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TRUST IN HUMAN-ROBOT INTERACTION WITHIN HEALTHCARE SERVICES: A REVIEW STUDY

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ABSTRACT

There has always been a dilemma of the extent to which human can rely on machines in different activities of daily living. Ranging from riding on a self-driving car to having an iRobot vacuum clean the living room. However, when it comes to healthcare settings where robots are intended to work next to human, making decision gets difficult because repercussions may jeopardize people's life. That has led scientists and engineers to take one step back and think out of the box. Having concept of trust under scrutiny, this study helps deciphering complex human-robot interaction (HRI) attributes. Screening essential constituents of what shapes the trust in human mind as s/he is working with a robot will provide a more in-depth insight through how to build and consolidate the trust. In physiotherapeutic realm, this feeds into improving safety protocols and level of comfort; as well as increasing the efficacy of robot-assisted physical therapy and rehabilitation. This paper provides a comprehensive framework for measuring trust through introducing several scenarios that are prevalent in rehabilitation environment. This proposed framework highlights importance of clear communication between physicians and how they expect robot to intervene in a human centered task. In addition, it reflects on patients' perception of robot assistance. Ultimately, recommendations are made in order to maximize trust earned from the patients which then feeds into enhancing efficacy of the therapy. This is an ongoing study; authors are working with a local hospital to implement the know in a real-world application.

Keywords: trust, human-robot interaction, characteristics, physical therapy, healthcare

1. INTRODUCTION

Imagine a life where humans and robots coexist and interact with each other every day, much like the 1960's Hanna-Barbera produced animated show, *The Jetsons*. Though we are far from having flying cars and sky-built homes, life as we know it is slowly becoming similar to the show as technology progresses. The applications of robots have shifted from industrial uses to more social interaction such as within healthcare services. Assistive technology is playing a crucial role in the healthcare industry as it reduces time and increases accuracy [1]. Such technologies would help the increase in aging population, as it is projected that 21.1 percent of the worldwide population will reach over 60 years old by the year 2050 [2].

Collaborative robots (CoBots) are being utilized in medical settings to assist physicians with rehabilitations, mental health patients, and those with disabilities [3]. With the substantial increase of patients in hospitals, along with exponential raise in demand for telerehabilitation, CoBots would help reduce the burnout of healthcare workers. A study with 53,846 nurses in six countries showed the correlation between burnouts and the decrease in quality of healthcare [2], which essentially becomes a liability that can be prevented. With technology advancing and in the time of a pandemic, such as COVID-19, affecting people's lives, more trust should be put in human-robot interaction within healthcare services.

Telehealth has never been more important than now as needed for minimum human contact has affected the way in-person healthcare has been provided. Telehealth robots provide interaction between doctor and patient without risk of exposure. For example, there are diagnostic robots that carry out consultations with patients, measure their temperatures, detect coughs, etc. to diagnose COVID-19 [4]. Telehealth robots connect patients with their family and friends while also assisting healthcare workers. These robots can store data and stay up to date on the patients' status and inform staff in cases of emergencies [5].

In all stated cases, robots are expected to work alongside patients and/or physicians to deliver the most optimum outcome. They can also be used as replacement for therapists. Human-robot interaction is a subject that is slowly being introduced into the medical field as trust needs to be earned from the patient. Experiments and surveys were conducted and further analyze what factors a robot needs to have to increase trust within human-robot interaction in healthcare environments, and particularly in physical therapy.

This study will provide a holistic integration of critical parameters in human-robot interaction and importance of trust that needs to be established by human agent. This will then lead to facilitating an impactful treatment protocol using robot-assisted technology. The outcome of this research benefits patients in physical therapy as well as other healthcare services as it provides recommendations to help human and robot communicate more efficiently. Depending upon setting, a task-specific survey can be leveraged to bridge the human-machine gap and relate qualitative human traits to mathematical models that robot can comprehend. The flowchart below (FIGURE 1) shows an overview of the content studied and how it helps the future studies through recommending crucial factors and provisions.

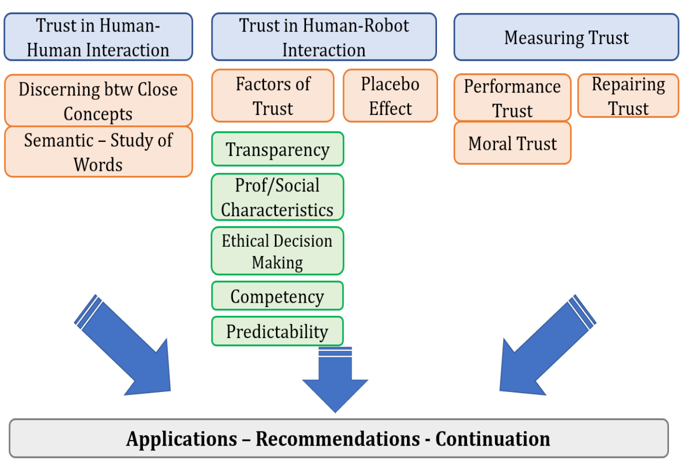

FIGURE 1 OVERVIEW OF KEY TOPICS AND FACTORS

2. TRUST IN HUMAN-HUMAN INTERACTION

Trust within human-human interaction coincides with personality and behaviors of an individual. According to [6], individual differences is what influences trust in early interactions. If one is not familiar and does not have enough information, then one will rely on their own bias. When knowledge is gained then trust increases. Personal traits also play great role when two people try to carry out a collaborative task; such as age, gender, level of education, race, cultural background, attitude toward new technology, propensity to have confidence in others, prior experience with trusting other.

2.1 The Concept of Hope vs. Trust

The difference between hope and trust is based on the level of confidence one has in something or someone. Hope involves an emotional expectation or belief that something good can happen when it is beyond one's control [7]. Hope also carries a low level of confidence due to factored uncertainties and other possible outcomes that one does not desire or expect [8]. Trust has many similarities as hope; though, trust involves vulnerability and is based on the way of acting [7].

To be vulnerable is to also have in mind that one's trust can be betrayed. Yet, trust enhances the willingness to cooperate, and to have high level of confidence and belief in something or someone.

Based on prior experience the authors have in the field of medical robotics, it is imperative that patients that are filling out the survey would be able to discern the different between concepts and factors such as hope vs. trust; and accuracy vs. precision (dart board example), respectively. This is discussed in detail in the conclusion and recommendation section.

2.2 Studies of Words Corresponding to Trust

In the healthcare domain, trust between human and robot needs to develop to the equivalent level of human-to-human trust as if it is a patient-doctor relationship. An experiment was conducted where participants interacted with a virtual reality game, aimed to improve upper body motor function, while a robot provided corrective feedback based on their motor performances [9]. They had hypothesized that a user's trust in a robot would be equal to or greater to that in a system with a human. The experiment used a self-report survey to compare the results of participants who have interacted with a robotic agent to those with a human agent. This survey used a scale seen in TABLE 1 to measure trust between people and automated systems, which used 12 potential factors from a cluster analysis [10].

A robust survey should check consistency of answers provided by participants. As mentioned earlier, physicians need to assure that selected words/clauses/scenarios given as choices or suggestions to participants contain best terms that can convey their feelings toward that factor.

Results of the experiment showed that participants who interacted with the robot therapist had an overall higher level of trust than those who interacted with a human. The participants described and believed the robot therapist to be less deceptive and suspicious, more dependable, and reliable [9].

3. TRUST IN HUMAN-ROBOT INTERACTION

Trust in human-robot interaction investigates the aspects and capabilities of a robot. Factors of trust are analyzed to provide a gateway to help increase trust from humans, as well as ways to measure it. This further guides into healthcare services in ways a robot should perform according to the needs of the patient. In the following, concept of trust is characterized through associated factors and venues for measuring trust are presented:

TABLE 1: TRUST SCALE FOR HUMAN-ROBOT TRUST AND CORESPONDING CLUSTER OF TRUST-RELATED WORDS [11]

Item	Word Groups from Cluster Analysis
The system is deceptive	Deception, Lie, Falsity Betray, Misleading Phony, Cheat
The system behaves in an underhanded manner	Sneaky, Steal
I am suspicious of the system's intent, action, or output	Mistrust, Suspicion Distrust
I am wary of the system	Beware
The system's action will have a harmful or injurious outcome	Cruel, Harm
I am confident in the system	Assurance, Confident
The system provides security	Security
The system has integrity	Honor, Integrity
The system is dependable	Fidelity, Loyalty
The system is reliable	Honesty, Trustworthy Reliability, Promise Friendship, Love
I can trust the system	Entrust
I am familiar with the system	Familiarity

3.1 Factors of Trust

Factors of trust indicate characteristics needed to gain one's trust. Throughout research, the following common factors include: (1) Transparency, (2) Professional and social characteristics, (3) Ethical decision-making. Although these are a few factors, research shows these are the main ideas to eventually gain the trust of the patients [12, 13, 14, 15, 16, 17].

3.1.1 Transparency

Transparency behavior in a robot is the ability to self-explain what it is doing to increase confidence in both the user and patient [18]. This can be achieved through communication such as verbal, written, images, sound, etc. The best way to be transparent with the patient is through verbal communication. An experiment where a robot was performing a standard blood pressure routine tested if transparency and adaptability from the robot would increase trust from the patient [12]. Four conditions were given during the experiment where one of the conditions included both transparency and adaptability from the robot as shown in FIGURE 2. This hypothesis was proven to be true.

Another experiment was conducted where a teleoperated robot performed medical tasks in a room that simulated an Ebola outbreak [13]. Results showed that trust from the patients increased when the patients were able to see the operator. However, this trust was more developed in the operator than the robot itself. In other words, transparency through verbal communication from the robot, as well as the ability to see the operator is a form to gain trust of the patient.

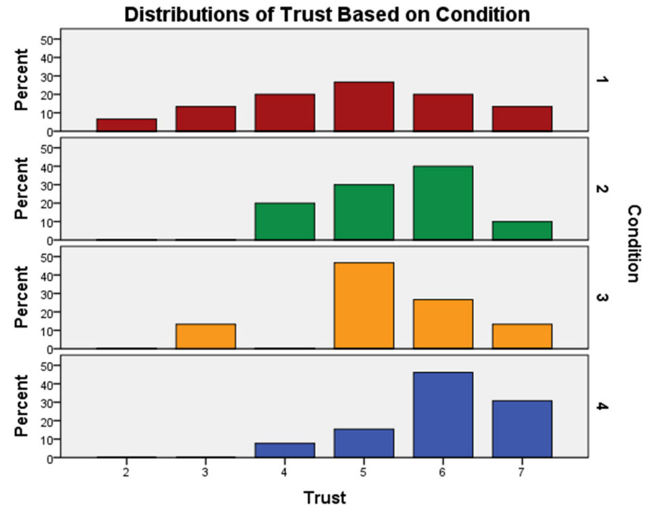

FIGURE 2: PERCENTAGE OF TRUST IN HUMAN-ROBOT INTERACTION WITH CONDITION 4 OF BOTH TRANSPARENCY AND ADAPTABILITY BEING THE DOMINANT FACTOR [12]

Some forms of non-verbal communication include body movement or gestures, social distance, interacting via touch, etc. Research shows that body movements or gestures indicating confidence in tasks from a robot increases trust [19]. Ultimately, when a robot enters one's personal space, although uncomfortable, trust increases between human and robot. There are many characteristics to consider in order for a robot to gain the trust of the human. As seen in FIGURE 3 below, when robot operates too close (YELLOW) to the patient, s/he feels insecure comparing to the times training occurs in GREEN zone. This factor impact the effect of therapy process [20]. Evidently, when robot is too far away, it will not be able to leverage its full range of motion to deliver required therapeutic motions.

FIGURE 3: WORKSPACE ZONES: YELLOW=CLOSE, GREEN=NORMAL, RED=FAR AWAY

3.1.2 Professional and Social Characteristics

Professional and social characteristics are described as the robot having safety, precision and accuracy of a consistent performance, capability, and predictability [14]. It is worth mentioning that high level of predictability is not necessarily an advantage since it make the system more machine-like and less-human-like. Although this improves the efficacy of the treatment which is celebrated by physicians, patients on the other side experiences more rigid force exerted that is discomforting. Since prescribed trajectory can be maintained with higher precision, training process will be safer and more efficient but is perceived from patients as less human-like. Robots should also contain the ability to adapt to the patient, express and recognize human emotions, and continually learning, building, and maintaining social relationships [21]. Research on surveys conducted with parents of children with Autism Spectrum Disorder (ASD) indicated that robots should assist healthcare providers through social interaction and monitoring the patient's progress [15]. The parents found it ethically acceptable to use a robot in healthcare systems, but not ethically acceptable to replace humans. Other surveys were conducted on older adults as the number of patients increase. The survey focused on their perceptions of supporting factors of trust in a robot care provider [14]. Ethical attunement is a noteworthy parameter as robotic technology is getting more attention and acceptance from people across different cultures with various ethical values and beliefs. Human-robot interactions were performed in scenarios such as bathing, medication assistance, transfer, and household tasks. Since the patients had little to no experience with robots and low self-efficacy in operating one, they overall preferred to trust a human instead of a robot. However, the patients indicated they would trust robots over humans in doing tasks such as household chores. Based on human' perception, transparency [22], explanation [23], personal traits, and professional skills would increase their trust in robot [14] as shown in FIGURE 4.

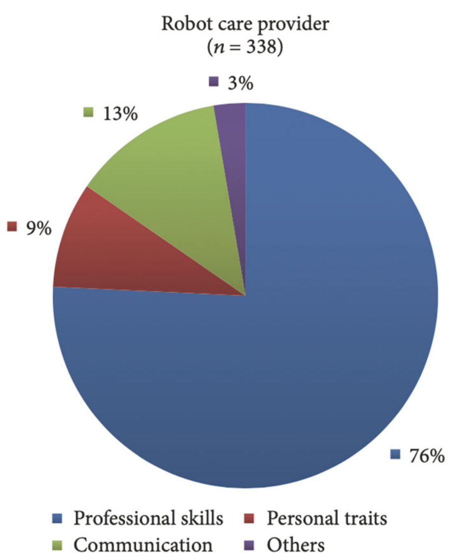

FIGURE 4: FACTORS TO INCREASE TRUST IN ROBOTS AS A CARE PROVIDER [14]

This shows that due to the levels of experiences with human-robot interaction, humans need to feel in control of their situation to increase trust and continue exposure.

3.1.3 Ethical Decision-Making

Ethical decision-making in a robot would include programmed fixed laws controlling their actions, computing, and evaluating consequences, and a learning system to obtain ethic principles [24]. Surveys conducted were to test the validity of the ethical decision-making process controlled by a care robot. The test included ethical scenarios in which each one had an initial situation where the interacted robot had a certain value, they held most high, and used its knowledge to make ethical decisions [16]. Results showed that the patients would only want transparency when they did not know the specifics of what the robot was going to do. Overall, the patients would not trust the robot on ethical decision-making and needed more transparency even after demonstrations of human-robot interaction scenarios. Although in [15], parents find it ethically acceptable (shown in FIGURE 5) if robots were to assist healthcare workers while they are making ethical decisions and providing therapy for children with autism.

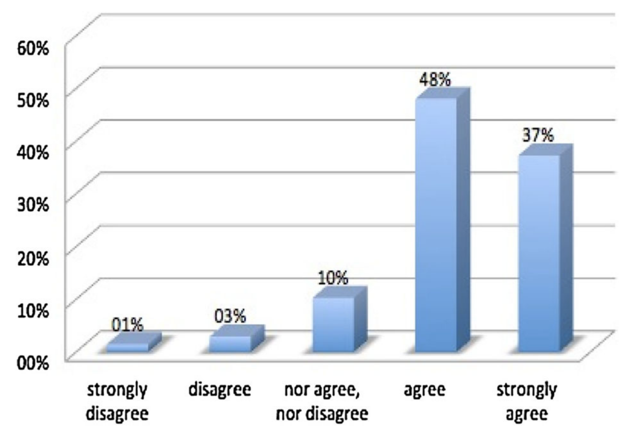

FIGURE 5: SURVEY ABOUT BEING ETHICALLY ACCEPTABLE FOR SOCIAL ROBOTS TO BE USED IN THERAPY FOR CHILDREN WITH AUTISM [15]

3.1.4 Competency

Competence in a robot is a contributing factor in increasing trust. In [25], this study explores and test these social aspects and how it influences interpersonal trust development by designing and manipulating robot competence. The study compared high versus low competence where the robot's judgement was correct three out of four times (high) and one out of four times (low). Overall, the anticipated trust and attributed trustworthiness towards the robot competency exhibited a positive effect. In [26], the behavior of the robot was examined under three conditions where the robot behaved slightly different in each scenario. Positive results showed where having competence is a preferred behavior in a robot in human-robot interaction.

3.1.5 Predictability

A robot is expected to repeatedly complete their given tasks, therefore having enough predictability for humans to have gained trust for the robot. This is especially established in [27], where they studied the interplay between autistic children, their behavioral and visual response, and the robot. Results showed that the less predictable the robot is, the less visual attention the children had; but, this did not affect their behavior in engaging with the robot.

3.2. Placebo Effect

Assistive devices are meant to work in conjunction with a physician to provide better care and help them carry out the labor work. However, one has to ascertain leveraging robots in the training process delivers the necessary care that patients should have from the service provider. Patients watch giant exoskeletons helping physicians with the rehabilitation process; from a psychological standpoint, they perceive they are getting adequate treatment, but this should be put under scrutiny.

4. METHODS OF MEASURING TRUST

To formulate concept of trust in human-robot interaction, the multidimensional measure of trust (MDMT) can be of use. The MDMT is a measurement tool that adapts to the relevant dimensions of each domain and provides a standard of comparison across studies and domains [8]. A recent version of this measurement contains 20 items that analyze five factors of trust: transparency, ethicality, benevolence, reliability, and competence [28]. These factors are then in broader categories: moral and performance trust, where ethicality, transparency, and benevolence are moral, and reliability and competence are performance-based trusts. Each factor has a subscale that consists of four items seen in TABLE *2*.

TABLE 2: MULTI-DIMENSIONAL MEASURE OF TRSUT (MDMT)-FACTORS OF TRUST [8].

Performance Trust		Moral Trust		
Reliable Subscale	Competent Subscale	Ethical Subscale	Transparent Subscale	Benevolent Subscale
Reliable	*Competent*	*Ethical*	*Transparent*	*Benevolent*
Predictable	*Skilled*	*Principled*	*Genuine*	*Kind*
Dependable	*Capable*	*Moral*	*Sincere*	*Considerate*
Consistent	*Meticulous*	*Has integrity*	*Candid*	*Has goodwill*

- Performance Trust
  - Reliable: according to Hancock *et al.* [29], this performance aspect has the strongest influence.
  - Competent/Ability: the knowledge to perform tasks. In [30], Kim *et al.* state that competent/ability plays an important role in aspects of trust.
- Moral Trust
  - Ethical: being unbiased and honest. It is preferred not to replace human workforce.
  - Transparent: informing, being truthful and providing access [8].
  - Benevolent: appears to have good motives. In [30], benevolence plays an important role in aspects of trust.

According to research on surveys and experiments resulting in the common trust factors indicated in previous sections, the MDMT is a tool that can implement analysis to provide and increase trust within human-robot interaction.

4.1 Repairing and Regaining Trust

A study conducted by Desai *et al.* [31], researches the changes of reliability which influences the trust in a robot system. This study indicated that trust is affected if the reliability decreases, as well as the timing of reliability decreases. Drops in reliability after a certain time of good performance has the greatest effect on trust than experiencing failure early on. To repair and regain the trust between human and robot, Baker *et al.* [32] suggest five recommendations to achieve this:

1. Use previous trust research designs to reduce the amount of time spent in the research phase. This can be adapted to recent research to examine the effectiveness of human-like robots in human-robot trust.

2. Study the 'human' in human-robot trust. Previous research lacks knowledge about what types of humans are expected to interact with robots. The effects of human characteristics and their differences need to be considered in human-robot trust (i.e. physical rehabilitation patients).

3. Cultural and social constraints have an impact on how behaviors are perceived or interpreted, especially when repairing trust. Robots need to behave in a way that coincides with cultural and social norms.

4. Trust needs to be evaluated over time during interaction to pinpoint where trust has been gained or lost. This way, the robot analyzes and evaluates human behavior and knows when to work on repairing trust lost.

5. Research the appropriateness of trust and its effects in the levels of vulnerability in situations. Robots should be able to adapt to users and its use of social cues, as well as its demeanor should align with the seriousness of assigned tasks.

These recommendations are a starting point in gaining and repairing trust between human and robot interaction. This will help better understand the needed tools to achieve this as technology advances. In addition to the stated recommendation toward regaining trust, authors will provide further comments and recommendations at the end of this study.

5. HUMAN-ROBOT INTERACTION APPLICATIONS

Robots have been used in a variety of ways within the healthcare system. Robots within healthcare used for social interaction, surgical assistance, rehabilitation, companionship and entertainment, and telemedicine [33]. Social robots are designed to provide affordable homebased, personalized and telemedicine technologies for preventive and curative care. Such robots are characterized through theories based on reported self-attributes with regard to inference [34]; compartmentalizing the errors involved [35], and comparing warmth and acting humane [36] are also subjects that researchers are interested to explore. Surgical robots are used to support face-to-face and remote surgical operations which result in minimally invasive surgeries and have increased precision, improved vision for the operator, and protects the patient and healthcare workers from exposure [1]. Rehabilitation robots provides physical and cognitive therapy as well as assist people with disabilities. Therapy robots are a common use in the rehabilitation field as studies have shown that children with Autism Spectrum Disorder (ASD) have responded positively to treatments involving human-robot interaction [11]. Mosqueda et al. studied motivation of participants as they interact with assistive robots that intervene on as-needed basis [37]. They found Judgments of Difficulty (JODs) among subjects are unique yet related. Companion robots have been used to enhance the health and well-being of individuals such as older adults and those who are sick through companionship and ease their stress. Entertainment robots used in the healthcare system interacts with patients through videos, audio by a humanoid [38], games, music [39], and accepting user input, all while providing care [40]. Social robots in healthcare deal with enhancing social skills [41], interacting with children as vulnerable a group [42], telehealth robots can be used to provide patient monitoring and management such as daily vital measurements [43], telepresence robots within the healthcare field provides for medical professionals to be in a remote location while providing patient care. [44].

MajidiRad *et al.* investigated robot intervention effect in an upper limb rehabilitation task [45]. Participants were directly interacting with a 6-DoF collaborative robotic (CoBot) arm in active mode. The robot navigated a prescribed path as participants grabbed onto a customized fixture at the robot's end-effector. In continuation of that study, the authors of the present work are working with local hospitals in Jacksonville, FL, to have their survey filled by their patients on-site, as well as healthy subjects doing the same tasks on the same site with identical physiotherapeutic machines. Additionally, leveraging the knowledge obtained from this review study and the technology such as a 7-DoF FRANKA EMIKA (FIGURE 6) collaborative robot that authors have, a meta-analysis study will be designed to investigate stated factors of trust and methods to measure those factors through scenarios such as pre-post treatment with patients in conjunction with healthy participants and control groups. In addition, the FRANKA arm will be used for continuation of current studies, where participants fill out surveys before and after interacting with the robot, as long as it runs through paths prescribed by physical therapists.

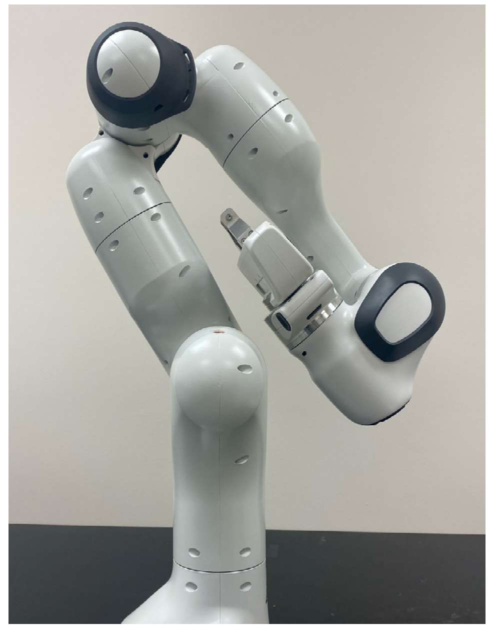

FIGURE 6: 7-DoF FRANKA EMIKA Collaborative Robotic Arm at UNF [45].

5.1 Human-Robot Interaction in Non-Medical Cases

Robots are not only used in the medical field but used as assistive robots in everyday life as well. Assistive robots use Integrated Augmentative Manipulation and Communication Technology (IAMCAT) to close the learning gap between children with and without disabilities [46]. Those with communication limitations and neuromotor disabilities, such as cerebral palsy, tested this technology with mathematics, science, social studies, etc. to manipulate objects and adapt to the child's disabilities. This helps the child communicate with their classmates and teachers and can participate in class.

Other studies, such as [47] and [48], have similar approaches where an assistive robot was used in the classroom for children with motor and speech disabilities. This robot was used through a speech generating device to conduct various hands-on academic activities such as mathematics measurement activities and putting together puzzles. Assistive robots are also used to enhance playfulness in children with limited motor disabilities [49]. Playfulness within children is an important part of developing social skills, problem solving skills and adaptive behaviors. Those with limited mobility have fewer opportunities to develop these skills. The assistive robot helped reinforce those skills as the children operate the robot. In the end, 81 percent of the children's playfulness had significantly increased.

6. CONCLUSION AND RECOMMENDATIONS

This review paper studied most recent research and investigations toward a better understanding of trust concept when human interplays with robot(s) in a therapeutic environment. Results of experiments and surveys testing trust conclude its common factors to further increase trust from humans. These common factors include transparency, professional and social characteristics, and ethical decision-making. The psychology behind the concept of trust versus hope were mentioned and how to repair and gain trust between human and robot. This analyzation includes using previous trust designs, studying what types of are expected to interact with robots, as well as the cultural and social aspects. Methods to measure trust were discussed, such as cluster analyses; and the Multi-Dimensional Measure of Trust (MDMT), was investigated to further implement these factors in later research. Current human-robot applications that are in the world today are discussed to emphasize how the age of technology is rapidly changing and adapting, especially in the environment of a pandemic.

In order to avoid misunderstanding, authors recommend clarifying the intent through providing a scenario in which a certain factor is involved and being measured. Use of clauses or sentences in lieu of words would help better convey the concept to participants and patients. Clarity is of paramount importance. Survey needs to be structured in such a way that relevant questions are included to ascertain reliable responses. To meet this, a reliability analysis is recommended utilizing cluster analysis of clause/sentence groups. Additionally, it is recommended that investigators leverage large number of participants through outsourcing services such as Amazon MTurk to have a more inclusive pool of candidates which leads to a rather robust conclusion. This is in addition to studying patients in a pre/post robot-assisted therapy condition to make sure the trust gained by them is assessed while interacting with an actual robot. This study is on-going and will be updated in follow-up research. Authors are working with a local hospital to implement the know in a real-world application.

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