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Electronic Keyboard Prototype in the Form of a Mat Aimed at Children with Autism Spectrum Disorder (ASD)

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Abstract: The present work shows the development of a prototype that aims to offer an alternative tool through the implementation of a musical instrument, such is the case of a mat-type electronic keyboard, with the purpose that children with ASD, after interacting with the instrument to way of playing, they can receive motor, sensory, cognitive and emotional stimulation based on the fact that it has been shown that auditory stimulation is an excellent aid in treatments against stress and anxiety, among other different problems of the general population around the world.

Keywords: Autism Spectrum Disorder (ASD), Electronic keyboard, Auditory stimulation, Music therapy.

I. INTRODUCTION

The American Psychiatric Association APA, published on May 18, 2013 the Diagnostic and Statistical Manual of Mental Disorders (DSM), in whose fifth edition, Autism Spectrum Disorder (ASD) is defined as the persistent difficulty in the development of the process of socialization, along with a restricted pattern of behaviors and interests, within which sensory restrictions are included and this is due to a complex neurobiological alteration that is associated with rigid routines and repetitive behaviors [1].

The National Institute of Statistics, Geography and Informatics (INEGI) published in 2013 that 5 million 739 thousand 270 people have some type of disability, which represents 5% of the total population in Mexico [2]. Within this group of people, one in 112 children have ASD [3]. This sector of the population lacks government support for its due care and also has difficulties in accessing institutions dedicated to treating the aforementioned disorder; Due to the great demand and in many cases when the patient's turn finally arrives on the waiting list it is too late for the therapies to be used correctly, considering that it is proven that early intervention improves results in the rehabilitation process of children with this disorder [4], [5]. It should be noted that an adequate treatment for ASD must be multidisciplinary, in the case of auditory stimulation it has been shown that music acts positively at the neuronal level. The English Nordoff Robbins method, created after 17 years of collaboration with Paul Nordoff and Clive Robbins, has shown great benefits for children with developmental disorders, through music therapy.

On the other hand, music is a form of communication that can be a threat-free zone and a relaxing medium for children with ASD, since they may present hypersensitivity or hyposensitivity to external stimuli, but have a tendency to show a taste or affinity for listening to music and playing musical instruments [6]. This can be addressed through therapies that help its development. In 1987 a study was published in the Journal of Autism and Developmental Disorders in which it was shown that children with ASD retain their sensitivity to music and may even be even more attracted to musical stimuli than other children. This explains why stimulation through music is so effective in the treatment of ASD, especially when conventional therapies such as occupational, speech, behavioral therapy, etc., fail. It is then that auditory stimulation expands the connection to use music as a strong support tool to improve speech skills and eye contact [7].

To this end, the development of a keyboard prototype in the form of a mat or floor is considered, since it is considered a suitable instrument to interact with children in a game way, allowing an improvement in motor, sensory and cognitive stimulation, as well as in the emotional aspect of children.

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II. DESCRIPTION

The prototype design consists of two basic stages: the electronic stage and the mechanical stage, as shown in Fig. 1.

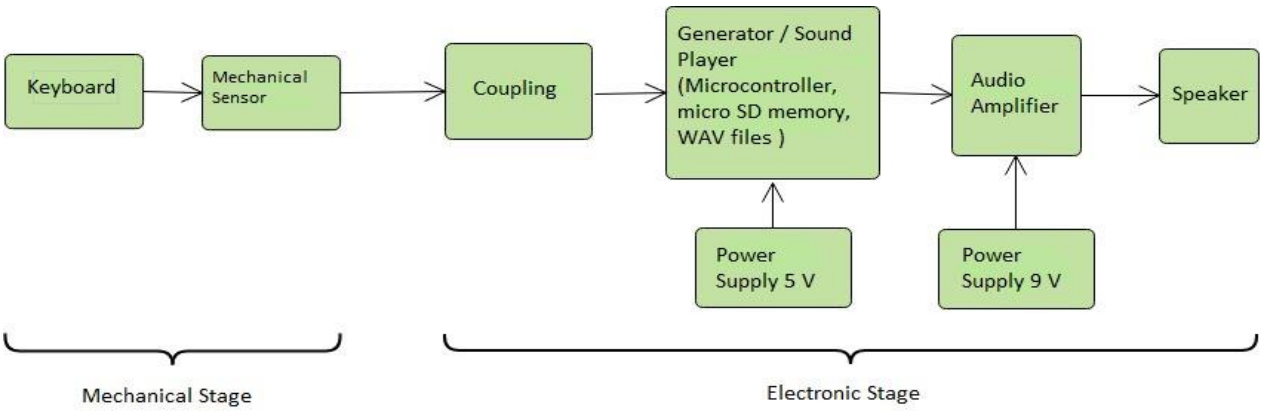

Fig. 1 Block diagram of the prototype design proposal

For the realization of the mechanical part, two materials are considered for the construction of the prototype: hall mat that is used as anti-slip (reverse side) and automotive fabric for the keys (front side).

KEYBOARD

Two rectangles are obtained, one of each material, 180 x 54 cm and the rectangle of the automotive fabric is divided across the width into 12 rectangular parts also 54 x 15 cm, as shown in Fig. 2. As the mat is intended to be a tool for tactile and visual sensory stimulation, fabrics of different textures and colors were placed.

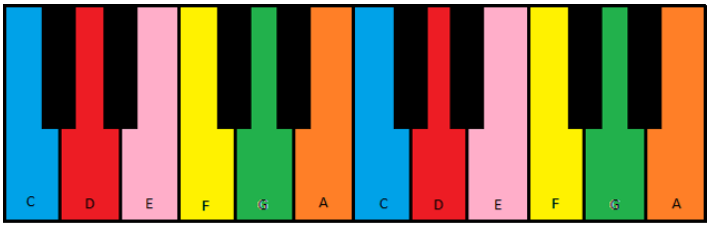

Fig. 2 Design with proposed colors

It is emphasized that the red and orange colors should not be adjacent because they generate a negative reaction, as it could be synonymous with aggressiveness. The keys corresponding to "sharps and flats" were left in black because too many visual stimuli were considered if they were presented in other colors. An octave has 12 different sounds that are known as semitones. However, it was necessary to remove the last two of the chromatic scale, that is, LA # and SI, in order that the prototype had a symmetrical shape and some dynamics related to memorization could be performed with the children.

MECHANICAL SENSORS

Aluminum plates are used that act as mechanical sensors, for this, 2 rolls of aluminum foil are used, whose sections were cut to the shape of each key; as shown in Fig. 3. Two aluminum plates are used for each key, one on the hall mat that is connected to ground, and one on the automotive fabric that is connected to the microcontroller.

Fig. 3 Aluminum spacers and plates

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To achieve the damping of each key, Polyphon is used, achieving the separation between the floor mat and the automotive fabric, achieving that the two aluminum plates touch only when the key is pressed and return to its original position when it is not.

For the realization of the electronic part, the following stages are considered:

COUPLING

Among the objectives of this project is to offer an easy-to-transport prototype. For which, the keyboard is separated from the electronic part. So then, a cabinet was designed that contains the amplifier, the speaker and the Arduino UNO development board, which can be seen in Fig. 4.

Fig. 4 Cabinet

The way in which there is communication between the Arduino and the mechanical sensors of the mat will be through XLR connectors. This type of connectors were chosen, because they are robust, inexpensive and easy to obtain, in addition to connecting when necessary and disconnecting in the same way for the storage or transportation of the mat. Within this coupling stage it is important to point out that it is necessary to use 1 MΩ resistors between the male XLR connectors and the Arduino pins. The connection diagram of the coupling stage can be seen in Fig. 5.

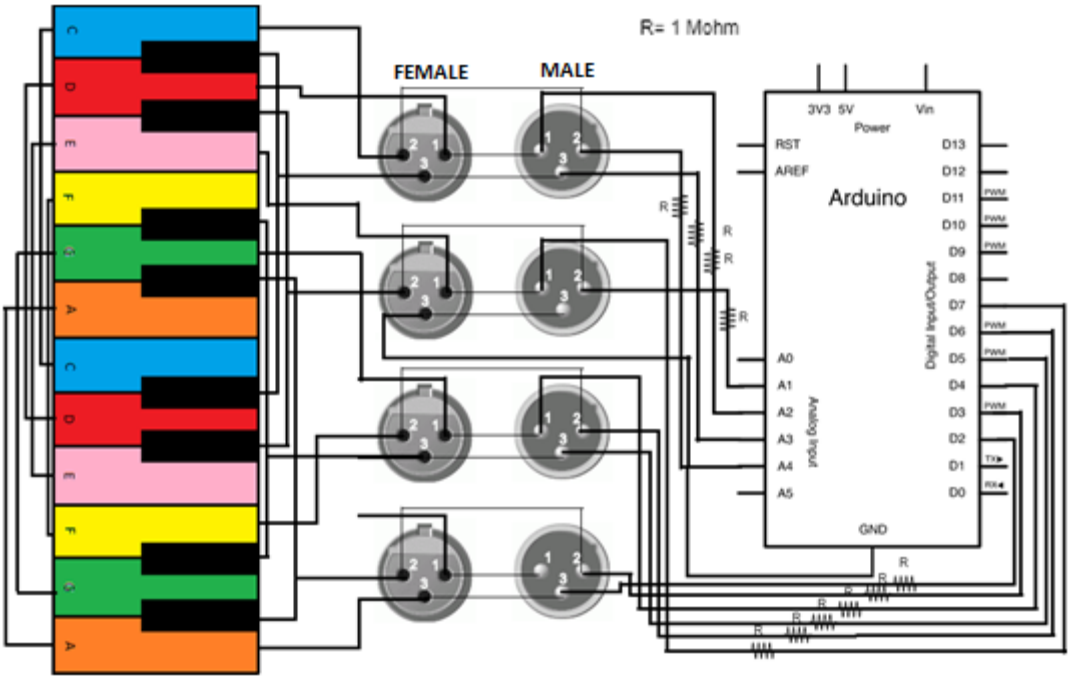

Fig. 5 Connection diagram of the coupling stage

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TONE GENERATOR / PLAYER

For this prototype, a microcontroller is used, since it has an oscillator that will allow to generate the tones of the keyboard notes that are required, in addition from the therapeutic point of view, the harmonic content of the sounds also represents an important issue. The reason for this is that children with ASD perceive sounds in a different way than people who do not have this condition of life, so it is necessary to find a way to generate tones with the harmonic content of a conventional musical keyboard or piano, thus offering a sound that is pleasant to the ear and that does not generate negative reactions in children after interacting with the prototype.

During the investigation of the operation of commercial musical keyboards, it was found that many of them do not have a microcontroller that generates the tones of each key as such, but that said microcontroller reproduces the tones that have been recorded [8]. In this context, a microcontroller is used that allows to generate tones with a high harmonic content. However, it is important to note that not all microcontrollers can process audio. For this, the Arduino development board is chosen due to its great versatility and flexibility in the development of prototypes, among other characteristics it has. Given the above, it was decided to sample the tones of a commercial keyboard. In other words, using an M-Audio audio interface, Audacity software and a Korg brand MIDI keyboard, each of the tones corresponding to the fourth octave were recorded.

Each generated file is saved in a 32GB class 10 Adata brand micro SD memory. For the prototype, it is not really necessary to have so much storage but this memory was already available and it was decided not to acquire another. To communicate the micro SD memory to the Arduino there is a micro SD memory reader module that Arduino offers as one of its accessories compatible with all its development boards.

AMPLIFIER

Due to the use of an 8-inch speaker, the prototype is not capable of emitting an adequate volume level, for this the TDA7297 amplifier is used; which is a dual audio amplifier, in other words, two speakers can be placed to create a stereo system.

POWER SUPPLY

A charger is used to power the Arduino board, which offers a voltage of 5 V and a current of 0.5 A. On the other hand, in the case of the amplifier, it needs to be powered with a source other than the Arduino UNO board, Because the amplifier requires 9 V, it is also powered by a charger that works on the same principle as the previous one.

SPEAKER

As this prototype handles medium frequencies (256 Hz - 2 kHz), a dynamic speaker of 8” diameter and 4Ω output impedance was used.

Finally, the electrical diagram and the final product of the prototype are shown in Fig. 6 and 7, respectively.

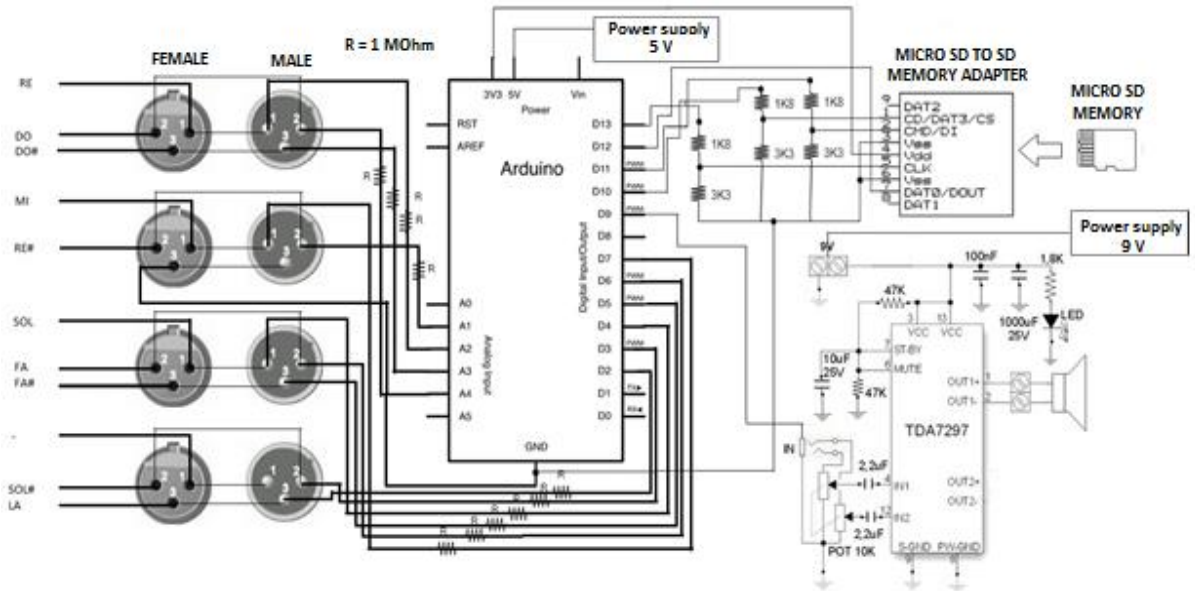

Fig. 6 Electrical diagram of the prototype

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Fig. 7 Final product of the prototype

III. RESULTS

We proceeded to record the samples for each note on the keyboard, which could be considered as a digital oscillator.

Cubase Elements 8 software was used as a tool for the first test recording, which is currently used professionally by many renowned recording studios and producers. However, despite the fact that the computer is capable of reproducing the recordings, this was not the case with the Arduino card, but rather that it presented difficulties in reproduction.

For this, a programming code was used that is capable of reading the header of a wav file. This program can be easily run from the command prompt of any computer. The header is understood as the information of that file with fields such as: its sampling frequency, file size, type of format, number of channels, etc. Once the header of the files generated from Cubase was displayed, it was noticed that the file format was WAVJUN and that the vast majority of the fields were empty.

To solve this problem, tests were carried out with other files that the microcontroller could read and when printing their header it was observed that the supported format for a suitable reading is WAVfmt. So it was decided to make the recordings again but using the Audacity software with very good results. So the tones were recorded at different sampling frequencies (8000 Hz, 11025 Hz, 32000 Hz and 44100 Hz) to later select the frequency that had the best quality in the reproduction. Finally, the recordings whose sampling frequency is 11025 Hz at 8 bits were selected and exported at the same frequency. To ensure that the recorded notes approximated those of a commercial keyboard, they were compared to the spectrum of notes corresponding to the 4th octave of the Yamaha brand PSR220 keyboard.

A noteworthy fact is that in the programming the Capacitive Sensor library was used, which converts the pins of the Arduino board into sensors capable of detecting the electrical capacitance of the human body that affects some metal, or failing that, the contact of a metal with another metal. The sensitivity of the sensor is a function of the value of the resistors used. The 1 MΩ value provides absolute touch triggering of the sensor. However, the value of the resistive elements can be chosen between 100 KΩ and 50 MΩ; the higher the value, the sensor is triggered at a greater distance. When the aluminum foil plates are touched, through the Arduino TMRpcm library, it is possible to access the micro SD memory, search for the wav file corresponding to the pressed key and play the sound through the speaker.

IV. CONCLUSION

The prototype complies with the characteristics of sound, texture and color, which when interacting as a game, can be an alternative tool to improve the lifestyle that children with ASD lead. However, field tests are pending to observe the benefits of this prototype to the sector of the child population living under the condition of life of Autism Spectrum Disorder. It is necessary to remember that the main purpose of the prototype is not for artistic purposes or for the study of music itself, but to develop a more comprehensive sensory stimulation.

Another drawback that arose was the elaboration of the mechanical sensors (contacts), because the chosen cable tended to break very easily generating several false contacts and this was reflected in that sometimes the keyboard sounded by itself or by on the contrary, there were certain keys that did not work. This is not only attributed to the cable used, but also to the aluminum plates that tended to break when the mat was rolled. This situation was solved by holding the cables better, even gluing them to the mat with glue, as well as placing aluminum reinforcements on each key to ensure better contact.

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After a long process of searching and testing with various tools and techniques, it was possible to generate and reproduce the tones of the notes with a harmonic content very similar to that of a commercial keyboard or piano, an important issue for the positive processing of these stimuli in children with ASD. This could be achieved thanks to the comparison of the spectrum of each note of the keyboard prototype with the commercial Yamaha keyboard, where it was noted that the fundamental frequency and harmonics are similar.

Finally, as work in the future and as part of the improvements that the prototype can have, is to include lights that are activated from each key when it is played, as well as aromas. Which will allow to offer a playful tool for comprehensive sensory stimulation. On the other hand, to facilitate transportation, it is intended to implement a Bluetooth system, thus eliminating the cables that were used in this first version of the prototype. In the same way, it is planned to change the type of sensor that was used, for another that provides a faster response to contact and to implement the mat using lighter materials to facilitate its handling.

Although this instrument is not a substitute for therapy assisted by a specialist, it can be of great use to parents who have children with ASD to stimulate the development of their skills through play. The use of the prototype can provide greater benefits to the infant if the assistance of a specialist in this disorder is available.

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BIOGRAPHY

Joel Flores Martínez received his B.Sc. in electronics and communications engineering from ESIME Zacatenco IPN, Mexico, in 1997 and M.Sc. degree in Bioelectronics from CINVESTAV IPN, Mexico in 2000. Currently he is a professor at the Department of Electronics and Communications engineering in ESIME Zacatenco. His research interests are in acoustics and biomedical engineering.

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