2020 IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES)

Simple Touch Sensor-based Game as Ambient Assistive Device for Mild Autism Spectrum Disorder Children

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2020 IEEE-EMBS Conference on Biomedical Engineering and Sciences (IECBES) | 978-1-7281-4245-6/21/$31.00 ©2021 IEEE | DOI: 10.1109/IECBES48179.2021.9398802

***Abstract*—As of today, children diagnosed with Autism Spectrum Disorder (ASD) are becoming an increasingly common occurrence in our schools and society. Consequently, this increases the need to develop assistive devices for ASD children. This paper shows the development of a system designed to facilitate learning in ASD children. This Arduino-based game is equipped with common components such as touch sensor, MP3 player and LEDs to increase replicability. A research was done based on the Early Intervention module to develop a game that could help improve cognitive skill of ASD children. Early Interventions for children with ASD has proven to be effective in reducing ASD symptoms.**

Keywords— Autism Spectrum Disorder (ASD), assistive devices, touch sensor

I. INTRODUCTION

Autism spectrum disorders (ASD), is a neurological disorder that affects social interaction, communication, and behaviors. ASD children (ASDC) may display behavior that is repetitive or rigid during play. For example, a toddler with ASD may spend more time arranging their toys in a particular manner instead of actually playing with the toys [1]. The Centers for Disease Control and Prevention (CDC) estimate that "the global prevalence of autism increased twentyfold to thirtyfold since the earliest epidemiologic studies conducted in the late 1960s and early 1970s", by early 2000s the prevalence rates increased to 1-2 in 100 children [2]. As the term spectrum already means "wide range", it is a disorder in which their symptoms and severity vary widely across the core characteristic symptoms, meaning that not everyone will have the same symptoms. They may share similar difficulties while growing up, however these symptoms affect their lives differently. No two individuals with autism are the same, each of them will have different degree of difficulties. [3]

There is no medical cure that can help ASDC to permanently make their symptoms disappear. Currently, various methods of interventions, mainly behavioral are currently used to help these children. The most common method of early interventions (EI) are Applied Behavioral Analysis, Sensory Integration Therapy and LEAP. Behavioral intervention has been proven to help ASDC improve in functioning [3]. (Corsello,2005) reviewed multiple studies and the result suggested that EI lead to better outcomes. Children entering interventions at a younger age make greater gains [4]. As children progress into school-age, targets, intensity, methodologies and context of the intervention will change as the child's individual needs evolve with age. EI is expected to help in reducing developmental delay and behavioral problems in inclusive educational contexts. Among the skills focused during EI is physical skill, cognitive skills, communication skills, self-help, social and sensory processing skills.

Apart from conventional therapies, current research focuses on utilizing technology as a part of assistive tool for ASDC [5-7]. Assistive technology refers to "an electronic item/equipment, application, or virtual network that is used to intentionally increase, maintain, and/or improve daily living, work/productivity, and recreation/leisure capabilities of adolescents with ASD" [8]. These technologies can be taken advantage of to improve the development of skills for ASDC. Learning can be much more effective and less intimidating for ASD children by using systems that are systematic, predictable and repetitive which in turn can help them learn better [9].

This paper focuses on the development of a simple touch sensor based game to improve cognitive skill in ASD children. Cognitive skills include thinking, learning and solving problems. The game designed in this system will help the child to learn colors and shapes through sorting and classifying the blocks. Although naming colors and classifying shapes is second nature to most adults, it is actually a cognitively complex task for young children. The purpose of this study is to build an assistive device that can be an effective learning medium for ASD child and can be used by therapists during session. This device is able to log data in real-time which can help lessen therapist's workload and help them focus on the child during therapy.

In Section II, we describe the system's architecture, hardware details and the flow of the game. In Section III, experimental results and the prototype built after stabilizing a few components were introduced followed by a brief discussion on limitations of the current work and future work in Section IV.

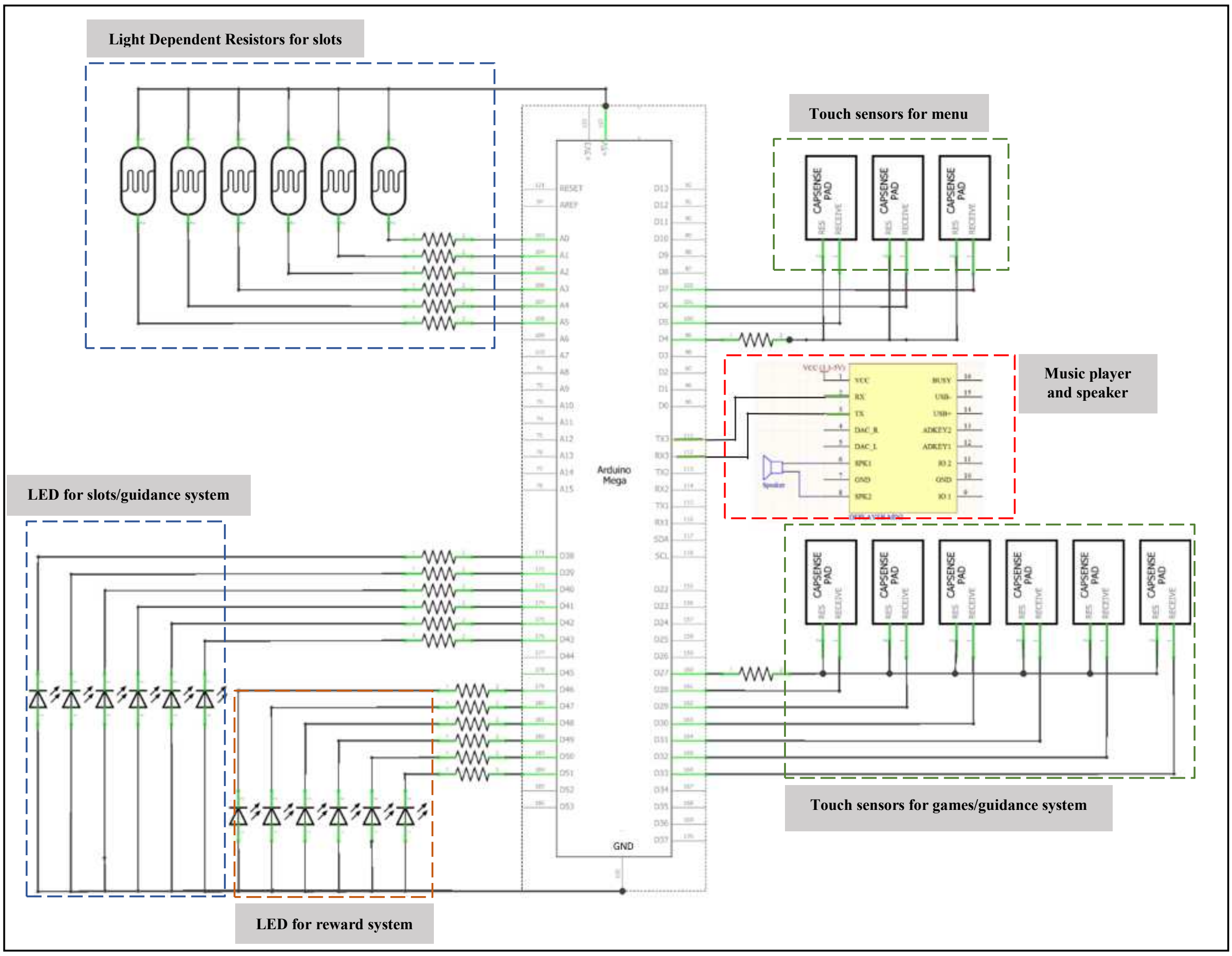


Fig. 1. Circuit diagram of the device.

II. METHODOLOGY

A. System Architecture

The system consists of touch sensor and LDR as the input, ATmega2560 as the microcontroller, interfaced with LED, MP3 player and speaker as the output. This system is also capable of real-time data logging (only for Mode 1 and Mode 2). As the mode gets chosen, Arduino will start to log data from the LDR and send the information to Excel in real-time. The circuit diagram is shown in Fig. 1. This device will have to be connected to a laptop/computer during use as the Arduino will log data to an existing Excel file in the laptop. The data obtained can help researcher or therapist to track child's progress based on the time taken for child to place the blocks on the correct slot.

B. Hardware Details

1) Copper plate-based touch sensor

Copper plates were used for touch sensor. The copper plates were manipulated to be capacitive touch sensors using Arduino's 'CapSense' library. To manipulate any conductive materials to become capacitive sensors, both input and output matters. The output will transmit a pulse while the input will receive the pulse and compare it to the transmitted pulse. Placing a finger on or near the sensor will create a delay in the pulse, the library will recalculate the delay and generate a value that be used for triggering.

This method toggles a microcontroller send pin to a new state and then waits for the receive pin to change to the same state as the send pin. A variable is incremented inside a while loop to time the receive pin's state change. The method then reports the variable's value, which is in arbitrary units. The library turns two or more Arduino pins into a capacitive sensor which can sense the electrical capacitance of the human body. Each touch sensor requires a medium to high value resistor and a piece of wire and copper plate on the end. At its most sensitive, the sensor will start to sense a hand or body inches away from the sensor. This method was chosen as one of our aims is to increase replicability, this method enables future researchers to use any conductive materials as a touch sensor.

2) Light Dependent Resistor (LDR)

Fig. 2. Prototype of the system.

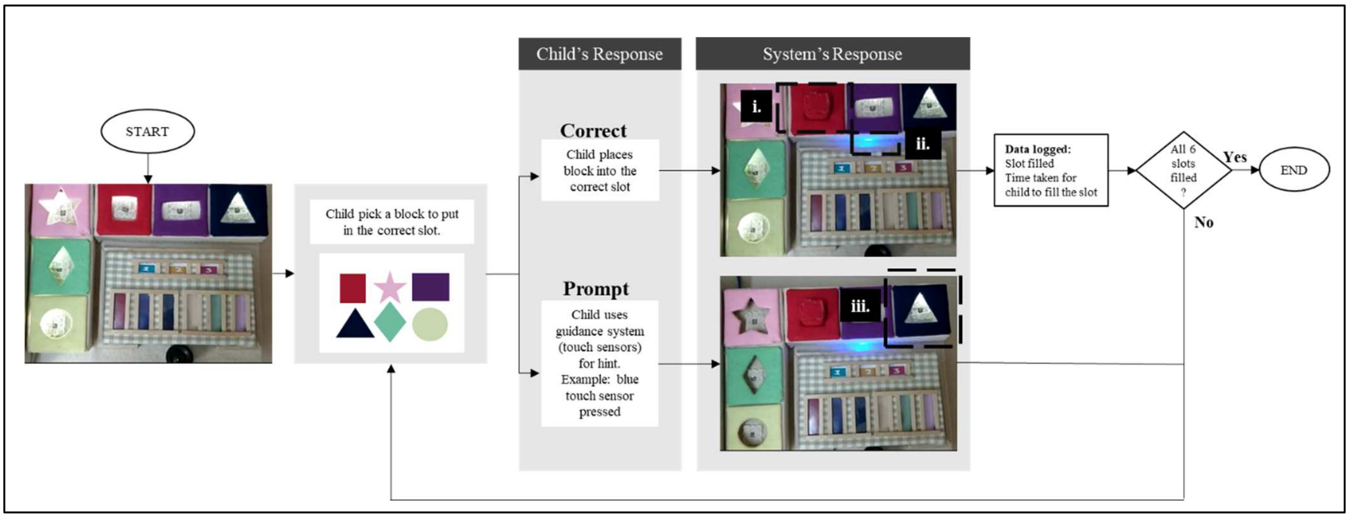


Fig. 3. Flow of game for Mode 1 and Mode 2.

An LDR or a photoresistor is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity. The supply voltage for the LDR is 3 – 5.5V and has an operating temperature of -60 to 75 degree Celsius. Each slot was equipped with an individual LDR to detect the time taken for child to get a correct answer. Total absence of light in a particular slot signifies child being able to place the correct block into the correct slot. The system will then log the time taken for child to get the correct answer.

3) DFPlayer (MP3 player)

The DFPlayer Mini MP3 Player For Arduino is a small and low price MP3 module with a simplified output directly to the speaker. The module can be used as a stand-alone module with attached battery, speaker and push buttons or used in combination with an Arduino UNO or any other with RX/TX capabilities. The supply voltage is 4.2 – 5V and supports a sampling rate (kHz) of 8/11.025/12/16/22.05/24/32/44.1/48. The module comes with an SD card slot where all sound files are stored and supports both FAT16, FAT32 file system.

4) Light-Emitting Diode (LED)

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode that emits light when activated. When a suitable current is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons.

5) Speaker

Speaker used for this project is a 4-ohm speaker with a power of 3W. This speaker was chosen as this speaker has a full-audio range and can play audio files with high clarity. The speaker was connected to the MP3 Player and will play audio files corresponding to the touch sensor assigned.

C. Game Design

We developed an interactive game based on EI's module. The game also applied two techniques used in ABA, which is prompting and reinforcement. Prompt is any assistance or hint provided to help child get the correct answer. The rationale of using prompts is to make learning easier and avoid frustration in ASDC by helping them feel successful. Reinforcement or reward are consequences that strengthen behaviour. To strengthen a behaviour means to increase the likelihood that it will occur again in the future. In this context, when the game starts, reinforcement is given when ASDC gives the correct answer. Over the course of learning, an association is formed between a cue or action and a reinforcer with some inherent motivational value [9].

This system consists of 3 modes where the user can choose desired mode using the touch sensors. The 3 modes available are shape-identifying game, color-identifying game and a free play mode. For every mode chosen, the date the game is played will be recorded, PLX- DAQ is used for this purpose. The first two modes, although different in learning objectives (identify colors and shapes), uses the same technique. Firstly, the therapist will choose the mode desired. Once the game starts, the child will pick up a block to be placed into the right slot. The correct answer will be determined by whether or not child placed the blocks in the correct slot. Each slots are designed in a way that only the correct blocks can be fit into their rightful slot. For example, a square block can only fit in the square slot. The flow of the game can be referred to in Fig. 3. Each slot is equipped with an LED and LDR. The LED functions as a source of light for the slot. When the child successfully fit the correct block, as in Fig. 3(i), the LDR in the respective slot will detect an absence of light signifying a correct answer. A score of (+1) will be added in the Excel sheet for each correct block fitted. Once a child answered correctly, an LED will light up as a reinforcement. Reinforcement method for this system can be referred to in Fig. 3(ii).

Another important technique adapted from the ABA technique is prompting. By referring to the device's current components and capabilities, verbal and visual prompt were possible to be implemented in this system. Aside from touch sensor for the user to choose mode, another set of touch sensor is also available as a guiding system for the user. This set of touch sensors are connected to the MP3 player and speaker. In case the child is confused and cannot fit the right piece into the corresponding slot, the child can touch the touch sensor with color corresponding to the block they are trying to fit. By referring to Fig. 3(iii), when the sensor for guidance system is touched, the MP3 player and speaker will turn on and tell the user what color or block they are currently trying to fit and only the LED in the corresponding slot will light up to show the child which slot the block should be placed.

Another practice of ABA is keeping track of child's progress by collecting data for every therapy session. To implement this practice in our study, this device is also capable of logging data in real-time to Excel. The data recorded are date, time, current mode, timer (time taken for child to get the correct answer), slots filled and score (current number of slots filled). The date and time are recorded to keep track of child's progress for each therapy session. The time taken for child to get the correct answer is an important information as the child are supposed to be able to fill in the slots correctly faster as they progress through each therapy [11]. If the therapist notices that the child takes a long time to get the correct answer even after multiple sessions, then it is possible for therapist to predict whether or not the child has a deficit in classifying or sorting colors/shapes. Logging data of the child's correct answer is also important as it can help therapist identify particular colors/shapes the child is having difficulty with.

Mode 3 is a free play mode where child will be able to use the guidance system touch sensors as a toy piano. This mode can act as a break between Mode 1 and Mode 2. Considering that ASD children has a low and fluctuating attention span, most ABA practice will alternate between learning and play time. For example, a schedule for a child will go as follows: learning time–play time–learning time-play time-break time. In this case, Mode 1 (shape identifying game) and Mode 2 (color identifying game) can be used for learning time while Mode 3 (free play mode) can be used for play time. Alternating learning time and break time can be important to keep the child engaged and motivated to learn.

III. RESULTS AND DISCUSSION

A. *Experimental Test – Stabilizing touch sensors and DFPlayer*

For this device, copper plate was used as a touch sensor. The physical setup includes a medium to high value (100 kilo-Ohm - 50 mega-Ohm) resistor between the send pin and the receive (sensor) pin. The receive pin is the sensor terminal. A wire connected to this pin with copper plate at the end makes a good sensor.

When the send pin changes state, it will eventually change the state of the receive pin. The delay between the send pin changing and the receive pin changing is determined by an RC time constant, defined by R * C, where R is the value of the resistor and C is the capacitance at the receive pin, plus any other capacitance (e.g. human body interaction) present at the sensor (receive) pin. Since the resistor value affects the distance needed for the touch sensor to start sensing touch, a test was done to choose the value of resistor that is needed for this project as for this project, absolute touch is needed.

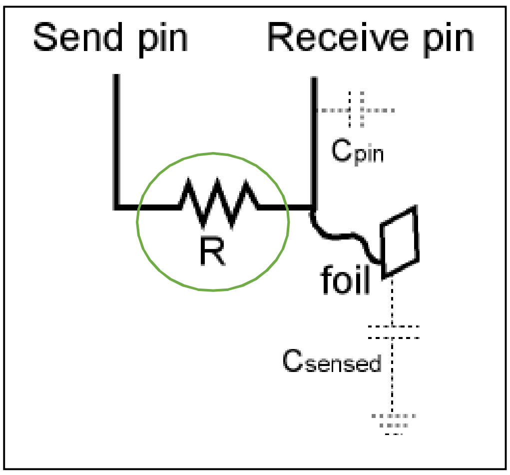


Fig. 4. Different resistor values were used as a variable

The test was done by using 9 resistors with different values (Fig. 4). The results obtained can be referred to in Table I. Based on the test done, it was found that the higher the resistor value, the further away the sensor can sense touch. One trade off with larger resistors is that the sensor's increased sensitivity means that it is slower. If the sensor is exposed metal, it is possible that the send pin will never be able to force a change in the receive (sensor) pin, and the sensor will timeout. The reason why the higher the resistance value, the further away the sensor can detect touch is because there is only one source of charge, through the resistor. Therefore, increasing the room for storage of charge by adding the capacitance of the finger it will take longer to fill, and thus the further away the sensor can sense touch. Based on the result, 1 MΩ resistor was chosen for this device.

The DFPlayer plays a fundamental part for this system as it serves as a guidance system for the user. During the experimental test, it was found that the volume of the speaker was excessively loud. A 1kΩ resistor was then connected to one of the component's pin (TX pin) to limit the current entering the DFPlayer.

B. *Prototype*

1) *Slots for blocks*

Every slot is equipped with an LDR and a super bright LED. The LED is used to provide light to the LDR when no block is placed into the slot, signifying empty slot. As in Fig. 3(i), once the correct block is placed into the slot, the LDR will detect an absence of light and the datalogger will record the time taken for the slot to be filled and the current score.

2) *Touch sensor for menu*

This set of touch sensor (labeled 1, 2 and 3) is used for the user to change mode of games. There are 3 available modes for this game which is color-identifying game, shape-identifying game and a free play mode.

3) *Touch sensor as part of the guidance system*

This set of touch sensor acts as a guidance system for the user, should the user get confused or do not know the color or shape they are currently trying to fit, the user can touch the sensor that corresponds to the current block they are holding and the speaker will tell the color or shape they are holding. By referring to Fig. 3(iii), when one of the touch sensors from the guidance system is touched, taking the blue color as an example, only LED from that particular slot will light up. This helps the child to know that the block they are currently holding, should be fitted into that particular slot. The speaker will also spell out the block's color/shape.

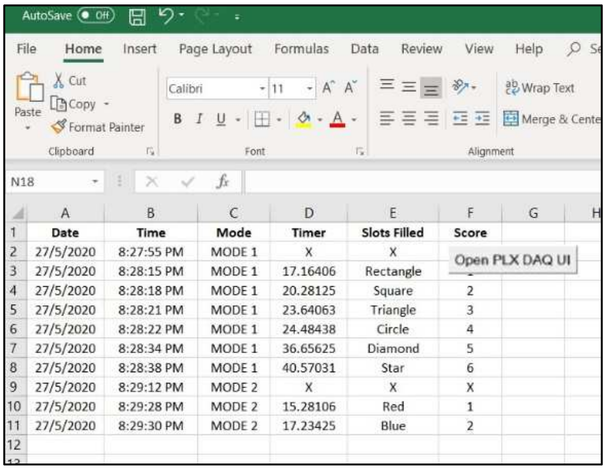
TABLE I. COMPARISON OF DIFFERENT RESISTOR VALUES

Resistor Value (MΩ)	**Distance taken for sensor to respond (cm)**
0.8	0 (absolute touch)
1.0	0 (absolute touch)
2.2	0.3
3.0	0.7
4.0	0.9
5.6	1.0
6.8	1.2
8.2	1.5
10.0	2.0

C. Datalogging

Datalogging was done by using PLX-DAQ. This datalogging ability can track records of the date the game was played, the modes played on that day, the time taken for the correct slot to be filled, the correct slot filled and the current score.

The data is sent from the Arduino to the laptop in real-time. The data will then be stored in an Excel file and can be used for future analysis. The USB jack is used instead of power supply as this USB jack's intended purpose is to power the device and it must also be connected to a laptop or computer so that the datalogger can receive and store data in the laptop in an Excel file.



	A	B	C	D	E	F	G
1	Date	Time	Mode	Timer	Slots Filled	Score	
2	27/5/2020	8:27:55 PM	MODE 1	X	X		
3	27/5/2020	8:28:15 PM	MODE 1	17.16406	Rectangle	[illegible]	
4	27/5/2020	8:28:18 PM	MODE 1	20.28125	Square	2	
5	27/5/2020	8:28:21 PM	MODE 1	23.64063	Triangle	3	
6	27/5/2020	8:28:22 PM	MODE 1	24.48438	Circle	4	
7	27/5/2020	8:28:34 PM	MODE 1	36.65625	Diamond	5	
8	27/5/2020	8:28:38 PM	MODE 1	40.57031	Star	6	
9	27/5/2020	8:29:12 PM	MODE 2	X	X	X	
10	27/5/2020	8:29:28 PM	MODE 2	15.28106	Red	1	
11	27/5/2020	8:29:30 PM	MODE 2	17.23425	Blue	2	
12							

Fig. 5. Example of Excel file created.

IV. LIMITATION AND FUTURE WORKS

Due to time constraint, we were unable to do any experimental test with ASDC. There are a few improvements that can be made to make the device more helpful. The device can be improved further by sending the stored data to cloud instead of keeping it offline in a laptop/computer. The data can be directly sent to Google Drive or other cloud options for easier access. The data stored can be viewed by therapists online and this can help ease therapists or practitioners to make plans for future treatments. The data stored can also be improved by automating graph plotting so that the trend for each child's progress can be analyzed easier. Next, more blocks and slots can also be added to the device to enable the children to learn even more colors and shapes.

Our current device limits data storage for only Mode 1 and Mode 2, for future works, data for the free play mode can also be added to know which tones the children are keen to listen to. This can be used to find out which tones can calm the children, as every tone has a frequency, the effect of the frequency on children with autism can then be studied to develop a more impactful intervention program.

V. CONCLUSION

In summary, this work has explored the possibility of embedding conventional therapy modules into assistive technologies. This step is important in helping ASD children learn effectively and to help lessen therapist's workload in order for them to be able to focus more on the child themselves. For researchers, this study has offered for additional data and insight into how technologies, even games can be assistive in nature and with therapeutic uses. Simple devices such as these may not always be immediately recognized as assistive technology, but it is able to help therapists by providing an alternative to conventional therapy and data-taking.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the Ministry of Education Malaysia (MOE) for funding the research project through the Transdisciplinary Research Grant Scheme (TRGS) [Ref. No TRGS/1/2019/UIAM/02/4/3]. Acknowledgment is also accorded to Universiti Teknologi MARA (UiTM).

REFERENCES

[1] DeFilippis, M., & Wagner, K. D. (2016). Treatment of Autism Spectrum Disorder in Children and Adolescents. Psychopharmacology bulletin, 46(2), 18–41. PMCID: PMC5044466

[2] Maenner, M. J., Shaw, K. A., Baio, J., Washington, A., Mary, P., DiRienzo, M., Christensen, D. L., Wiggins, L. D., Pettygrove, S., Andrews, J. G., Lopez, M. L., Hudson, A., Baroud, T., Schwenk, Y., White, T., Rosenberg, C. R., Lee, L. C., Harrington, R. A., Huston, M., … Dietz, P. M. (2020). Prevalence of Autism Spectrum Disorder Among Children Aged 8 Years-Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2016 Centers for Disease Control and Prevention MMWR Editorial and Production Staff (Serials) MMWR Editor. Morbidity and Mortality Weekly Report Surveillance Summaries, 69(S-4), 1–12.

[3] Martínez-Pedraza Fde L, Carter AS. Autism spectrum disorders in young children. Child Adolesc Psychiatr Clin N Am. 2009;18(3):645-663. doi:10.1016/j.chc.2009.02.002

[4] Corsello, C. M. (2005). Early intervention in autism. Infants and Young Children, 18(2), 74–85. https://doi.org/10.1097/00001163-200504000-00002

[5] So, W. C., Wong, M. K. Y., Lam, C. K. Y., Lam, W. Y., Chui, A. T. F., Lee, T. L., Ng, H. M., Chan, C. H., & Fok, D. C. W. (2018). Using a social robot to teach gestural recognition and production in children with autism spectrum disorders. Disability and Rehabilitation: Assistive Technology, 13(6), 527–539.

[6] Hawks, O., Dunst, C. J., Hamby, D. W., Trivette, C. M., Prior, J., & Derryberry, G. (2013). Effects of a Socially Interactive Robot on the Conversational Turns Between Parents and Their Young Children with Autism. 6, 1–8.

[7] Pop, C. A., Simut, R. E., Pintea, S., Saldien, J., Rusu, A. S., Vanderfaeillie, J., David, D. O., Lefeber, D., & Vanderborght, B. (2013). Social robots vs. computer display: Does the way social stories are delivered make a difference for their effectiveness on ASD children. Journal of Educational Computing Research, 49(3), 381–401.

[8] Hedges, S & AFIRM Team. (2018). Technology-aided Instruction & Intervention. Chapel Hill, NC: National Professional Development Center on Autism Spectrum Disorders, FPG Child Development Center, University of North Carolina. Retrieved from http://afirm.fpg.unc.edu/Technology-aided-instruction-and-intervention

[9] So, W. C., Cheng, C. H., Lam, W. Y., Huang, Y., Ng, K. C., Tung, H. C., & Wong, W. (2020). A Robot-Based Play-Drama Intervention May Improve the Joint Attention and Functional Play Behaviors of Chinese-Speaking Preschoolers with Autism Spectrum Disorder: A Pilot Study. Journal of Autism and Developmental Disorders, 50(2), 467–481. https://doi.org/10.1007/s10803-019-04270-z

[10] Schuetze M, Rohr CS, Dewey D, McCrimmon A, Bray S. Reinforcement Learning in Autism Spectrum Disorder. Front Psychol. 2017;8:2035. Published 2017 Nov 21. doi:10.3389/fpsyg.2017.02035

[11] Cooper, J., Heron, T., & Heward, W. (2007). Applied Behaviour Analysis. New Jersey: Pearson Education.