Toward Soft, Robust Robots for Children with Autism Spectrum Disorder

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***Abstract*—A meltdown is one of the most challenging behaviors of children with Autism Spectrum Disorder (ASD), where a child could not calm down or too overwhelmed with a certain situation. Because social robots are becoming useful as a therapy tool between the therapist and a child with ASD, as robot designers, we want to anticipate that a robot could be thrown on the floor or to the therapist or caregiver. In addition, we want to investigate how to better protect the robot from being damaged. Typical robots are constructed in plastic material. In this paper, a sample of plastic material and a sample of silicone material were compared in a drop test experiment at the heights of 0.0254 m, 0.5 m, and 1 m. These heights simulate a possible situation where the robot can be dropped. Our result shows the differences in the impact between the silicone and the plastic samples. This work provides a baseline study as a step toward soft, robust robots for children with ASD.**

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is characterized by a triad of impairments in social communication, social interaction and imaginative skills [1]. The Center for Disease Control in the USA estimates that 1 out 68 children are diagnosed with ASD. Some children with ASD could go into a meltdown because they could find themselves overwhelmed in a certain situation. Such situations could include loud noises, bright lights, strong smells, and many other situations.

Research efforts have been put into the field of social robotics in an attempt to use robots to assist humans in a diverse number of ways. Socially interactive robots are used to communicate, express and perceive emotions, maintain social relationships, interpret natural cues, and develop social competencies [2,3]. To ensure the suitability of the robot's design, research studies have been conducted to obtain requirements from the end-user group who are children with autism. Since these children have impaired communication, therapists, parents and teachers were asked to give their feedback on suitable design of robots [4]. Other efforts have also been made to compile a detailed set of design requirements that are not subjective, but can be generalized to most of the children's preferences [5,6]. Robots with overly mechanized appearances may also not derive the best results since too many exposed mechanical parts can cause the child to shift focus from the interaction itself [7,8].

A robot is not meant to replace therapists but is meant to be used as a mediator to provoke interaction between the child and another person. The objective behind using robot is to increase their interactions through longer eye contacts, which are important to build the child's confidence level. This can be done through touching, playing and engaging in imitation games with the robot. By doing so, they are able to open up and allowing themselves to engage in discussion about the robot's activities.

Research studies have shown that using robots as therapeutic tool for autism often lead to increase in certain areas such as engagement, attention, spontaneous imitation and novel social behaviour such as joint attention [9-11]. Robots are nonthreatening and can be design in such a way that they are engaging and allowing productive interaction.

The current robots seen to date have internal components consisting of microcontrollers, mechanisms, sensors, and actuators. However, most of the robots are lacking the robustness in the design. Robustness refers to the ability to operate without failure when subjected to a variety of harsh handling conditions. In order for a robot to be robust, the robot must be able to absorb impact in situations such as dropping onto the concrete ground from high ground, thrown against the wall or knocked repeatedly by force.

The soft and robust features of a robot are especially important when children with ASD are in a meltdown situation. This will occur when their needs and wants are not met or when they are not able to adapt to the changes in the environment. If they lose control, the child may pick up a robot that is in sight and exert force on it. There is a possibility that the exterior structure housing the components will crack under impact with another structure. Furthermore, the robot may cease functioning because of damages in the internal components.

For a robot to be robust, the materials and the embedded technologies are important in ensuring that a robot can withstand harsh handling conditions. Materials that are able to cushion the impact upon landing are generally preferred. Such shock absorbing materials are commonly used by designers to protect products such as phones, hard disks and equipment. For example, a hard disk is incorporated with an accelerometer that will send a signal to immediately unload its head when it is under free fall. This prevents the hard disk's head from coming in contact with the platter, which can cause considerable damage to the device.

Most of the manufacturers prefer using plastic as the exterior structure for robots because it can be readily molded to shape. Rubber materials have generally excellent tensile strength, elongation, tear resistance, and resilience properties and are commonly used to function as a shock absorber, as

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vibration isolator or as dampers. Rubber has low modulus of elasticity, it is capable of sustaining a deformation and will return to its original dimension.

How well the robot reacts to the shock is dependent on the choice of material. In the next sections, we describe a series of drop test experiments at 0.0254 m, 0.5 m and 1 m heights. These heights simulate possible conditions that a robot might be subjected to.

II. DROP TEST EXPERIMENT

A. *Calibration of Accelerometer and Conversion of Units*

An accelerometer was embedded in the internal structure of the test object. Acceleration is the rate of change of velocity over time. Dynamic responses can be inferred from the experiment to which the accelerometer is mounted. In order to convert the voltage output from accelerometer to acceleration in *G*, intermediate steps were needed. Firstly, the analog voltage reading from the output of the accelerometer was obtained under static acceleration when it was in the direction of Earth's gravity field (9.8 m/s^2). Secondly, this analog voltage value will be reduced when it is not in the direction of Earth's gravity field to obtain the difference with respect to 0 *G* point. Lastly, the value is divided by the sensitivity of the device to obtain the acceleration value in *G*. Calibration of the accelerometer and a conversion of unit were needed to convert the output analog reading to the correct corresponding *G* values. This conversion of values allowed better analysis of the results. As the output voltages reading from the tri-axis accelerometer are different from the ideal case, the axis had to be calibrated individually. Attention was be placed on the square root of the sum of the 3-axis as it represents the total acceleration acting on the device during the drop test experiment.

B. *Experimental Samples*

A proper cylindrical housing for the devices was first selected. The devices that were secured in the housing included a 9-volt battery to provide power supply to the Arduino board, accelerometer, and data logging device. Caution has been taken to ensure that there was enough space for the impact to take place. The side of the housing was designed not to hit the accelerometer during the impact to prevent erroneous reading.

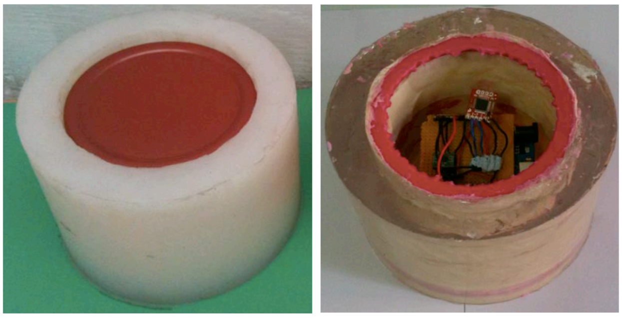

Fig.1. Experimental samples, silicone (left), polyester (right).

With the structure selected, a polyester resin sample and a silicone rubber sample were prepared to identical size and shape for better comparison.

C. *Procedures*

The silicone rubber sample was subsequently brought to the 0.0254 m height and held in stationary position for a few seconds to allow the registration of 1 *G* value before dropping onto the concrete floor. Caution has to be taken to prevent exerting extra pressure to the experimental object to avoid erroneous readings. Any suspected pressure applied to the experimental object during the trials will not be used for analysis. Both samples were subjected to the same starting drop position with the cross sectional area of the sample parallel along to the axis of the concrete floor. The sample must land with the cross sectional parallel along the concrete floor during the impact and after the impact for accurate comparison. This experiment was conducted 8 times for the same height. The data from the drop test was then plotted out. This same procedure was repeated for other heights. After the experiment for the silicone rubber sample was completed, the same set of experiment procedure was applied to the polyester resin sample. An illustration of the experimental set-up is shown in Fig. 2.

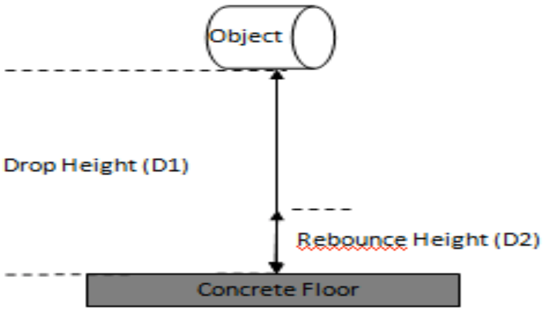

Fig. 2. Experimental set-up

III. RESULTS

In this drop test experiment result, we focused on the acceleration peak and time interval between impact experienced by the material to the time that the material was at rest. Each figure shows the response graph at different heights.

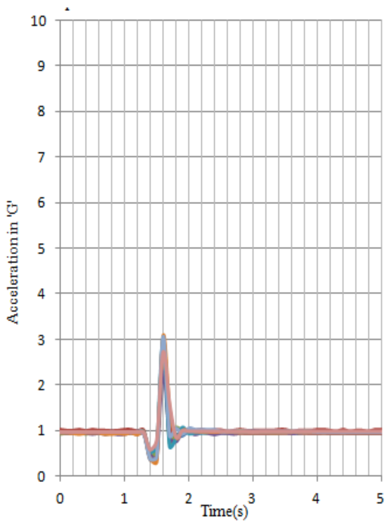

Fig. 3. Silicone Response at 0.0254m

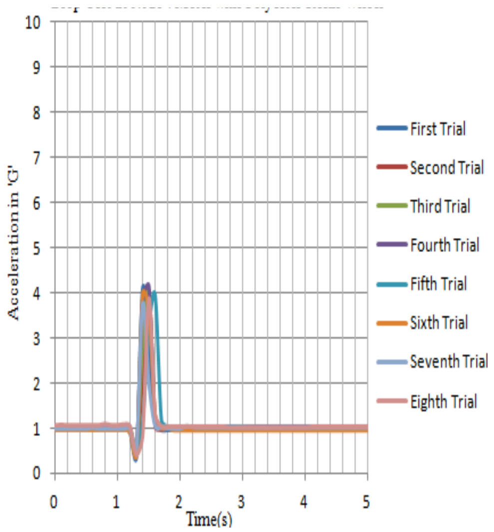

Fig. 4. Polyester Response at 0.0254m

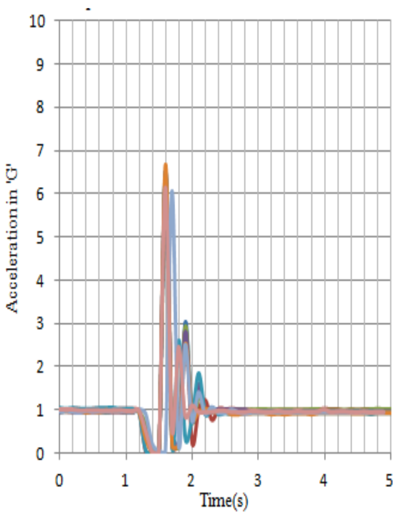

Fig. 5. Silicone Response at 0.5m

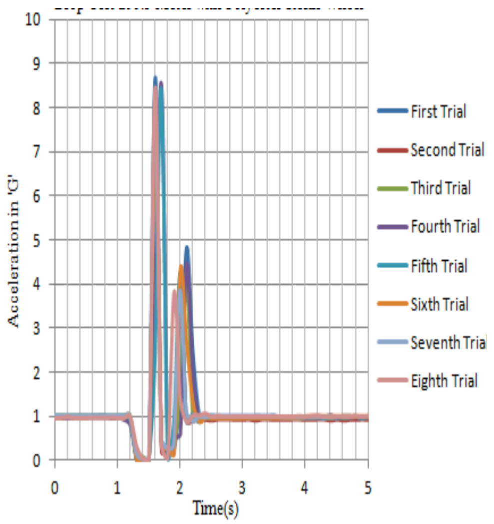

Fig. 6. Polyester Response at 0.5m

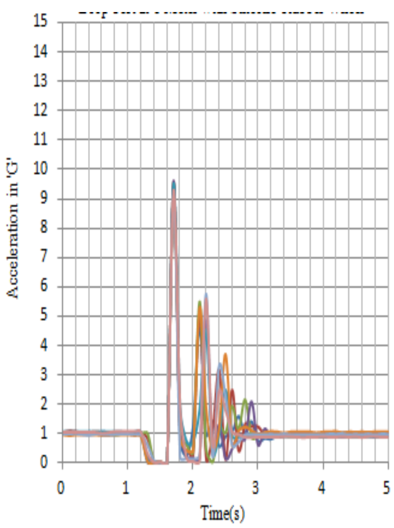

Fig. 7. Silicone Response at 1m

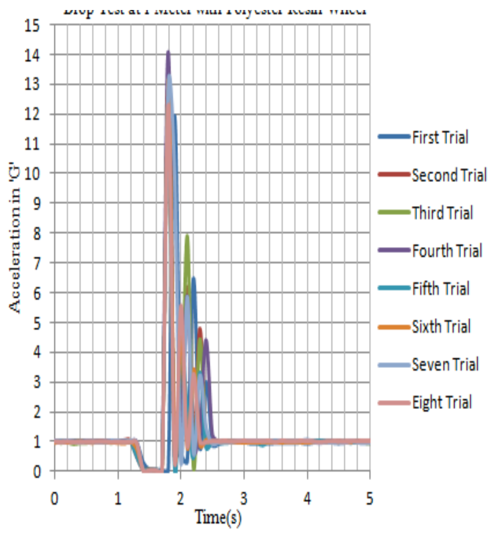

Fig. 8. Polyester Response at 1m

The settling time of a sample from the time of impact to the time the sample is at rest is shown in Table 1.

Height (m)	Material	Settling time response (sec)
0.0254	Silicone	0.4
0.0254	Polyester Resin	0.3
0.5	Silicone	0.9
0.5	Polyester Resin	0.8
1.0	Silicone	1.6
1.0	Polyester Resin	0.8

Table 1. Settling time response at different heights

From the experiment, it can be observed that the acceleration is much higher in polyester resin wheel than silicone rubber wheel especially during the first impact for the same drop height.

Acceleration is defined as the rate of change velocity over time. Since velocity is independent of mass during free fall period as it is under the influence of gravity (g = 9.8 m/s^2), the shorter the rate of change of time, the higher the acceleration. From Fig. 2, the downward velocity V_1 represents the velocity before the impact while V_2 represents the upward velocity after the impact. From Eqn. 1-3, the variables used were a_x (constant gravitational acceleration), x_f (final distance), x_i (initial distance), V_{xf} (final velocity) and V_{xi} (initial speed).

$$V_{xf}^2 = V_{xi}^2 + 2a_x(x_f - x_i) \tag{1}$$

$$V_1 = -\sqrt{2g(D_1)} \tag{2}$$

$$V_2 = \sqrt{2g(D_2)} \tag{3}$$

$$Acceleration = \frac{V_2 - V_1}{t_2 - t_1} \tag{4}$$

High acceleration especially for the first impact is harmful as it shows that the material is stiffer and does not respond well to the impact. It is noticeable that it took much longer time for the silicone rubber sample to settle down to stationary as compared to polyester resin sample. Longer time period shows the presence of elasticity in the material, which was required to absorb the shock within the material. Evidence of cracks was subsequently observed on the polyester resin wheels while the trials are being conducted at 1 m height. A comparison between the two experimental objects is shown in Fig. 9. Cracks are shown on the polyester resin sample.

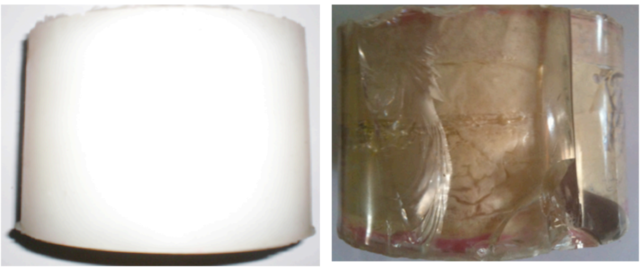

Fig. 9. Results of drop test from 1 m height for silicone rubber (left) and polyester resin (right) samples. The polyester resin has noticeable cracks.

IV. CONCLUSION

Analysis of the experimental result shows that silicone rubber material displayed lower *G* value as compared to polyester resin, which was noticeable during the first impact. The subsequent number of damping is an indication of how well the material reacts to the impact. From the results, it can be concluded that rubber material took more time to react to the change of velocity during the impact as most of the impact would have been absorb and dissipated in the material.

Social robots are now being used as a tool for autism therapy and diagnosis [12]. Experiments have shown that children with autism prefer playing with interactive, robotic toys rather than passive toys [13,14]. They also direct more eye gaze and focus more attention towards robots [15]. Therapy for children with autism not only applies to their impairments but also to their growth needs, hence encompassing their educational needs as well. Robots are less intimidating than humans; they not only act as playmates for the child, but they can be used as small, colourful toys, ensuring that the child feels at ease during the interaction [5,14,16,17,18]. They can be programmed to adapt their behaviour in accordance to the specific needs of a child with whom it is interacting, hence customizing the therapy for a child [5,19]

The robustness of the robot is especially important when the child with ASD is in a meltdown situation. The consequences and damages due to the child's action during meltdown situation could not be predicted. The experimental result conducted from three different heights shows that silicone rubber material displayed lower *G* value noticeable on the first impact as compared to the response graph of the polyester resin. The rubber material took more time to react to the change of velocity during the impact as most of the shock would have been absorbed and dissipated in the material before changing the course of direction. This is different from the polyester material whereby it received most of the impact, which eventually lead to cracks. The outcome shows that rubber material is more robust and should be used to protect the hardware and software of the robot as it is capable of absorbing the impact better. Future work involves recreating and analyzing a scenario where an object is thrown to the wall.

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