagonists in a maze-exploration model of ‘fear’- motivated behaviour. Naunyn-Schmiedeberg’s Archives of Pharmacology, 327, 1-5.
26. Huang, R., Bell-Horner, C. L., Dibas, M. I., Covey, D. F., Drewe, J. A., & Dillon, G. H. (2001). Pentylenetetrazole-induced inhibition of Recombinant-g-Aminobutyric Acid Type A (GABAa) Receptors: Mechanism and site de action. Journal of Pharmacology and Experimental Therapeutics, 298, 986-994.
27. Wong, C. G. T., Bottiglieri, T., & Snead. O. C. (2003). GABA, g-hydroxybutyric acid, and neurological disease. Annals of Neurology, 54, (Suppl. 6), S3-S12
28. Pais-Vieira, Miguel, Lebedev, Mikhail, Kunicki, Carolina,Wang, Jing, Nicolelis, Miguel A. L., A, Brain-to-Brain Interface for Real-Time Sharing of Sensorimotor Information - Scientific Reports - 2013/02/28/online -3-1319.

29. Shuler MG, Krupa DJ, Nicolelis MA. Bilateral integration of whisker information in the primary somatosensory cortex of rats. J Neurosci. 2001 Jul 15;21(14):5251-61.
30. Jacklin DL, Kelly P, Bianchi C, MacDonald T, Traquair H, Winters BD. Evidence for a specific role for muscarinic receptors in crossmodal object recognition in rats. Neurobiol Learn Mem. 2015 Feb; 118:125-32. doi: 10.1016/j.nlm.2014.11.017. Epub 2014 Dec 6.
31. ALPHA, A. et al. Encyclopedia of Child Behavior and Development. [s.l: s.n.].
32. DEBERT, PAULA; MATOS, M. A. DISCRIMINAÇÃO CONDICIONAL: DEFINIÇÕES, PROCEDIMENTOS E DADOS RECENTES. Revista Brasileira de Análise do Comportamento, v. 2, n. 1, p. 37–52, 2006.
33. TODOROV, J. C. Contingências e Metacontingências. v. 8, p. 95–105, 2012.
34. IBRAHIM, D. Microcontroller Based Applied Digital Control. [S.l.]: Wiley, 2006.