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# An Analysis of Robot-Assisted Social-Communication Instruction for Young Children with Autism Spectrum Disorders

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# AN ANALYSIS OF ROBOT-ASSISTED SOCIAL-COMMUNICATION INSTRUCTION FOR YOUNG CHILDREN WITH AUTISM SPECTRUM DISORDERS

by

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ABSTRACT

Social and communication deficits are a core feature of Autism Spectrum Disorders (ASD) and impact an individual's ability to be a full participant in their school environment and community. The increase in number of students with ASD in schools combined with the use of ineffective interventions have created a critical need for quality social-communication instruction in schools for this population. Technology-based interventions, like robots, have the potential to greatly impact students with disabilities, including students with ASD who tend to show increased interest and engagement in technology-based tasks and materials. While research on the use of robots with these learners is limited, these technologies have been successfully used to teach basic social-communication skills. The purpose of this study was to examine the effects of a social-communication intervention for young children with ASD that is rooted in evidence-based practices and utilizes a surrogate interactive robot as the primary interventionist. This study utilized a multiple baseline design across behaviors to determine the impact of the robot-assisted intervention on the manding, tacting, and intraverbal skills of four, 3-year old students with ASD. The researchers found that this intervention was effective in increasing the rate of all three the target behaviors.

My dissertation is dedicated to my parents, Ross and Michele, who have always encouraged and supported in me in every possible way, and my soon-to-be husband Dedrick, who believed in me unconditionally and kept me on track throughout this process. Thank you, I love you, and I could not have done this without you all.

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LIST OF ACRONYMS

AAP: American Academy of Pediatrics

ABA: Applied behavior analysis

ANCOVA: Analysis of covariance

ANOVA: Analysis of variance

APA: American Psychiatric Association

AR: Artificial reality

ASD: Autism Spectrum Disorder

ASQ: SE-2: Ages and Stages Questionnaire – Social Emotional: Second Edition

CBM: Curriculum-based measurement

CDC: Center for Disease Control

CEC: Council for Exceptional Children

CoSN: Consortium for School Networking

CP: Cerebral palsy

DEC: Division for Early Childhood (of the Council for Exceptional Children)

DSM: Diagnostic and Statistical Manual

DTT: Discrete trial training

DV: Dependent variable

EBP: Evidence-based practices

ECE: Early childhood education

EIBI: Early and intensive behavioral intervention

GB: Gigabyte

IDEA: Individuals with Disabilities Education Act

IEP: Individualized Education Program

IOA: Interobserver agreement

IQ: Intelligence quotient

IV: Independent variable

NAC: National Autism Center

NAP: Non-overlap of all pairs

NIH: National Institute for Health

NMC: New Media Consortium

NSF: National Science Foundation

PDD-NOS: Pervasive Developmental Disorder – Not Otherwise Specified

PND: Percent of non-overlapping data

RAT: Robot-assisted therapy

RCT: Randomized control trial

RLC: Robot learning companion

SES: Socio-economic status

SGD: Speech generating device

STEM: Science, technology, engineering, and mathematics

TD: Typically developing

USDOE: United States Department of Education

VB: Verbal behavior

VB-MAPP: Verbal Behavior Milestones Assessment and Placement Program

# CHAPTER 1: INTRODUCTION

## Background and Need for the Study

In 2014, the CDC released results estimating the prevalence of Autism Spectrum Disorder (ASD) in the United States at an average of 1 in 68 children. The number of children identified with ASD increased by 52% from 2010 to 2014 whereas the number of children identified across all other disability categories decreased by 1% over the same time period. The United States Department of Education (2014) reported in Fall 2011 that among students ages 6 through 21 served under IDEA, Part B, the autism category ranked as the fifth most prevalent disability category. Increasing numbers of young children identified with ASD have emerged as a unique challenge for the field of special education (Boyd, Odom, Humphreys, & Sam, 2010). According to the Center for Disease Control (CDC, 2014), "This recent and rapid increase in ASD prevalence underscores the importance of continuing surveillance...and the need to continue expanding research into risk factors, etiology, and effective interventions" (p. 2).

In the United States, individuals with ASD have the lowest rates of employment when compared to persons with other disabilities (Shattuck, Narendorf, Cooper, & Sterzing, 2012) and social skills deficits are frequently cited as barriers to improved employment outcomes (Burke, Andersen, Bowen, Howard, & Allen, 2010; Cimera & Cowan, 2009). Social and communication related challenges can significantly affect many aspects of an individual's life including obtaining and maintaining employment, forming and maintaining relationships, and functioning independently (Howlin, 2013). These deficits typically present in early childhood and although it was initially believed that the social deficits associated with ASD would abate naturally in adolescence and adulthood, recent findings suggest that the symptoms do not subside with age (American Psychiatric Association, 2013; Baghdadli, Assouline, Sonié, & Pernon, 2012; Howlin, Moss, Savage, & Rutter, 2013). Explicit instruction in the area of social-communication skills beginning in early childhood and continuing through K-12 and beyond is recommended (National Autism Center, 2009; 2015).

## Typical Language Development

Typical language development begins even before children are born as they are exposed to the language spoken around them in utero (Gleason & Ratner, 2016). For children who exhibit typical developmental patterns, they begin to acquire and demonstrate communicative skills such as joint attention long before they say their first words (Gleason & Ratner, 2016). From about age 1 to age 4, typically developing children show rapid and dramatic changes in their language and communication skills. Many children say their first word by 12 months and by 16-18 months have a vocabulary of about 50 words (Hoff & Shatz, 2009). By kindergarten, most children have a vocabulary of 8,000 to 10,000 words, understand some grammatical conventions, and have started to learn to navigate different social situations (Gleason & Ratner, 2016).

Typically developing preschoolers are able to produce a variety of direct and indirect requests and are starting to become aware of formal and information request forms that are appropriate for different communication partners (Gleason & Ratner, 2016). Preschoolers are also starting to have increasingly complex conversations as they begin to understand conversational turn-taking, topic maintenance, and giving and responding to feedback within a conversation (Gleason & Ratner, 2016).

## Language Development in Children with ASD

Children with ASD frequently exhibit atypical receptive, expressive, and/or pragmatic language development (Gleason & Ratner, 2016). Even prior to the emergence of verbal speech, infants with ASD often show significant impairments in pre-linguistic social-communication skills such as eye contact and joint attention (Gleason & Ratner, 2016). Children with neurodevelopmental disorders such as ASD often hit developmental milestones later than their peers and take longer to develop the same skills. In many cases, language and social-communication skills never fully develop or mature in individuals with neurodevelopmental disorders (Gleason & Ratner, 2016).

Autism Spectrum Disorder (ASD) is characterized by "persistent deficits in social communication and social interaction across multiple contexts" and "restricted or repetitive patterns of behavior, interests, or activities" (American Psychiatric Association, 2013, pp. 50-51). Although individuals with ASD can vary widely in their cognitive, behavioral, and social-communication abilities; social-communication impairments are frequently the most impactful deficit (Scattone, 2007).

The heterogeneity of presentation of skills in students with ASD combined with the need to address social-communication goals in addition to helping these students achieve academic standards creates a challenge in the classroom (Gallant, 2009). At present, school-based social-communication interventions are minimally effective and produce low treatment and generalization effects (Bellini, Peters, Benner, & Hopf, 2007). The increase in the number of students with ASD in schools combined with the use of non-research based, ineffective interventions has created a critical need for quality social-communication instruction in schools for this population (Hess, Morrier, Heflin, & Ivey, 2008).

## Early Childhood Education and Early Intervention

The goal of early childhood education is to help lay a foundation of academic, social-communication, and school readiness skills for young learners. Social-communication skills are as important as pre-academic skills (e.g., naming letters, numbers, and shapes) for the success of early learners. However, with the introduction of more and more rigorous academic standards for students as young as kindergarten age, teachers have less flexibility in their schedules to address these critical skills (Gallant, 2009). As early childhood educators work to embed instruction in all of these areas into the school day, there are several widely accepted models for providing high quality early childhood education including the DEC Recommended Practices**,** Pyramid Model for Supporting Social Emotional Competence in Infants and Young Children, and early intensive behavioral intervention. Each model offers a unique perspective on instruction in the early childhood classroom.

The Division for Early Childhood of the Council for Exceptional Children (2014) developed a list of recommended practices to provide guidance to educators and families on the best ways to promote the development of young children. The DEC Recommended Practices are organized into eight topic areas: leadership, assessment, environment, family, instruction, teaming and collaboration, and transition. The topic area of instruction includes 13 recommendations and provides the foundation for early intervention and early childhood special education practices (DEC, 2014):

1. Practitioners, with the family, identify each child's strengths, preferences, and interests to engage the child in active learning.

2. Practitioners with the family, identify skills to target for instruction that help a child become adaptive, competent, socially connected, and engaged and that promote learning in natural and inclusive environments.
3. Practitioners gather and use data to inform decisions about individualized instruction.
4. Practitioners plan for and provide the level of support, accommodations, and adaptations needed for the child to access, participate, and learn within and across activities and routines.
5. Practitioners embed instruction within and across routines, activities, and environments to provide contextually relevant learning opportunities.
6. Practitioners use systematic instructional strategies with fidelity to teach skills and to promote child engagement and learning.
7. Practitioners use explicit feedback and consequences to increase child engagement, play, and skills.
8. Practitioners use peer-mediated intervention to teach skills and to promote child engagement and learning.
9. Practitioners use functional assessment and related prevention, promotion, and intervention strategies across environments to prevent and address challenging behavior.
10. Practitioners implement the frequency, intensity, and duration of instruction needed to address the child's phase and pace of learning or the level of support needed by the family to achieve the child's outcomes or goals.
11. Practitioners provide instructional support for young children with disabilities who are dual language learners to assist them in learning English and in continuing to develop skills through the use of their home language.

12. Practitioners use and adapt specific instructional strategies that are effective for dual language learners when teaching English to children with disabilities.
13. Practitioners use coaching or consultation strategies with primary caregivers or other adults to facilitate positive adult-child interactions and instruction intentionally designed to promote child learning and development (DEC, 2014).

The Pyramid Model for Supporting Social Emotional Competence in Infants and Young Children is a conceptual framework of evidence-based practices focused specifically on social skills and challenging behavior (Fox, Carta, Strain, Dunlap, & Hemmeter, 2009). Program evaluation data over the last decade has shown the Pyramid Model to be a sound framework for early childhood classrooms. The Pyramid Model utilizes a tiered approach to support the social emotional development of young learners. The model indicates that educators should provide universal supports to all children, targeted services to those who need more support, and intensive services to those who need them (see Figure 1).

Additionally, given the increase in prevalence of ASD and the potential impact of long-term outcomes, early identification and treatment of this disability is critical (Bekele, Crittendon, Swanson, Sarkar, & Warren, 2014). Meta-analyses of early intervention research indicate early and intensive behavioral intervention (EIBI) is a powerful tool and can have long-term impacts on cognition (i.e., IQ) and adaptive behavior (Reichow, 2012).

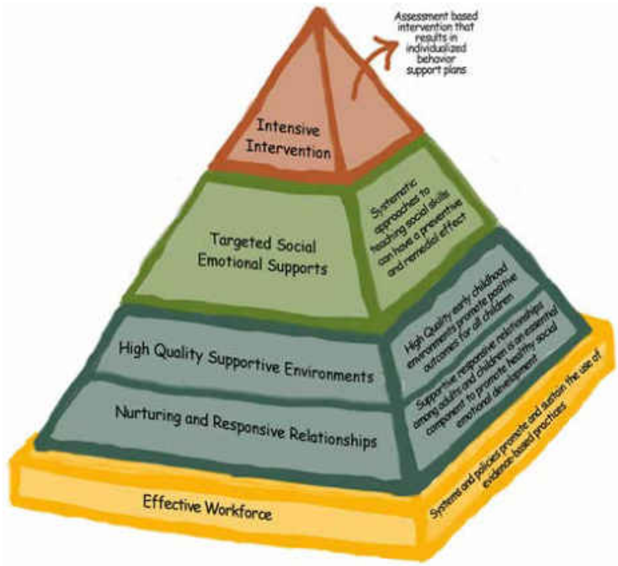


Figure 1. Pyramid Model for Supporting Social Emotional Competence in Infants and Young Children

## Interventions for Students with Autism Spectrum Disorders

After a rigorous review of 389 studies published since 2007, the National Autism Center (2015) recognized the following as established treatments in the second phase of the National Standards Project: (a) Behavioral Interventions, (b) Cognitive Behavioral Interventions, (c) Language Training, (d) Modeling, (e) Naturalistic Teaching, (f) Parent Training, (g) Peer Training, (h) Pivotal Response Treatment (PRT), (i) Schedules, (j) Scripting, (k) Self-Management, (l) Social Skills Package, and (m) Story-Based Interventions. While many of these practices or interventions did not originally include a technology-based component, in today's classrooms, technology can be used to deliver or enhance these evidence-based instructional practices.

It is important to note that individuals with ASD tend to show increased interest and engagement in technology-based tasks and materials, making technology a potential vehicle for teaching social skills to children and adolescents with ASD (Chen & Bernard-Opitz, 1993; Tincani & Boutot, 2005). This makes the intersection of EBPs and technology critical in the instructional planning and delivery for students with ASD.

## Technology-Based Instruction

Emerging technologies are one vehicle for supporting educators in differentiating and adapting content for learners with different abilities. By utilizing classroom-based technologies in combination with more traditional instructional practices, early childhood educators can provide their students access to activities that support the development of both their social-communication and pre-academic skills.

The role of technology in education is continuing to expand each year and it is critical that school leaders and educators keep pace. Schools need to foster professional learning communities where teachers have the resources and supports to learn and evolve as they rethink their pedagogies and curricula (Adams Becker, Freeman, Giesinger Hall, Cummins, & Yuhnke, 2016). Teachers, in turn, need to become more active participants in ongoing professional development on technology-enabled education practices that will help them meet the academic, behavioral, and social-communication needs of all students including those with ASD by informing their selection and embedding of appropriate technologies throughout the school day (Adams Becker et al. 2016). "When carefully designed and thoughtfully applied, technology can accelerate, amplify, and expand the impact of effective teaching practices. However, to be transformative, educators need to have the knowledge and skills to take full advantage of technology-rich learning environments" (United States Department of Education, 2016, p. 2).

It is important to note that there are developmental and health concerns associated with excessive digital media usage for children under five years old.  The American Academy of Pediatrics (AAP) recommends that children 2 to 5 years should be engaged with digital media no more than1 hour per day to allow them time to engage in other activities that support their development (American Academy of Pediatrics Council on Communications and Media, 2016). The AAP also notes that parents and teachers should look for "social and creative" ways to engage young children with new technologies and ensure that technology usage does not displace social interactions (American Academy of Pediatrics Council on Communications and Media, 2016, p. 3).

Given that many students with ASD show increased engagement with technology-based tasks (Chen & Bernard-Opitz, 1993; Tincani & Boutot, 2005), innovative technology has a role in addressing the core deficits associated with ASD (i.e., communication and social interaction skills).  The 2016 National Education Technology Plan states the following, "Technology can be a powerful tool for transforming learning.  It can help affirm and advance relationships between educators and students, reinvent our approaches to learning and collaboration, shrink long-standing equity and accessibility gaps, and adapt learning experiences to meet the needs of all learners" (United States Department of Education, 2016, p. 1).

## Robots and Instruction

Many emerging technologies, like robots, were originally developed to serve professional and recreational purposes.  After a product is released, over time, parents and educators become familiar with it and other technologies and find ways to repurpose them for use in the classroom as learning aides for their students with and without disabilities (Adams Becker et al., 2016).  In the NMC/CoSN Horizon Report: 2016 K-12 Edition, robotics is highlighted as a technology that is two to three years from widespread use in classrooms (Adams Becker et al., 2016).

There are several concerns about the use of robots in education including the novelty effect and "uncanny valley." The novelty effect is the phenomenon by which people are highly engaged by the robot at the beginning and rapidly lose interest (Kanda, Hirano, Eaton, & Ishiguro, 2004). While this is a legitimate concern, modifications to features of the robot and research or intervention design can reduce the likelihood of this effect. Some of the modifications include: such as appearance, continuity and incremental novel behaviors, affective interactions and empathy, and length of intervention (Leite, Martinho, & Paiva, 2013). "Uncanny valley" describes the negative response of humans to robots that closely resemble humans. Again this variable can be addressed through the application of careful thought to the design features of the robot for the target population.

At present there is a paucity of research on using robots to teach social-communication skills to early childhood learners with ASD. In fact, only eight empirical manuscripts were found that focused on robot-assisted social-communication instruction for young learners with ASD (Bekele et al., 2016; Peca et al., 2015; Pop et al., 2013; Pop et al., 2014; Simut et al., 2016; Tapus et al., 2012; Wainer et al., 2015). The current research focuses on three skill sets for this population: (a) joint attention and pre-linguistic communication skills, (b) imitation and physical interaction, and (c) play and social skills. Five of the eight existing studies focused on the effects of robot-mediated or robot-assisted interventions on the joint attention or pre-linguistic communication skills of early learners with ASD. This study made a contribution to the extremely limited work on using robot-assisted instruction to teacher more advanced, linguistic communication skills to this group of students.

## Statement of the Problem

There is existing research on the importance of early intervention with children with ASD, specifically with regards to social-communication skills. There is also research on the efficacy of some technology-based interventions, including the use of robots, with students with ASD. Despite this foundation, there is a void in the research when looking at the use of robots to teach social-communication skills to young children with ASD. Social-communication skills represent a critical instructional domain for this population of learners.

## Rationale

Young children with ASD struggle with a variety of social-communication challenges that impact their ability to participate fully in school, family, and community-based activities. These skills also may affect their ability to be successful as they transition into the PK-12 education system and adulthood. For this population, highly effective and engaging instruction in social-communication skills should begin at an early age. Interactive technologies, such as robots, are one vehicle for delivering this type of instruction. Research on robotics and early childhood education, robotics and ASD, and robotics and communication skills is emerging but is very limited. In this study, the researcher addresses this critical area of need for three year-old students with ASD.

## Overview of Methodology

The researcher utilized a multiple baseline design across behaviors to determine the impact of social-communication instruction delivered by an interactive robot on the manding, tacting, and intraverbal skills for students with ASD in early childhood settings.

## Research Questions

The research questions used to guide the researcher were as follows:

(1) To what extent does social-communication instruction mediated through a surrogate interactive robot impact manding skills of preschool students (age 3) with ASD?

(2) To what extent does social-communication instruction mediated through a surrogate interactive robot impact tacting skills of preschool students (age 3) with ASD?

(3) To what extent does social-communication instruction mediated through a surrogate interactive robot impact intraverbal skills of preschool students (age 3) with ASD?

(4) To what extent do stakeholders find the goals, procedures, and outcomes of a social-communication intervention mediated through a surrogate interactive robot?

## List of Terms, Acronyms, and Definitions

Autism spectrum disorders (ASD) will be defined by the diagnostic criteria outlined in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V; American Psychiatric Association, 2013). According to this manual, ASD is characterized by “persistent deficits in social communication and social interaction across multiple contexts” and “restricted or repetitive patterns of behavior, interests, or activities” (American Psychiatric Association, 2013, p. 50-51). The manual also provides guidance for specifying the severity of social-communication and restricted or repetitive behaviors (see Table 1).

Table 1

Severity levels for ASD from DSM-V (American Psychiatric Association, 2013)

| Severity level | Social communication | Restricted or repetitive behaviors |
|---|---|---|
| Level 3 "Requiring very substantial support" | Severe deficits in verbal and nonverbal social communication skills cause severe impairments in functioning, very limited initiation of social interactions, and minimal response to social overtures from others. For example, a person with few words of intelligible speech who rarely initiates interaction and, when he or she does, makes unusual approaches to meet needs only and responds to only very direct social approaches. | Inflexibility of behavior, extreme difficulty coping with change, or other restricted/repetitive behaviors markedly interfere with functioning in all spheres. Great distress/difficulty changing focus or action. |
| Level 2 "Requiring substantial support" | Marked deficits in verbal and nonverbal social communication skills; social impairments apparent even with supports in place; limited initiation of social interactions; and reduced or abnormal responses to social overtures from others. For example, a person who speaks simple sentences, whose interaction is limited to narrow special interests, and who has markedly odd nonverbal communication. | Inflexibility of behavior, difficulty coping with change, or other restricted/repetitive behaviors appear frequently enough to be obvious to the casual observer and interfere with functioning in a variety of contexts. Distress and/or difficulty changing focus or action. |
| Level 1 "Requiring support" | Without supports in place, deficits in social communication cause noticeable impairments. Difficulty initiating social interactions, and clear examples of atypical or unsuccessful response to social overtures of others. May appear to have decreased interest in social interactions. For example, a person who is able to speak in full sentences and engages in communication but whose to- and-fro conversation with others fails, and whose attempts to make friends are odd and typically unsuccessful. | Inflexibility of behavior causes significant interference with functioning in one or more contexts. Difficulty switching between activities. Problems of organization and planning hamper independence. |

The surrogate interactive robot, Romibo (see Figure 2), is capable of conveying emotions and verbal responses. Romibo's original design is to provide motivation and social therapy for individuals with conditions including ASD, traumatic brain injury, and dementia. The platform provides a fully customizable interface for facilitating instruction.

Figure 2. Romibo Robot

A mand is a verbal operant that is under the control of a condition of satiation or deprivation and reinforced by a characteristic consequence (Skinner, 1957). A mand has occurred when an individual asks for what he or she wants using verbal language, verbal approximation, gesture, sign, or other form of communication. An individual can mand for an item, action, activity and they can mand to remove or end an item, action, or activity (Sundberg, 2014). Mands often are the first form of language acquired by a child and are fundamental to the development of language (Bijou & Baer, 1965). Mands also are the only form of language that directly benefits the speaker (Skinner, 1957).

A tact is a verbal operant evoked by a nonverbal discriminative stimulus and followed by generalized conditioned reinforcement (Skinner, 1957). When an individual is tacting, they are labeling items, actions, and attributes in their environment (Sundberg, 2014). The individual must be in the presence of the non-verbal stimuli in order for the verbal behavior to be considered a tact. Developing a strong tact repertoire is also considered critical to language development (Sundberg, 2014).

An intraverbal is a verbal operant involving a response that is evoked by a verbal discriminative stimulus that does not have point-to-point correspondence with that verbal stimulus (Skinner, 1957). Intraverbals are a type of language where the individual is responding to the language of others (Sundberg, 2014) and can include but is not limited to answering questions and filling in the blanks. Intraverbal behaviors allow the child to engage in conversations with others. Many children with language delays or language-based disorders such as ASD struggle to acquire functional intraverbal skills (Sundberg, 2014).

Curriculum based measurement (CBM) is an approach for assessing skills acquisition or growth in students (Deno, 2003). It is a progress-monitoring tool that can be used to make instructional decisions about individual learners of groups of students. Generally, CBMs are created from materials used in the classroom (Deno, 2003) and are embedded into the naturally-occurring instructional sequence.

## Organization of the Dissertation

This dissertation is divided into five chapters. Chapter 1 introduced the background and need for the study as well as some foundational information on language development, early intervention practices, technology-based practices, and robotics in education. Chapter 2 provides a systematic review of the existing literature on robotics and early intervention, autism spectrum disorders, and communication skills. This chapter provides the empirical foundation basis for the present study.  Chapter 3 provides a detailed description of the methodology including the research questions, research design, descriptions of the participants, setting, and materials used, descriptions of the independent and dependent variables and data analysis procedures.  The results of the study are presented in Chapter 4.  Chapter 5 presents a discussion of the findings including limitations and implications of the analysis.

# CHAPTER 2: LITERATURE REVIEW

## Chapter Overview

In this chapter, the researcher presents the results of a systematic literature review on the intersection of robotics and early childhood education, Autism Spectrum Disorders (ASD), and communication skills instruction. An overview of the prevalence, diagnostic criteria, and social-communication challenges associated with this diagnosis is provided. The researcher provides a detailed summary of the literature on (1) robotics and early childhood education, (2) robotics and ASD, and (3) robotics and communication skills.

## Introduction

The rate individuals are diagnosed with Autism Spectrum Disorders (ASD) continues to rise with a recent projected rate of 1:68 children (Center for Disease Control, 2014). According to Center for Disease Control (2014), the rapid increase in ASD prevalence underscores the gravity and need to continue expanding research into risk factors, etiology, and effective interventions. Increasing numbers of young children identified with ASD have emerged as a significant challenge for educators (Boyd et al., 2010). Researchers suggest school district administrators, teachers and parents will continue to have challenges meeting the needs of students with ASD (Koegel, Matos-Freden, Lang, & Koegel, 2012). One domain where students with ASD need effective interventions is social-communication skills.

Social skill and pragmatic language impairments represent a core deficit for individuals with ASD across their lifespans (American Psychiatric Association, 2013; Baghdadli et al., 2012; Howlin et al., 2013). Social deficits impact an individual's ability to be successful in school and community, access employment, and demonstrate independence as they transition into adulthood

(Howlin, 2013). These difficulties also can prohibit students with ASD from being full participants in the inclusive classroom environment, even at a very young age. Given the increased prevalence of ASD in schools and communities, it is important that educators provide effective and evidence-based intervention and treatment (Wong, Odom, Hume, Cox, & Fettig, 2015). Groups of researchers and organizations have developed methods and systems for determining what practices should be labeled "evidence-based" in order to inform policy and teacher practice (National Autism Center, 2009; 2015; Odom, Collet-Klingenberg, Rogers, & Hatton, 2010; Wong et al., 2015). Many of these evidence-based practices are flexible and frequently used to teach academic, behavior, and social-communication targets.

Technology is becoming increasingly a part of everyday life and assessing how to integrate technology and evidence-based practices is an important aspect of teaching. The fast paced growth of the education technology market shows no signs of deceleration and has helped develop a marketplace full of new devices, apps, and programs, though most show no empirical support demonstrating efficacious outcomes for students, parents, or educators. Thus making meaningful and targeted recommendations is tenuous at best.

The National Education Technology Plan highlights technology as a powerful tool for transforming learning, helping affirm and advance relationships between educators and students, reinventing approaches to learning and collaboration, shrinking equity and accessibility gaps, and adapting learning to meet the needs of all learners (U.S.Department Of Education, 2016). Technology can be used to teach academic skills across content areas but also has a role in teaching social skills, communication skills, and adaptive behaviors. These domains all represent core deficits associated with ASD.

Technology holds great promise when it comes to impacting students with disabilities (U.S.Department Of Education, 2016). Specifically, individuals with ASD tend to show increased interest and engagement in technology-based tasks and materials, making technology a potential vehicle for teaching social skills to children and adolescents with ASD (Tincani & Boutot, 2005; Vasquez et al., 2015). The role of technology in education is continuing to expand each year. However, to be transformative, educators need to have the knowledge and skills to take full advantage of technology-rich learning environments (U.S.Department Of Education, 2016). Robotics is one type of technology where further investigation needs to occur.

## Purpose

In one literature review the researchers conducted an in depth analysis of the clinical use of robots for students with ASD (Diehl, Schmitt, Villano, & Crowell, 2012). The researchers organized the studies into four categories: (a) the response of individuals with ASD to robots as compared to humans ($n$ = 7), (b) the use of robots to elicit behaviors ($n$ = 10), (c) the use of robots to model, practice, or teach a skill ($n$ = 1), and (d) the use of robots to provide feedback on performance ($n$ = 1). Diehl and colleagues (2012) found that most studies were exploratory in nature and many had significant methodological limitations. Additionally, they noted that much of the existing research focused on technology development rather than use or application.

The purpose of this review was to identify the existing literature at the intersection of robotics, ASD, early childhood education, communication skills instruction. This review was done through the lens of the research questions used to guide this researcher's own study.

## Research Questions

The review was driven by the following research question and sub-questions:

Research Question: To what extent are robotics-based interventions represented in the literature on early childhood learners, students with ASD, and instruction on communication skills?

Sub-question 1: What empirical literature is available for the use of robotics to teach students in early childhood settings?

Sub-question 2: What empirical literature is available for the use of robotics to teach students with Autism Spectrum Disorders (ASD)?

Sub-question 3: What empirical literature is available for the use of robotics to teach communication skills?

# Methods

## Criteria

The criteria used for selection of articles included in this review were those articles published as empirical studies in peer-reviewed journals in 2010 or after that contained the search term "robotics," and one of the three other search terms (i.e., early childhood education/early intervention, autism, or communication skills). Next, the identified articles were hand-coded to exclude studies that (a) were duplicates from other search term combinations or search engines, (b) were not empirical (e.g., brief reports, program or curriculum descriptions) or did not involve an intervention (e.g., focused on technology development), (c) did not have students as the primary participants (e.g., studies that looked at training teachers to provide robotics instruction), and (d) were coded incorrectly. These criteria were chosen since the intent of the systematic literature review was to identify and review research on the use of robotics in the following domains: early childhood education, Autism Spectrum Disorders (ASD), and communication instruction.

## Data Sources

The search began by selecting two major databases through the University of Central Florida Library System and included Ebscohost: ERIC and PsychINFO.

## Search Procedures and Study Selection

Searches were conducted using the following search terms: (a) robotics and early childhood education/early intervention; (b) robotics and autism/Autism Spectrum Disorders; and (c) robotics and communication skills. The table presents the total number of articles located in the two phases of the search. The number of articles initially retrieved from the electronic search is presented in the first column, "Initial." This pool of articles was screened to eliminate those that were duplicated from another search engine or did not meet the criteria listed above. After the initial and hand-coding phase, a total of 23 articles met the criteria for inclusion in the review.

## Results

A systematic literature review was conducted to identify existing literature designed to examine the use of robotics with early childhood learners, the use of robotics with students with ASD, and the use of robotics to teach communication skills.

Table 2

Systematic Review of Literature Results

| Database | Robotics and ECE | | Robotics and ASD | | Robotics and Communication Skills | |
|---|---|---|---|---|---|---|
| | ERIC | PsychINFO | ERIC | PsychINFO | ERIC | PsychINFO |
| Phase 1: Initial Search | 27 | 3 | 13 | 44 | 3 | 3 |
| Phase 2: Excluded duplicates and studies not in English | 28 | | 47 | | 4 | |
| Phase 3: Excluded studies that were not empirical or did not involve an intervention | 12 | | 25 | | 2 | |
| Phase 4: Excluded studies that did not have students as participants | 10 | | 22 | | 2 | |
| Phase 5: Moved studies that were coded under wrong age group/category or fit under multiple categories | 9 | | 4 | | 2 | |
| | 10 (Robotics, ASD, and communication skills) | | | | | |
| | 1 (Robotics, ECE, and ASD) | | | | | |
| | 8 (Robotics, ECE, ASD, and communication skills) | | | | | |

## Study Selection

Five levels of searches were conducted. Phase 1 of the search included entry of key search terms in multiple search fields and Phase 2 involved removing any studies that were duplicates from other databases. In Phase 3, the researcher removed the studies that were not empirical or were not intervention studies. Phase 4 involved removing any studies that did not have children or students as the primary study participants. Phase 5 involved shifting or re-categorizing any studies that were miscoded. A summary of results is provided in Table 2.

## Results of Individual Studies

### Robotics and Early Childhood Education

Research on robotics and early childhood education has focused on several subtopics including: robotics and sequencing skills, robotics and programming knowledge, gender differences, age differences, and user engagement (see Table 3).

#### Sequencing

Kazakoff, Sullivan, and Bers (2013) looked at the impact of a one-week intensive robotics workshop on the sequencing skills of pre-kindergarten and kindergarten students in an urban, STEM magnet school. Again, the researchers used a picture sequencing assessment as a pre- and posttest. The results show that both the pre-kindergarten and kindergarten students who had received the intensive robotics intervention As a follow-up to the previous study, Kazakoff, Sullivan, and Bers (2013) looked at the impact of a one-week intensive robotics workshop on the sequencing skills of pre-kindergarten and kindergarten students in an urban STEM magnet school. Again, the researchers used a picture sequencing assessment as a pre- and post-test. The results show that both the pre-kindergarten and kindergarten students who had received the intensive robotics intervention displayed statistically significant differences in sequencing abilities from pre- to post-test while the students in the control group did not. Collectively, this research supports further exploration of the use of robot-based interventions in teaching academic skills to young students.

Kazakoff and Bers (2014) also looked at the effect of three, 1.5 hour sessions on the sequencing skills of 4.5 to 6.5 year old students. The researchers assessed all of the participants' sequencing skills before and after the intervention. They found that there was a statistically significant difference between pre- and post-test scores therefore supporting the concept that there is inherent value in exposing young learners to robotics and teaching basic programming skills at an early age.

### Programming Knowledge

Strawhacker and Bers (2015) compared the programming knowledge of kindergarteners after a 9-week robotics curriculum. Each group of students was exposed to a different teaching condition within the same robotics curriculum: (a) tangible condition, (b) graphical condition, and (c) hybrid condition. The researchers did not find a significant difference in student outcomes among the groups.

### Gender Differences

There is some initial or exploratory research on the impact of a robotics curriculum on the programming knowledge of early childhood learners. Sullivan and Bers (2013) used a group design to assess the differences in programming knowledge of kindergarten-age boys and girls following a 20-hour robotics curriculum. The curriculum was implemented in three kindergarten classrooms with 53 participants. The researchers concluded that both boys and girls were able to access and complete the curriculum and final project. Boys and girls scored comparably in all areas assessed with the exception of two areas in which boys scored higher: (a) properly attaching robotics materials and (b) programming with "ifs." While ASD occurs more frequently in males, this study supports the idea that robotics-based interventions may be effective with both boys and girls.

In a follow-up study, Sullivan and Bers (2016a) implemented the KIWI Robotics curriculum once a week for eight weeks with students in kindergarten through second grade. The researchers looked at student performance, across grade levels and genders, on beginner and advanced programming tasks. Additionally, they probed any preconceived notions or stereotypes that the students had about technology and engineering tools. The researchers found that boys and girls performed equally well on beginner programming tasks but boys performed significantly better on advanced programming tasks. They also concluded that children in kindergarten through second grade were already beginning to form ideas and opinions about which technologies and engineering materials or tools would be better suited for boys and girls.

### Age Differences

Also in 2016, Sullivan and Bers looked at the impact of a robotics curriculum on the robotics and programming knowledge of early childhood learners. In this study, the researchers administered an 8-week robotics curriculum to 60 students ranging from pre-kindergarten to second grade. The researchers used the Robot Parts test to assess robotics knowledge and the Solve-Its task to assess programming knowledge. They found that pre-kindergarten students were able to master basic skills in this time frame, while older students were able to master more complex skills or understand more complex concepts in the same time frame. This study supports the notion of "developmentally appropriate design of technology" (p. 3).

Elkin, Sullivan, and Bers (2016) implemented the 9-hour KIBO Robotics Kit in seven preschool classrooms. Results indicated that children as young as three could create syntactically correct programs for the KIBO robot using wooden blocks, but older preschoolers performed better on standardized programming tasks. The researchers also noted that, on the whole, some components of the curriculum were appropriate for older students (closer to age 5) and not for younger students (age 3). This suggests that younger students may need modifications to the existing curriculum in order to participate meaningfully.

A small number of researchers have focused on early childhood learners' experiences and engagement with robots. Han, Jo, Hyun, and So (2015) examined the satisfaction (e.g., interest in dramatic play), sensory immersion (e.g., interactive engagement), and media recognition (e.g., empathy with media) of 81 five to six year-old students in a kindergarten afterschool program in Korea. The goal of the study was to compare these variables when the participants were exposed to computer-mediated augmented reality (AR) and robot-mediated AR. The researchers found that children in the robot-mediated condition showed greater interest in dramatic play, interactive engagement, and empathy with media. Additionally, the researchers concluded that younger participants had more positive perceptions of AR-infused play than older participants. These results support further exploration of robot-mediated interventions for young children.

### User Engagement

Hsiao, Chang, Lin, and Hsu, (2015) compared the reading performance of two groups of Pre-K students in Taiwan. One group had access to a tablet during reading instruction and the other group had access to a robot learning companion (RLC). The researchers found a statistically significant difference between the groups on both literacy skills and learning behaviors. The group that had access to the RLC showed an increase in motivation which led to improved performance.

Robotics and Children with ASD

Costescu, Vanderborght, and David (2015) assessed cognitive flexibility, engagement, and positive affect in 40 typically developing children (ages 4 to 7 years old) and 41 children with ASD (ages 4 to 13 years old) during a reversal-learning task. The participants were given a rule-based task in both a robot condition and a human condition. After the rules were learned, the researchers changed the rules and asked the participants to complete the task again. The order of the sessions was counterbalanced to control for sequence effects. The researchers found that the participants with ASD were more engaged and demonstrated more positive affect during the robot condition than the human condition. Additionally, the participants with ASD learned the rules better in the human condition, but demonstrated similar cognitive flexibility in the robot and human conditions.

Costa, Lehmann, Dautenhahn, and Robins (2015) used a humanoid robot with 6 to 9 year old children with ASD to teach body awareness and appropriate physical contact. The robot was equipped with sensors that were able to distinguish between gentle and harsh touch and was programmed to respond accordingly via facial expressions and gestures. The researchers found that the students performed more gentle touches as the sessions progressed but there was not a significant difference in knowledge of body parts from pre- to post-test most likely because a majority of the students were able to identify body parts during the pretest.

Giannopulu, Montreynaud, & Wantanabe (2016) conducted a study on 32 students with and without ASD who were classified as being at the 6 to 7 year old developmental level. The researchers compared the participants' heart rate, frequency of spoken nouns and verbs, and intensity of emotional feeling across robot and human conditions. The participants with ASD had a lower heart rate than their developmental peers during the human condition but comparable heart rates during the robot condition. Additionally, the participants with ASD used more nouns and verbs in the robot condition and also experienced a more intense emotional feeling.

Giannopulu and Pradel (2010) conducted an exploratory, post-test only single group design with four children between the ages of 7-9 years old. The researchers introduced a mobile toy robot into 5 min sessions with the participants and measured the amount of time that the children engaged with the robot. On average, the participants spent more than 79% of their time with the robot.

Robotics and Teaching Communication Skills

Two intervention studies that target communication skills using robot-mediated or robotics interventions is very limited (see Table 5). Skorinko and Doyle (2012) looked at the impact of explicit goal setting around social skills on the social skills outcomes of 215 students between the ages of 13 and 18 who participated in an afterschool FIRST Robotics Program. They found that priming a social goal did positively impact the social skills of this population.

Wang and colleagues (2012) examined the impact of tangible learning robots on the English speaking skills of 63 Taiwanese fifth graders. Specifically, the researchers were looking at how the presence of the tangible learning robots impacted the speaking speed and pronunciation for students in the treatment group. The results reveal that using the tangible learning robots positive effects on learners' motivation, confidence and engagement especially for the lower-achieving students. Additionally, both students and teachers had positive perceptions about the robot and the outcomes for students who interacted with the robot.

## Robotics and Teaching Communication Skills to Students with ASD

Several studies involved teaching communication skills to school age students with ASD (see Table 6). Robotics and surrogate avatars have the potential to transform the way the students with ASD learn social and communication skills ranging from imitation to collaboration with peers. The addition of avatars and robots as models or interventionists for basic social-communication behaviors could change the way that evidence-based practices (EBP) like discrete trial training (DTT) are implemented in schools and home programs. By using avatars and robots for this purpose, teachers would be able to customize the instruction for social-communication behaviors and it would allow for greater independence, which is widely recognized as a concern for students with ASD.

### Joint Attention

Joint attention is considered to be a fundamental building block for social-communication skills and plays a significant role in language and social skills development. Anzalone and colleagues (2014) compared the joint attention skills of children with ASD and typically developing children in both robot and human conditions. There were 32 participants in this study, 16 with ASD (mean age = 9.25 years) and 16 typically developing children (mean age = 8.06 years). Participants in each group were matched on developmental age and sex. The researchers compared the responses of each participant when a joint attention task was cued by a small humanoid robot to the responses of each participant when cued by a human therapist. The results indicated that both groups of students performed better on the joint attention task with the human therapist. The participants with ASD had significantly lower scores than their typically developing counterparts when interacting with the humanoid robot.

Verbal Communication

Several researchers have looked at robot-based interventions to teach verbal communication skills to learners with ASD. Kim, Berkovits, Bernier, and Leyzberg (2013) compared the verbal utterances of 24 children with ASD (ages 4 to 12 years old) across three conditions: dinosaur robot, human, and touchscreen computer game. The researchers also collected data on the frequency of the utterances and the intended communication partner. Each of the three sessions lasted 6 mins and was presented to each participant in random order. The researchers found that the participants engaged in more verbal utterances with the robot than with the human or the touch screen computer game. Additionally, the social robot elicited verbal utterances that were directed at the robot but also at a human confederate. The researchers concluded that, "the robot best motivates and facilitates an ecologically useful social behavior – interaction with another person – not just social interaction with objects" (p. 1046).

Srinivasan and colleagues (2015, 2016a, 2016b) compared three interventions and their impact on the verbal communication skills of 36 students (ages 5 to 12) with ASD. The researchers looked at traditional instruction, rhythm and movement-based instruction, and robotics-based instruction and concluded that while the participants in the traditional instruction condition had higher levels of social verbalization at the beginning of the study, the participants in the rhythm and robot conditions showed greater increases in social verbalization over the course of the intervention window.

Huskens, Verschuur, Gillesen, Didden, and Barakova (2013) used a multiple baseline across participants design to look at the impact of human and robot-delivered ABA-based interventions on the frequency of self-initiated questions in six children, ages 8-14 years old, with ASD. The researchers divided the participants into two groups. After baseline data were collected on both groups, Group 1 received four, 10-min sessions of the robot-mediated intervention while Group 2 received four, 10-min sessions of the human-mediated intervention. Each group returned to baseline and then the treatments were reversed. The researchers concluded that both the human and robot conditions resulted in significant improvements in the self-initiated question asking of the participants. They were not able to establish whether this ABA-based intervention was more effective when delivered by a human or robot.

The same research group used a similar study design to look at the impact of a robot-mediated intervention on the interaction initiations, responses, and "play togethers" of 3 pairs of children (Huskens, Palmen, & Van der Werff, 2015). Each pair consisted of one child with ASD and their typically developing sibling. The participants engaged in a 30-min session with the robot every week for five consecutive weeks. The researchers found that there were no statistically significant changes in the three target behaviors for the participants with ASD. However, two out of three pairs of children showed an increase in overall responses during the robot-mediated intervention when compared to the baseline condition.

Collaboration and Social Skills

Barakova, Bajracharya, Willemsen, Lourens, and Huskens (2015), examined the effect of a brief robot-mediated intervention based on Lego therapy on the collaborative behaviors of six participants with ASD or Pervasive Development Disorder – Not Otherwise Specified (PDD-NOS) using a multiple baseline across pairs design. The participants were all male students between the ages of 8 and 12 years old. While there was significant variability in responses across participants and pairs, the researchers did conclude that the participants preferred attention from the robot when compared to the baseline condition.

Vanderborght and colleagues (2012) used a counter-balanced single-case design to compare the effects of social stories delivered in a traditional manner and social stories plus robot-assisted therapy (RAT) on the level of prompting required for participants to engage in a target behavior presented in a social story. There were four participants in this study all between the ages of 4 and 9 years old with ASD, two male and two female. Each participant was exposed to eight sessions with traditional social story delivery and six sessions with a social story plus RAT. The researchers found that social stories plus RAT had a stronger effect on decreasing the level of prompting when compared to baseline and social stories delivered alone.

Similarly, Pop, Simut, & Pintea (2013) used a quasi-experimental group design to compare the effects of robot-assisted social stories and computer-presented social stories on the level of prompting required for participants to engage in a target behavior presented in a social story. Target behaviors included eye gaze, greeting, asking questions, and asking for help. There were 20 participants, ages 4-9 years old. Again, the researchers found that social stories delivered with the assistance of the robot decreased the prompt level and increased the independence in expressing the target social abilities.

## Robotics and Teaching Communication Skills to Young Children with ASD

Five studies focused on using robots to teach social-communication skills to early learners with ASD. The research that intersects these domains falls into three categories: (1) joint attention, (2) imitation and physical interaction, and (3) play and social skills (see Table 7).

### Joint Attention and Pre-Linguistic Communication Skills

Bekele and colleagues (2014) conducted a feasibility study involving a humanoid robot that cues joint attention and then provides self-adjusting prompts according to a pre-determined least-to-most prompt hierarchy. The researchers used a group of 6 preschool students with ASD as the treatment group and a group of 6 typically developing preschool students as the control group for this study. Each group was exposed to joint attention tasks presented by both a human and the robot. The researchers concluded that participants in both groups required a higher level of prompting to orient to the robot than the human, but attended longer to the task during robot-administered trials.

Warren and colleagues (2015) also examined the impact of a robot-mediated intervention on the joint attention of early childhood learners with ASD. The researchers used a sample of six students (mean age = 3.46 years), eye-tracking software, and target monitors to determine whether or not participant performance was improving. They determined that not only did every participant demonstrate an improvement in joint attention as measured by target hit rate, but they also sustained attention to and engagement with the robot indicating that the novelty effect of the intervention did not wear off.

Tapus and colleagues (2012) used a single-case design (ABAC) to compare the effects of an intervention delivered by a human and a humanoid robot on the frequency of initiations, frequency of eye gaze shifting, duration of eye gaze, and duration of smile or laughter. The participants in this study were five children with ASD between the ages of 2 and 6 years old. The researchers found that the children’s responses to the humanoid robot were highly variable and difficult to categorize.

Similarly, Wainer, Dautenhahn, Robins, and Amirabdollahian (2014) used a single-case design to compare the effects of an intervention delivered by a human and a robot on the gaze, gaze shift, and positive affect of six participants with ASD between the ages of 6 and 8 years old.

The researchers concluded that the participants displayed more positive affect during robot sessions, but did not collaborate more or better during robot sessions.

Peca, Simut, Pintea, and Vanderborght (2015) used a two-way mixed factorial research design to evaluate the impact of the type of interaction partner and the type of interaction on the eye gaze, positive affect, initiations, and testing behaviors on 27 children with ASD or PDD-NOS between the ages of 4 and 8 years old. The interaction partners were robots and humans and the interaction types were contingent and non-contingent. The researchers found that the participants demonstrated more frequent eye gaze and more testing behaviors with the robot partner.

Imitation and Physical Interaction

Pop and colleagues (2013) used a single-case design to examine the impact of a robot-mediated intervention on the frequency of imitation gestures, physical interaction, and attention of two children with ASD (5 and 6 years old). The researchers found that while the robot did not increase the frequency of imitation when compared to baseline (i.e., human interventionist), it did increase physical interaction and attention in these students. In a second study, Pop and colleagues (2014) used a group design to compare the play and social skills of 4-7 year old students with ASD ($n$ = 11) in role-play activities with a human and robot. The researchers found that the participants exhibited more collaborative play, showed more engagement, and demonstrated less stereotypic behaviors in the robot condition than in the human condition.

Play and Social Skills

Pop, Pintea, Vanderborght, and David (2014) looked at the impact of "doctor role play" with a human patient and a robot patient on the play skills, engagement in play, and social skills of 4 to 7 year old children with ASD who had an IQ greater than 70 but minimal verbal abilities.

In this study, the child was asked to play the doctor role and was charged with helping the patient feel better. The researchers found that while there was not a statistically significant difference in play skills between the two groups, the participants with ASD engaged in more collaborative play and demonstrated fewer stereotypic behaviors with the robot as the play partner than with the human as the play partner.

Simut, Vanderfaeillie, Peca, Van de Perre, and Vanderborght (2016) employed a repeated measures group design to compare the social skills (e.g., detecting a preference, eye contact, initiating joint attention, verbal utterances) and asocial behaviors of 5 to 7 year old children with ASD in both robot-mediated and human-mediated conditions. Other inclusion criteria for participants included an IQ score greater than 70 and the ability to detect preferences in human partners with 80% accuracy or better. The researchers found that the only behavior that differed significantly across the two conditions was eye contact. The participants with ASD displayed more eye contact in the robot condition than in the human condition.

While there is limited research in this area, the researcher looked at the current funded projects though the National Institute for Health (NIH) and the National Science Foundation (NSF). Table 8 outlines the existing projects in this area.

Table 3

Summary of Literature on Robotics and Early Childhood Education

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Elkin et al. (2016) | 64 primarily low-income, Hispanic children | 3-5 years old | 64 | Post-test only single group design | IV: introductory robotics and programming curriculum<br>DV: Solve-it task | 9 hour curriculum | Descriptive statistics | Children, ages 3 to 5, were able to successfully master sequencing a syntactically correct program. |
| Han et al. (2015) | 48 male<br>33 female | 5-6 years old | 81 | Quasi-experimental group design | IV: Computer-mediated AR vs. robot-mediated AR<br>DV: Satisfaction, sensory immersion, and media recognition as measured by questionnaire | Session length: 1 hour | Descriptive statistics and independent t-tests | Participants in the robot-mediated condition showed greater interest in dramatic play, interactive engagement, and empathy with media. |
| Hsaio et al. (2015) | Enrolled in pre-K in Taipei and New Tapei | Pre-K | 57 | Quasi-experimental group design | IV: Tablet-PC vs. robot learning companion (RLC)<br>DV: Reading comprehension, storytelling ability, word recognition, and the retelling of stories | Twice week for 4 weeks<br><br>Session length: 40 mins | T-tests, Pearson correlation, and ANCOVA | There was a significant different in reading performance between the group that used a tablet-PC in reading instruction and the group that used an RLC. |

| Citation | Participants | Age/ Grade | $n$ | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Kazakoff et al. (2013) | Publicearly childhood magnet school | Pre-K to K | 27 | Quasi-experimental group design | IV: One week intensive robotics workshop<br>DV: Sequencing | 1 week intensive program | Dependent t tests | Pre-K and K students who participated in the intensive robotics intervention displayed statistically significant differences in sequencing abilities from pre- to post-test while the students in the control group did not. |
| Kazakoff & Bers (2014) | 68% males<br>32% females<br><br>29% PreK<br>71% K | 4.5 to 6.5 years old | 34 | Pre- and post-test single group design | IV: Computer programming activities with TangibleK program<br>DV: Sequencing skills | 3 sessions<br><br>Session length: 1.5 hours each | Paired samples *t*-test | There was a significant different in pre-test and post-test scores. |
| Strawhacker & Bers (2015) | Participants from 3 classrooms in urban, low-SES school | K | 35 | Mixed methods - quasi-experimental group design | IV: 3 different conditions within 9-week robotics curriculum: tangible condition, graphical condition, and hybrid condition<br>DV: Programming knowledge (Solve-It Tasks) | 12 days | Univariate ANOVA (midpoint assessment) and repeated measures ANOVA (midpoint and final assessments) | Results reveal little difference in scores across the three interface conditions. |

| Citation | Participants | Age/ Grade | $n$ | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Sullivan & Bers (2013) | 28 males<br>25 females | K | 53 | Quasi-experimental group design | IV: 20 hour TangibleK robotics curriculum<br>DV: Programming knowledge | 20 hours over six sessions | Pearson product-moment correlation coefficients | Curriculum is equally accessible to boys and girls. |
| Sullivan & Bers (2016a) | 15 Pre-K<br>18 K<br>16 1st grade<br>11 2nd grade | Pre-K to 2nd | 60 | Quasi-experimental group design | IV: 8-week robotics curriculum<br>DV: Robotics knowledge (Robot Parts Test) and programming knowledge (Solve-It Tasks) | Once a week for 8 weeks<br><br>Session length: 1 hour | Kruskal-Wallis H test | Pre-K children were able to master basic robotics and programming skills, while the older children were able to master increasingly complex programming skills. |
| Sullivan & Bers (2016b) | 18 K<br>16 1st grade<br>11 2nd grade | K to 2nd | 45 | Quasi-experimental group design | IV: 8-week KIWI robotics curriculum<br>DV: Robotics knowledge (Robot Parts Test) and programming knowledge (Solve-It Tasks) | Once a week for 8 weeks<br><br>Session length: 1 hour | Two-way ANOVA | Boys and girls performed equally well on beginner programming tasks but boys performed significantly better on advanced programming tasks. |

Table 4

Summary of Literature on Robotics and Autism Spectrum Disorders

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Costa et al. (2015) | All male, diagnosis of ASD reported by teacher | 6 -9 years old | 8 | Quasi-experimental group design | IV: Humanoid robot<br>DV: Body awareness and appropriate physical touch | Not specified | ANOVA | Participants performed more gentle touches with robots as the sessions progressed. |
| Costescu et al. (2015) | Students with ASD: 13 years old<br>TD students: 4-7 years old | 4-13 years old | 81 | Quasi-experimental group design | IV: Sessions with human and with robot (counterbalanced by participant)<br>DV: Errors, attentional engagement, and positive affect | Not specified | Pearson' s r<br>ANOVA | Children with ASD are more engaged in the task and they seem to enjoy more the task when interacting with the robot when compared with the adult. |

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Giannopulu et al. (2016) | 16 students with ASD 16 TD students | Develop -mental age of 6-7 years | 32 | Quasi-experimental group design | IV: Robot vs. human condition DV: heart rate, frequency of nouns and verbs, and intensity of emotional feeling | Session length: 15 mins | Chi square | For children with ASD, their heart rate was low during the human condition and similar to that of the TD group during the robot condition. The number of words expressed by and the emotional feeling experienced by the ASD group was higher in robot condition. |
| Giannopulu & Pradel (2010) | 3 male and one female student | 7-9 years old (mean 8.3 years) | 4 | Post-test only single group design | IV: Mobile toy robot DV: duration of child-robot interaction | Session length: 5 mins | N/A | The children spent more than 79% of their time with the robot. |

Table 5

Summary of Literature on Robotics and Communication Skills Instruction

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Skorinko & Doyle (2012) | 152 males and 99 females in FIRST Robotics | 13-18 years old | 251 | Quasi-experimental group design | IV: Length of time in program and mindset prime (academic focus, social focus, control)<br>DV: Academic self-efficacy, social connectedness, social skills, and competition | 3-4 months | Repeated measures ANOVA | Priming a social goal significantly influenced social outcomes |
| Wang et al. (2012) | 32 in treatment group, 31 in control group | $5^{th}$ grade | 63 | Quasi-experimental group design | IV: Tangible learning companion<br>DV: English speaking speed and pronunciation | Not specified. | Independent and dependent *t*-tests | There were significant differences between pre- and post-test scores for treatment group but not for control group. |

Table 6

Summary of Literature on Robotics and Communication Skills Instruction for Students with ASD

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Anzalone et al. (2014) | 16 with ASD 16 typically developing (TD) | Mean age for ASD = 9.25<br><br>Mean age for TD = 8.06 | 32 | Quasi-experimental group design | IV: Robot or therapist interactions DV: Joint attention | Not specified | Wilcoxon Mann Whitney rank sum test | Both groups of children performed well with the therapist, but with the robot the children with ASD had a significantly lower score than the TD children. |
| Barakova et al. (2015) | 6 male students with ASD or PDD-NOS | 8-12 years old | | Multiple baseline across pairs | IV: Brief robot-mediated intervention based on Lego therapy DV: collaborative behaviors | Baseline: 3-5 sessions Intervention: 5 sessions Post-intervention: 3 sessions | Qualitative and quantitative analysis | The participants preferred attention from the robot when compared to the baseline condition. |
| Huskens et al. (2013) | One individual in pair must have diagnosis of ASD | 5-13 years old | 6 (3 pairs) | Multiple baseline across pairs | IV: Robot-mediated intervention (Nao) DV: Interaction initiations, responses, “play togethers” | Five, 30 min sessions once a week | Visual analysis, descriptive statistics | All participants showed increase in initiations, most showed increase in responses, and “play togethers” decreased for all participants during treatment. |

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Huskens et al. (2015) | 3 children with ASD and their TD siblings | 5-11 years old | 6 (3 pairs) | Multiple baseline across pairs | IV: Robot-mediated intervention (Nao)<br>DV: Interaction initiations, responses, "play togethers" | Five, 30 min sessions once a week | Tau-U | There were no statistically significant changes in target behaviors for participants with ASD, but 2/3 pairs showed an increase in responses. |
| Kim et al. (2013) | 21 males and 3 females with ASD | 4-12 years old | 24 | Quasi-experimental group design | IV: Interactions with social dinosaur robot, human, and novel technology<br>DV: Frequency of utterances | Not specified | ANOVA, dependent t tests | Children with ASD engaged in more utterances when interacting with a robot than with a human or novel technology. |
| Pop et al. (2013) | 20 children with ASD | 4-9 years old | 20 | Quasi-experimental group design | IV: Robot-assisted social stories and computer-presented social stories<br>DV: Prompt level (verbal, gestural, physical) | Session length: 10-15 mins | Kruskal-Wallis | Social stories delivered with the help of the social robot Probo increased the independence in expressing social abilities of children with ASD. |

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Srinivasan et al. (2016a) | 32 male and 4 female students with ASD | 5-12 years old | 36 | Randomized control trial | IV: Rhythm and movement, robotics, or standard care<br>DV: Verbal communication skills | Four times a week for 8 weeks | Dependent t-tests and repeated measures ANOVA and ANCOVA | Rhythm group engaged in greater social attention than other groups. |
| Srinivasan et al. (2016b) | 32 male and 4 female students with ASD | 5-12 years old | 36 | Randomized control trial | IV: Rhythm and movement, robotics, or standard care<br>DV: Verbal communication skills | Four times a week for 8 weeks | Dependent t-tests and repeated measures ANOVA and ANCOVA | Children in the rhythm and robot groups increased levels of social verbalization over training sessions. |
| Srinivasan et al. (2015) | 32 male and 4 female students with ASD | 5-12 years old | 36 | Randomized control trial | IV: Rhythm and movement, robotics, or standard care<br>DV: Repetitive and maladaptive behaviors and affective states | Four times a week for 8 weeks<br><br>Session length: 45 mins | Repeated measures ANOVA | Participants in the robot group did not display sustained engagement due to the technical limitations of the robot. |
| Vanderborght et al. (2012) | 2 male and 2 female students with ASD | 4-9 years old | 4 | Single-case design (counterbalanced ABAC/ACAB) | IV: Social stories vs. social stories plus robot-assisted therapy (Probo)<br>DV: Level of prompting to perform social action from social story | 8 social story sessions (B)<br>6 social story plus robot-assisted therapy sessions (C) | Visual analysis and Mann-Whitney U | Social story plus robot-assisted instruction had a stronger effect on decreasing level of prompting when compared to social stories alone. |

Table 7

Summary of Literature on Robotics and Teaching Communication Skills to Young Children with ASD

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Bekele et al. (2016) | 6 Pre-K students with ASD<br>6 TD Pre-K students | Pre-K | 12 | Quasi-experimental group design | IV: Robot that cues joint attention and then provides self-adjusting prompts<br>DV: Joint attention | Single visit of 30-50 mins | t-tests | Participants in both groups attended longer to the task during robot trials. |
| Peca et al. (2015) | 18 children with ASD and 9 children with PDD-NOS<br>22 male<br>6 female | 4.5-8 years old | 27 | Two-way mixed factorial design | IV: type of interaction partner (robot/person) and type of interaction (contingent/non-contingent)<br>DV: eye gaze, positive affect, initiations, testing behaviors, tests per initiation | Session length: 80 s with 5 min pause in between | ANOVA<br>Mann-Whitney U | Participants demonstrated more frequent eye gaze and more testing behaviors with the robot partner. |
| Pop et al. (2013) | 2 students with ASD<br>1 male<br>1 female | 5-6 years old | 2 | Single-case design (ABAB) | IV: Presence of humanoid robot<br>DV: frequency of imitation gestures, physical interaction, and attention | Session length: 10 mins | Visual and statistical analysis | Imitation occurred less frequently in the presence of the robot, but physical interaction and attention increased. |

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Pop et al. (2014) | Students with ASD and IQ > 70 and minimal verbal ability<br><br>All male participants | 4-7 years old | 11 | Quasi-experimental group design | IV: Doctor role play with human and robot play partners<br>DV: Play skills, engagement in play, and social skills | Not specified | Mann-Whitney U | Participants with ASD engaged in more collaborative play and fewer stereotypic behaviors with the robot. |
| Simut et al. (2016) | Students with ASD and IQ > 70 | 5-7 years old | 30 | Repeated measures group design | IV: Robot vs. human condition<br>DV: Social skills and asocial behaviors | 7-10 days between conditions<br><br>Session length: 15 mins | Wilcoxon signed rank test<br><br>Mann-Whitney U | The participants with ASD displayed more eye contact in the robot condition than in the human condition. |
| Tapus et al. (2012) | 5 students with ASD | 2-6 years old | 5 | Single-case design (ABAC) | IV: robot vs. human person<br>DV: frequency of initiations and gaze shifting, duration of eye gaze and smile/laughter | 4 weeks, 2 intervention sessions per day | Visual and statistical analysis | The results across all four participants were mixed and suggest high variability in reactions to humanoid robot. |
| Wainer et al. (2014) | 6 children with ASD | 6-8 years old | 6 | Single-case design (ABAB) | IV: humanoid robot vs. human partner<br>DV: choosing, (un)successful shape selection, gaze and gaze shift, positive affect | Session length: up to 25 mins | Wilcoxon | Participants displayed more positive affect during robot sessions but did not collaborate more or better with the robot. |

| Citation | Participants | Age/ Grade | *n* | Design/Method | Variables | Duration | Analysis | Notable Results |
|---|---|---|---|---|---|---|---|---|
| Warren et al. (2015) | Students with ASD | Mean age = 3.46 | 6 | Repeated measures | IV: Robot-initiated joint attention intervention<br>DV: Joint attention | Four sessions over 2 weeks | Descriptive statistics<br><br>Wilcoxon signed rank test | Participants with ASD demonstrated improved joint attention and sustained interest in the robot across sessions. |

Table 8

Current Funded Projects on Robotics and Teaching Communication Skills to Young Children with ASD

| Funding Agency | Award Years | Name of Project | Summary |
|---|---|---|---|
| NIH | 2014-2015 | Transformative Co-Robotic Technology for Autism Intervention (Vanderbilt) | The researchers are investigating the realistic potential of robotic technology for young children with ASD via explicit design and tests of such a system to improve performance within the domain of early joint attention skills. |
| NSF | 2015-2017 | Individualized Adaptive Robot-Mediated Intervention Architecture for Autism (Vanderbilt) | Adapted robot-mediated intervention designed to create a highly flexible and adaptive intelligent environment to potentially advance early joint attention and imitation related skills for young children with ASD. |
| NIH | 2015-2017 | Developing an Automated Emotion Training System (VPI) | The researchers are developing a highly transportable, low-cost, and user-friendly technotherapy system that targets both facial emotion recognition and emotion expression. |
| NIH | 2013-2015 | Music-Based Interactive Robotic Orchestration for Children with ASD (GWU) | The researchers are developing a robotic architecture with music-based interactions to enhance the engagement of children with ASD in daily activities using musical stimuli. |
| NSF | 2014-2017 | EAGER: Studying Emotional Responses of Children with Autism in Interaction with Facially Expressive Social Robots (U of Denver) | This project explores several research questions including: (1) Do children with autism recognize facial expressions shown by an expressive robot similarly to typically developed (TD) children? (2) Should the robot use gestures and movement in conjunction with facial expression to better convey emotion to children with autism? |
| NSF | 2015-2017 | Integrating New Technologies to Assess Visual and Attentional Influences on Movement and Imitative Behavior in Autism (U of North Texas) | This project investigates visual, motor, and attentional processes in ASD and typical development to determine their relative contributions to accurate perception and action using virtual environments and human-robot interaction tasks that test visual and motor responses to motion and gesturing. |

### Synthesis of Results

The results of this systematic literature review reveal that there are three silos of literature: (a) robotics and early childhood education, (b) robotics and ASD, and (c) robotics and communication skills instruction. With regards to the body of research on the use of robotics with individuals with ASD, there are only a very small number of studies that focus on early childhood learners. More importantly, there are only six studies at the intersection of robotics, early childhood education, ASD, and social-communication skills.

All of the research on robotics and early childhood education utilizes quasi-experimental group designs with one study adding in a qualitative component. Similarly, two of the three existing studies on robotics and teaching communication skills use quasi-experimental group designs while only one of three studies uses a case study methodology. A wider variety of research designs and methods are represented in the literature on robotics and students with ASD.

## Discussion

### Summary of Evidence

The results of this systematic literature review support further investigation of the use of this technology as an instructional tool for early childhood learners (Han et al., 2015; Kazakoff et al., 2012; Kazakoff et al., 2013; Sullivan & Bers, 2013, 2016) and learners with ASD (Bekele, Crittendon, Swanson, Sarkar, & Warren, 2014; Pop et al., 2013; Simut, Vanderfaeillie, & Peca, 2016). Additionally, the initial findings from researchers who have used robots to teach social or communication skills are promising (Adams & Cook, 2014; Skorinko & Doyle, 2012a; Srinivasan, Lynch, Bubela, Gifford, & Bhat, 2013).

## Limitations

This systematic literature review has several limitations. At the article selection stage, some studies were characterized incorrectly (e.g., categorized as early intervention but not using an early childhood population). This limitation was controlled for during the hand-coding phases of study selection.

The results the literature review also have some limitations. First, only two studies looked at using robots to teach social-communication skills to early learners with ASD. Second, there are sampling and methodological issues with many of the studies. For example, some of the studies that compared students with ASD to typically developing students used significantly different age ranges for each group (Anzalone et al., 2014; Costescu et al., 2015). Third, female children with ASD were underrepresented in the research that included this population of learners.

## Conclusions

Students with ASD have deficits in social-communication skills that impact their ability fully participate in school and community-based activities and experiences. In the United States, individuals with ASD have the lowest rates of employment when compared to persons with other disabilities (Shattuck et al., 2012) and social skills deficits are frequently cited as barriers to improved employment outcomes (Burke et al., 2010; Cimera & Cowan, 2009). The total annual cost to society for supporting an individual with ASD across the lifetime is estimated at $3.2 million (Ganz, 2008). By improving critical social skills and, in turn, the individual’s ability to find and maintain employment, the cost to society could be significantly reduced.

At present, school-based social skills interventions are not meeting the needs of our students with ASD. The increase in number of students with ASD in schools combined with the use of ineffective interventions without research support have created a critical need for quality social skills instruction in schools for this population (Hess et al., 2008). Students are leaving the school system without the pivotal skills they need to obtain and maintain employment, live independently, and have meaningful interpersonal relationships in adulthood.

Some robots are specifically designed to deliver a social curriculum (Shick, 2013). Romibo is a robot that provides prompts and praise to facilitate social and academic skill development. Romibo is unique because while many robots and avatars used for this purpose are prohibitively expensive, this robot uses an open-source, customizable design, which allows for individualization across a heterogeneous population of learners. This study will contribute to theory and practice by building upon the existing but limited literature on the use of avatars and robotics to support the development of social-communication behaviors in early childhood learners.

# CHAPTER 3: METHODOLOGY

## Introduction/Statement of the Problem

The results of a systematic literature review support further investigation of the use of robots as an innovative technology for early childhood learners (Han et al., 2015; Kazakoff et al., 2012; Kazakoff et al., 2013; Sullivan & Bers, 2013, 2016) and learners with ASD (Bekele, Crittendon, Swanson, Sarkar, & Warren, 2014; Pop et al., 2013; Simut, Vanderfaeillie, & Peca, 2016). The existing research in each of these domains is limited and there are only two studies at the intersection of robotics, social-communication instruction, and early intervention for children with ASD. The purpose of this study is to address this void in the research and explore the impact of a robot-assisted social-communication intervention on the communication skills of three-year old students with ASD.

## Research Questions

Research Question 1: To what extent does social-communication instruction mediated through a surrogate interactive robot impact manding skills of preschool students (age 3) with ASD?

Research Question 2: To what extent does social-communication instruction mediated through a surrogate interactive robot impact tacting skills of preschool students (age 3) with ASD?

Research Question 3: To what extent does social-communication instruction mediated through a surrogate interactive robot impact intraverbal skills of preschool students (age 3) with ASD?

Research Question 4: To what extent do stakeholders find the goals, procedures, and outcomes of a social-communication intervention mediated through a surrogate interactive robot?

## Method

### Participants

The target population for this study was children who (a) are 3 years old, (b) are enrolled in a preschool program, (c) have a diagnosis of ASD, and (d) have an ASQ: SE-2 score over the cutoff range (see Table 9). Pseudonyms were used to protect the confidentiality of study participants. In order to gain more information about the participants' social-communication skills two questionnaires (i.e., demographics and Ages and Stages Questionnaire: Social-Emotional Second Edition) and one assessment (i.e., segments of the Verbal Behavior Milestones Assessment and Placement Program) were administered prior to the start of baseline data collection.

Table 9

ASQ:SE-2 Cutoff Scores by Age (in months)

| Participant | Age | Race/Ethnicity | Participant ASQ:SE Score *Cutoff score: 59 |
|---|---|---|---|
| Alex | 3 years, 9 months | White, Hispanic | 195 |
| Andrew | 3 years, 6 months | African American, non-Hispanic | 125 |
| Sam | 3 years, 4 months | White, Hispanic | 155 |
| Jeffrey | 3 years, 1 month | White, Hispanic | 110 |

Demographics Questionnaire

A brief survey of demographics and other basic information was completed prior to initiating baseline data collection (see Appendix C). Some of the items on this questionnaire include age, race/ethnicity, socio-economic status, diagnosis, number and ages of siblings, languages spoken in the home, school placement type (e.g., public, charter, private) and classroom placement type (e.g., inclusive, self-contained), information regarding frequency of interactions with other children and adults in the community, information regarding amount of time that parents read to the child, information regarding technology use in home and in school, and information regarding exposure to robots/robotics in home and in school.

Ages and Stages Questionnaire: Social-Emotional Second Edition (ASQ:SE-2)

The Ages and Stages Questionnaire: Social-Emotional Second Edition (ASQ:SE-2) was administered prior to the start of baseline data collection in order to gain more information about the social-communication skills of each participant. The ASQ:SE-2 is a parent- or caregiver-completed questionnaire that screens skills in the areas of self-regulation, compliance, social-communication, adaptive functioning, autonomy, affect, and interaction with people. The questionnaire comes with nine different forms and scoring sheets intended for children at 2, 6, 12, 18, 24, 30, 36, 48, and 60 months of age and has been normed from 0 to 72 months of age. All forms are available in both Spanish and English and take approximately 10-15 mins to complete. For the purposes of this study, the 33-41 month form was used.

Validity, reliability, and utility studies were conducted on ASQ:SE-2 between 2009 and 2011 to accurately determine the psychometric properties of the instrument. Normative studies included 14,074 children, ages 1 month up to 72 months. The results support the ability of ASQ:SE-2 to discriminate between children with social-emotional delays and those who appear to be developing typically in social-emotional areas (Squires, Bricker & Twombly, 2003).

Internal consistency, which measures relationships between questionnaire total scores and individual items, ranged from 71%–91% using Cronbach's alpha. Test-retest reliability, measured as the agreement between two ASQ:SE-2 questionnaires completed by parents at 1- to 3-week intervals, was 89%. Concurrent validity, as reported in percentage agreement between ASQ:SE-2 and concurrent measures, was calculated at 84% overall (range: 71% - 90%). Sensitivity, or the ability of the screening tool to identify those children with social-emotional disabilities, was calculated at 81% overall (Squires, Bricker & Twombly, 2003).

Verbal Behavior Milestones Assessment and Placement Program (VB-MAPP)

A portion of the VB-MAPP was administered prior to baseline data collection in order to obtain more information on the manding, tacting, and intraverbal skills of the participants. The VB-MAPP is a criterion-referenced assessment that has an accompanying curriculum guide and task analysis/skill tracking system. This assessment is designed for children with ASD related disorders characterized by language, communication, and social deficits. The VB-MAPP is based on Skinner's (1957) analysis of verbal behavior, established developmental milestones, and the principles of applied behavior analysis.

The VB-MAPP has five components including a milestones assessment, barriers assessment, transition assessment, task analysis and skills tracking, and placement and individualized education program (IEP) goals. Each of the skills in the VB-MAPP is developmentally appropriate, measurable, and is a comprehensive and balanced assessment of language skills. For the purposes of this study, only the milestones assessments for manding, tacting, and intraverbal skills were administered.

Construct validity and reliability for the intraverbal section of the VB-MAPP has been established (Sundberg & Sundberg, 2011). In this study, 110 children (39 typically developing and 71 with ASD) were assessed on an 80 item intraverbal subtest and the results of the two groups were compared. Reliability measures across both groups were calculated at 93%.

Participant Descriptions

Four participants were recruited for this study, which aligns with professional convention for studies that employ a multiple baseline design across participants (Gast, 2010; Horner, Swaminathan, Sugai, & Smolkowski, 2012; What Works Clearinghouse, 2014). The researcher visited two inclusive charter schools in a large city in the Southeast, provided a brief demonstration of the robot, and distributed flyers with details about the study to parents of children between the ages of 3 and 5 with a diagnosis of ASD. Parents expressed interest and children were screened to determine if they met the inclusion criteria for the study. Four participants were identified using this process.

Alex

Alex is a white, Hispanic male who lives with his mother and father who speak both English and Spanish in the home. He was 3 years, 9 months at the time of the study and had a ASQ:SE-2 score well over the cut-off range (i.e., 195). Alex was enrolled in a self-contained classroom designed for students with ASD within an inclusive charter school. Alex's mother indicated that he *sometimes* interacted with other children in school and *rarely* interacted with children in the community. She also noted that he *frequently* used a computer or tablet but had never interacted with a robot prior to this study.

Alex was also assessed using parts of the VB-MAPP, which utilizes a combination of direct testing, observation, and timed observation to assess the communication profile of learners with ASD and other communication related disorders. During the observations and testing sessions, Alex did not engage in any independent mands, tacts, or intraverbals using speech, sign, or augmentative and alternative communication (e.g., picture cards, communication boards). During one observation, Alex was working with a speech-language pathologist on manding and required full physical prompting to request a highly preferred item using a picture card. He did not engage in tacting or intraverbal communication even when provided with verbal, visual, and gestural cues from the teacher and other classroom staff.

Andrew

Andrew is an African American, non-Hispanic male who lives with both parents and one brother. English was the only language spoken in his home. He was 3 years, 6 months at the beginning of the study window and had an ASQ:SE-2 score over the cutoff range (i.e., 125). Andrew was enrolled in a self-contained classroom designed for students with ASD within an inclusive charter school. On the demographic questionnaire, Andrew's mother indicated that he *rarely* interacted with other children at school and in the community. She also responded that he *frequently* used a computer or tablet at home but had never interacted with a robot prior to this study.

Andrew was also assessed using parts of the VB-MAPP, which utilizes a combination of direct testing, observation, and timed observation to generate a language and communication profile. During observations and testing sessions, Andrew displayed a limited manding and tacting repertoire. He demonstrated the ability to emit two mands, but he required echoic or imitative prompts to do so. Similarly, he required echoic or imitative prompts to engage in tacting behavior. Andrew did not engage in any intraverbal behaviors during the baseline observations and testing sessions, but he did engage in classroom songs by clapping along with the teachers.

Sam

Sam is a white, Hispanic male who lives at home with both parents and one brother. English and Spanish are both spoken in the home. He was 3 years, 4 months at the start of the study window and had an ASQ: SE score over the cutoff range (i.e., 155). Sam was enrolled in a self-contained classroom designed for students with ASD within an inclusive charter school and had started transitioning to an inclusive classroom within the same school for the next school year.

Sam was also assessed using parts of the VB-MAPP, which utilizes a combination of direct testing, observation, and timed observation to generate a language and communication profile. During observations and testing sessions, Sam's manding and tacting patterns were variable. He was able to engage in manding and tacting behaviors with and without prompting (e.g., "What do you want?"). While Sam tended to tact preferred items in the classroom environment, he would also tact common objects that were used in routine activities such as circle time. Both his mands and tacts were almost exclusively 1-2 words and did not include carrier phrases (e.g., "I want___" or "That is a ____") or details (e.g., color, shape, or size). Sam's intraverbal skills included the ability to complete familiar fill-in-the-blank phrases, mostly in songs; answering the question, "What is your name?;" and answering a very limited number of who, what, and where questions.

Jeffrey

Jeffrey is a white, Hispanic male who lives with both parents. His mother notes that English, Spanish, and sign language are spoken in the home. Jeffrey was 3 years, 1 month at the beginning of the study window and had an ASQ:SE-2 score over the cutoff range (i.e., 110). On the demographic questionnaire, Jeffrey's mother indicated that he *sometimes* plays with other kids in school, but *rarely* plays with other kids in the community. She also noted that she *sometimes* reads to him at home, he *rarely* uses a computer or tablet, and he has never interacted with a robot.

Jeffrey was also assessed using parts of the VB-MAPP, which utilizes a combination of direct testing, observation, and timed observation. During the observations and testing sessions, Jeffery engaged in one prompted mand for "more," using sign language, when he was being pushed on a swing during recess. He did not engage in any independent tacts, or intraverbals using speech, sign, or augmentative and alternative communication (e.g., picture cards, communication boards). Jeffrey did show interest in communicating with both peers and adults in his environment, but did not have the necessary language and communication skills to engage with them in a functional way.

## Setting

### District

Participants for this study were recruited from a large school district in Central Florida. The district is comprised of 188 schools including 126 elementary schools, 35 middle schools, 4 K-8 schools, 19 high schools, and 4 schools dedicated to serving students with disabilities. The district serves over 200,000 students and families who speak 167 languages and represent about 200 countries. The student body is 40% Hispanic, 27% White, 26% Black, 5% Asian, and 2% multi-cultural. This study was conducted at two charter schools within this district. Both schools were a part of a larger charter school system consisting of seven schools serving students with and without disabilities in inclusive and self-contained classroom settings.

School A

School A served 344 total students in grades K-5. One hundred forty-seven of the enrolled students were in Pre-K and below. Additionally, 50% of the student body qualified for special education services. The demographic make-up of School is can be found in Table 11.

School B

School B served 206 total students in grades K-4. One hundred thirty-two of the enrolled students were in Pre-K and below. On this campus, 62% of the students qualified for special education services. The demographic make-up of School B can be found in Table 10.

Table 10

School Demographics

| Race/Ethnicity | School A | School B |
|---|---|---|
| White | 72% | 76% |
| Black | 23% | 13% |
| Native American | 0% | 0% |
| Asian | 1% | 3% |
| Pacific Islander | 0% | 1% |
| Multi-Racial | 4% | 7% |
| Hispanic | 69% | 45% |
| Non-Hispanic | 31% | 55% |

Classroom A

Classroom A was a self-contained preschool classroom designed specifically to meet the needs of students with ASD within School A (see Figure 2). The classroom was staffed with a teacher and two assistants and served eight students identified with developmental disabilities including ASD. The teacher in the classroom had a master's degree in Special Education and 20 years of experience. She had certifications in Pre-K/Primary Education, K-12 Special Education, Infant and Toddler Development, and ASD. The teacher and her assistants had been working together for about 13 years.

The room itself was divided into three sections: a play area, a circle/meeting area, and a table area. The play area was defined by two small shelves with toys and had soft mats for the students to sit on. The circle time/meeting area was defined by a large blue rug. The teacher had a flip chart near the wall that held materials for morning circle. When it was time for the students to move to the circle/meeting area, one of the assistants would move chairs onto the rug so the children could sit on them. In the table area, there were two tables and 8 student chairs. The tables were used for snack and meal times as well as for centers.

Classroom B

Classroom B was an inclusive preschool classroom within School B (see Figure 3). The classroom was staffed with a teacher and two assistants and served 12 students with and without disabilities. The teacher in Classroom B held a bachelor's degree in Early Childhood Education and Development and had 1.5 years of teaching experience. She was certified to teach students from birth to four years old and students with disabilities.

The room itself was divided into three sections: a play area, a circle/meeting area, and a table area. The play area was defined by a small rectangular rug and two shelves running along the wall and edge of the rug.  The circle/meeting area was defined by a large oval rug and an interactive screen where the teacher was able to project the images from a computer screen and play videos and songs during classroom activities.  When the students were participating in circle time, they sat in a circle around the outside of the rug.  In the table area, there were four tables arranged in a "T" formation with small chairs for the students.  The tables were used for snack and meal times as well as for centers and other seated classroom activities.

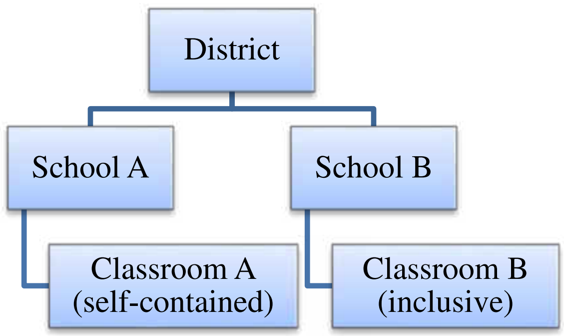


Figure 3. School and Classroom Organization Chart

Baseline Settings

Baseline data was collected in the classroom environment during regularly scheduled activities including breakfast, circle time, and recess.  The researcher observed the students from a non-intrusive location in order to obtain language samples that were representative of each participant's typical communication patterns.  Each baseline data collection session lasted 10-15 mins.

Intervention Settings

The intervention sessions with the interactive robot were conducted in a 1:1 setting with each student.  For students in Classroom A, intervention sessions were delivered at a small table in the classroom while other students were engaged in an activity in another area of the school (see Figure 4).

Figure 4. Intervention Area for Classroom A

For the student in Classroom B, a “bump-out” space in the hallway was used, as there were no small therapy or meeting rooms available in School B (see Figure 5).

Figure 5. Intervention Area for Classroom B

## Materials

<u>Surrogate Interactive Robot</u>

Figure 6. Romibo Robot

The surrogate interactive robot, Romibo (see Figure 6), is 12 inches tall, 9 inches wide, and 9 inches deep. Romibo is capable of moving around the intervention space on small wheels at the base of the body. An iPhone functions as the eyes of the robot and is able to track the participant using the camera feature. Romibo is also able to elicit verbal prompts and responses that are programmed into each palette in addition to spontaneous verbal speech that is entered in real time. Romibo's original design is to provide motivation and social therapy for individuals with conditions including ASD, traumatic brain injury, and dementia. The platform provides a fully customizable interface for facilitating instruction.


Figure 7. iPad Pro

<u>iPad and iPhone</u>

A 9.7-inch iPad Pro was used for the purposes of this study (see Figure 7). This device is 9.4 inches long, 6.6 inches wide, .24 inches deep, and weighs .96 lbs. The RomiboWeb app was installed on the device and then used to create the palettes that control where Romibo moves and what he says. The device connects to the iPhone via Bluetooth. The iPhone also functions as Romibo's eyes, which follow the user as they move around the intervention space.

Video Camera

A Canon Vixia HF R600 digital video camera equipped with a 64 GB memory card was used to record all intervention sessions.  The camera was positioned on a tripod in the corner of the intervention area.  At the end of each week of intervention sessions, the videos were downloaded off of the memory card and onto a password protected hard drive.

Communication Board

A communication board (see Figure 8) was created and available to all participants during the intervention.  This board was divided into eight cells with each cell containing a photographic image of a toy that was available.  During the tact intervention phase, a second communication board with six cells containing the colors red, orange, yellow, green, blue and purple (see Figure 9) was provided.  Finally, during the intraverbal intervention phase, a third communication board was introduced with six cells each containing an animal (see Figure 10).  These communication boards were used to give the participants who were non-verbal a vehicle with which to respond.

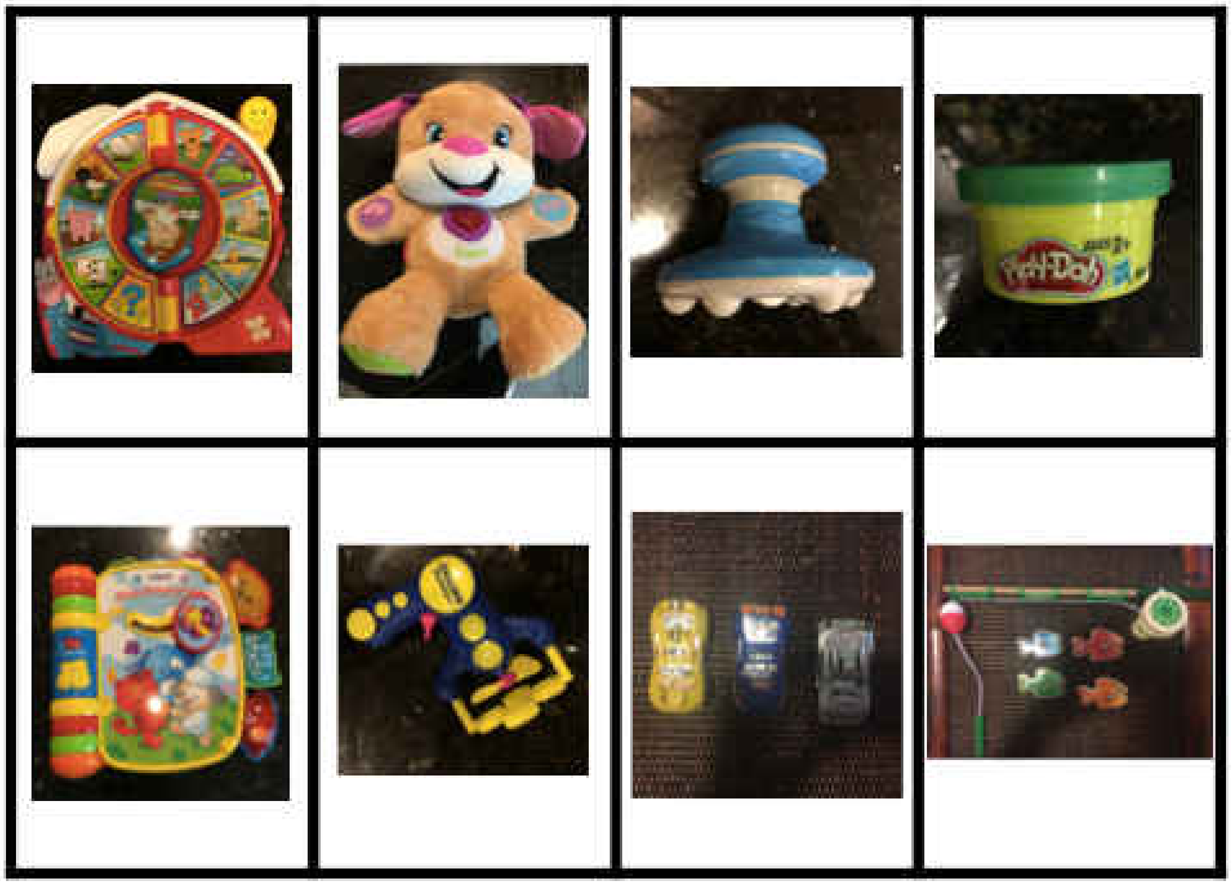

Figure 8. Communication Board (Preferred Objects)

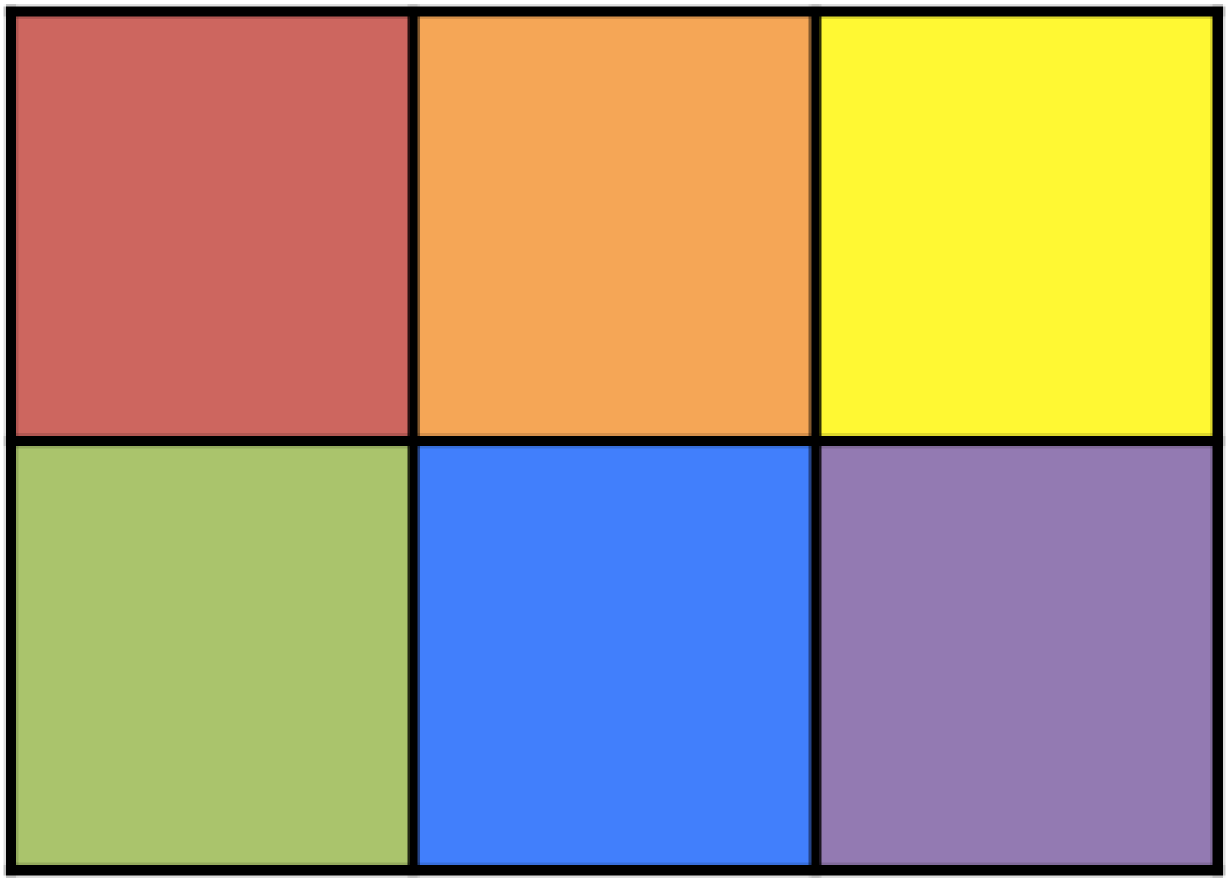

Figure 9. Communication Board (Colors)

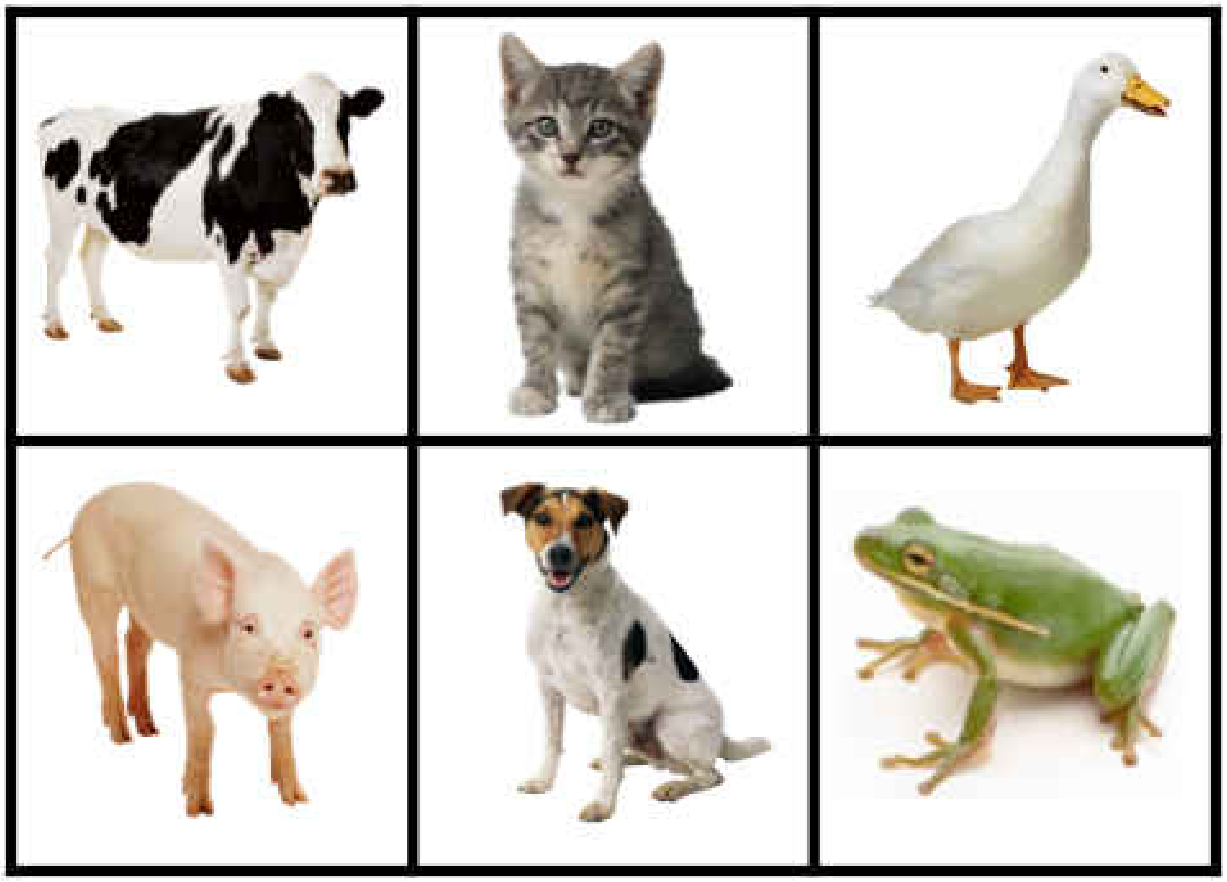

Figure 10. Communication Board (Animals)

Other Materials

The toys displayed on the choice board were available to all participants during all intervention sessions.

## Dependent Variable

### Response Definitions

The three target behaviors for this study are functionally independent, yet all three are social-communication behaviors (Gast, 2010). The target behaviors are: (a) mand, (b) tact, and (c) intraverbal.

Mand

A mand has occurred when the child asks for what he or she wants using verbal language, verbal approximation, or communication board. An individual can mand for an item, action, or activity and they can mand to remove or end an item, action, or activity. Mands can be used to request many things: desired items ("skittles"), information ("What's your name?"), assistance ("Can you help me?"), missing items (given a direction to cut out a shape but not given scissors, the child says "I want some scissors"), actions ("tickle me"); and negative reinforcement (when told to do something that's not preferred the student might ask "Can I take a break?").

Tact

When children are tacting they are labeling items, actions, and attributes in their environment (Sundberg, 2014). The individual must be in the presence of the non-verbal stimuli in order for the verbal behavior to be considered a tact. Some examples of tacts are as follows: saying "cookie" when you see a cookie; saying "cookie" when you smell a cookie; or, saying "cookie" when you taste a cookie. When we label actions or features of objects, we are also emitting tacts. We can also tact properties of our internal status such as labeling pain, fear, joy, and so forth. For the purposes of this study, a tact has occurred when the child labels something in the environment using verbal language, language approximation, or communication board.

Intraverbal

Intraverbals are a type of language where the child is responding to the language of others (Sundberg, 2014) and can include but is not limited to answering questions and filling in the blanks. Intraverbal behaviors allow the child to engage in conversations with others. Some examples of intraverbals are singing songs, answering factual questions, and filling in the blanks.

For the purposes of this study, an intraverbal has occurred when the child fills in or answers a question using verbal language, language approximation, or communication board.

## Measurement Procedures

Data was collected on all behaviors through the baseline and intervention phases and the rate (frequency/min) will be reported. The intervention was introduced when all behaviors showed acceptable pre-intervention stability in both level and trend. For the purposes of this study, pre-intervention stability was defined as all data points in baseline falling within a 20% range of the median level of all data-point values in this condition (Gast, 2010). After this criteria was met, the intervention was introduced for the first target behavior (i.e., mand). The set criterion (i.e., change in level and/or trend from baseline across 3 or more consecutive data points) was reached for that target behavior before the intervention was introduced for the second target behavior (i.e., tact) and subsequently the third target behavior (i.e., intraverbal).

## Experimental Design

A multiple baseline across behaviors design was used to measure the effect of the robot-assisted intervention on the social-communication skills of the students with ASD. The experimental conditions were baseline and the robot-assisted intervention for manding, tacting, and intraverbal skills. Once acceptable stability, level, and trend are achieved in the baseline condition, the robot-assisted intervention will be introduced to address manding while tacting and intraverbal skills will be held under the baseline conditions (Gast, 2010). After criterion-level responding is achieved for mands, the robot-assisted intervention will be applied to tacting.

Finally, after criterion-level responding is achieved for tacts, the intervention will be applied to intraverbal skills.

Benefits of this design are: (a) it allows for intra-subject replication which increases internal validity; (b) a return to baseline or withdrawal is not required to demonstrate experimental control; and (c) it provides a practical means for evaluating a social-communication intervention which would be inappropriate to reverse (Gast, 2010).

## Baseline Condition

Baseline data was collected to determine the frequency with which the participants display mand, tact, and intraverbal behaviors in the classroom environment. During each baseline probe, which lasted 10-15 mins, the teacher and/or teaching assistants would provide opportunities for each participant to engage in verbal behaviors during regular classroom activities. For example, during circle time the teacher would ask students to request and label materials such as the color and shape of the week and common object related to the weekly theme (e.g., sea creatures). They would also ask students to answer basic questions such as "What is your name?" and sing along with familiar songs. This study utilized a multiple baseline design across behaviors design and therefore the baseline phase for each condition contained a minimum of five data points (Kratchowill et al., 2010). The length of the baseline phase was extended if the rate of the target behavior was not stable.

## Robot-Assisted Instruction

The researcher implemented the intervention with each student 3-4 times per week. Each session lasted about 30 mins including transition time, greetings, and 10-15 mins of social-communication instruction with the surrogate interactive robot.  Researcher-created palettes were used to operate the robot during the intervention sessions.  Each palette had language specific to each target goal.  In addition, the researcher was able to type in an spontaneous language needed during the session.

Mand

During the mand intervention phase, the robot greeted the participant and then prompted them to request a preferred item (e.g., “”Let’s play” or “What do you want to play with?”).  If the participant requested an item, the robot delivered a praise statement and allowed the participant to engage with the item briefly before prompting them to make another request.  If the participant did not request an item, the robot provided additional prompts (e.g., verbal prompts such as “Show me what you want” or “Do you want play doh or book?”) until they made a request.  A sample manding palette can be found in Figure 11.

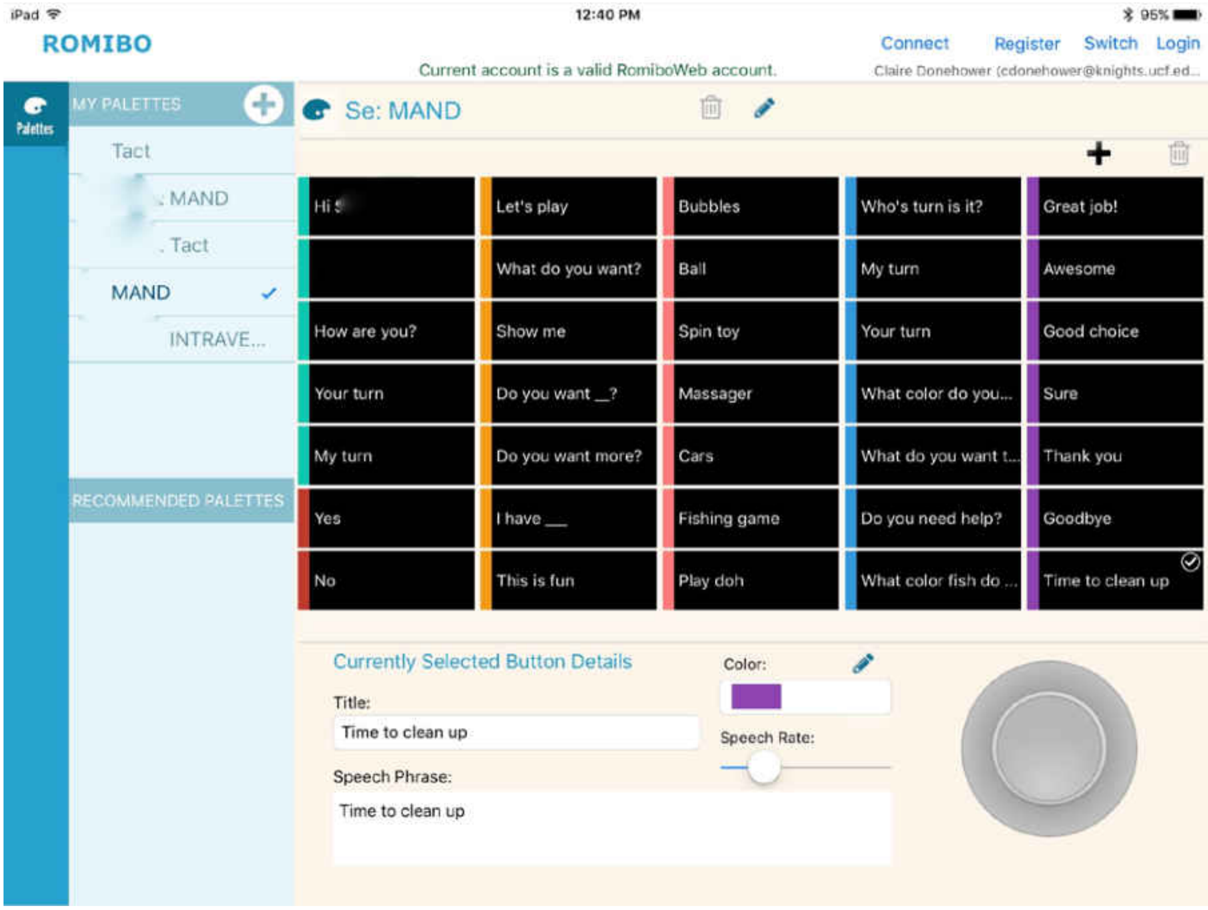


Figure 11. Sample Mand Palette

Tact

During the tact intervention phase, the robot greeted the participant and then prompted them to request a preferred item (e.g., "”Let's play" or "What do you want to play with?"). Once the participant requested an item, the robot delivered a mand-to-tact transfer prompt (e.g., "What is this?"). If the participant did not request an item, the robot provided additional prompts (e.g., verbal prompts such as "Show me what you want" or "Do you want play doh or book?") until they made a request. During the tact intervention sessions, the robot also prompted the participants to tact the color of preferred items (e.g., "What color is this?" or "Is this green or blue?"). A sample tacting palette can be found in Figure 12.

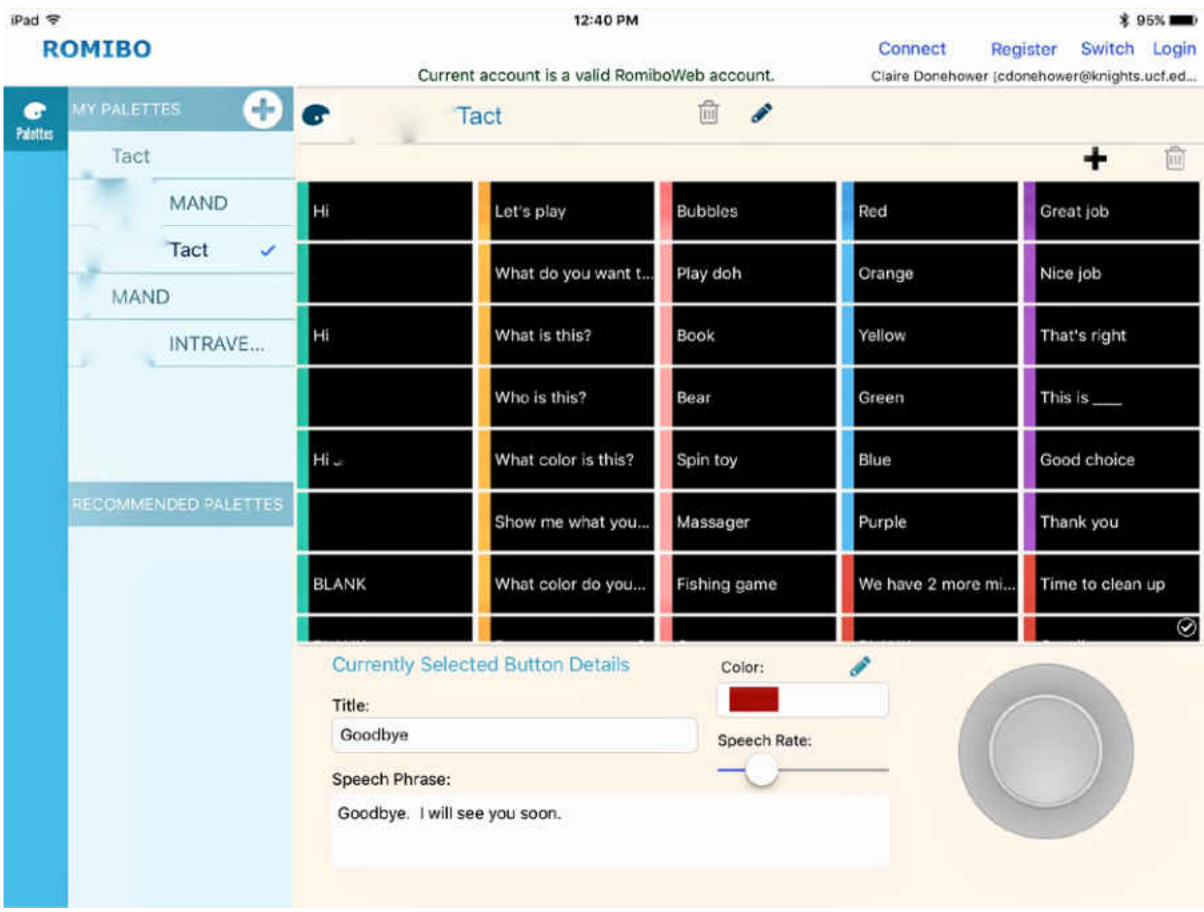


Figure 12. Sample Tact Palette

Intraverbal

During the intraverbal intervention phase, the robot greeted the participant and then prompted them to request a preferred item (e.g., “”Let’s play” or “What do you want to play with?”). Once the participant requested an item, the robot delivered a mand-to-tact transfer prompt (e.g., “What is this?”). If the participant did not request an item, the robot provided additional prompts (e.g., verbal prompts such as “Show me what you want” or “Do you want play doh or book?”) until they made a request. During the intraverbal intervention sessions, the robot also asked the participants simple “what” questions (e.g., “What animal says moo?” or “What animal says meow?”). A sample intraverbal palette can be found in Figure 13.

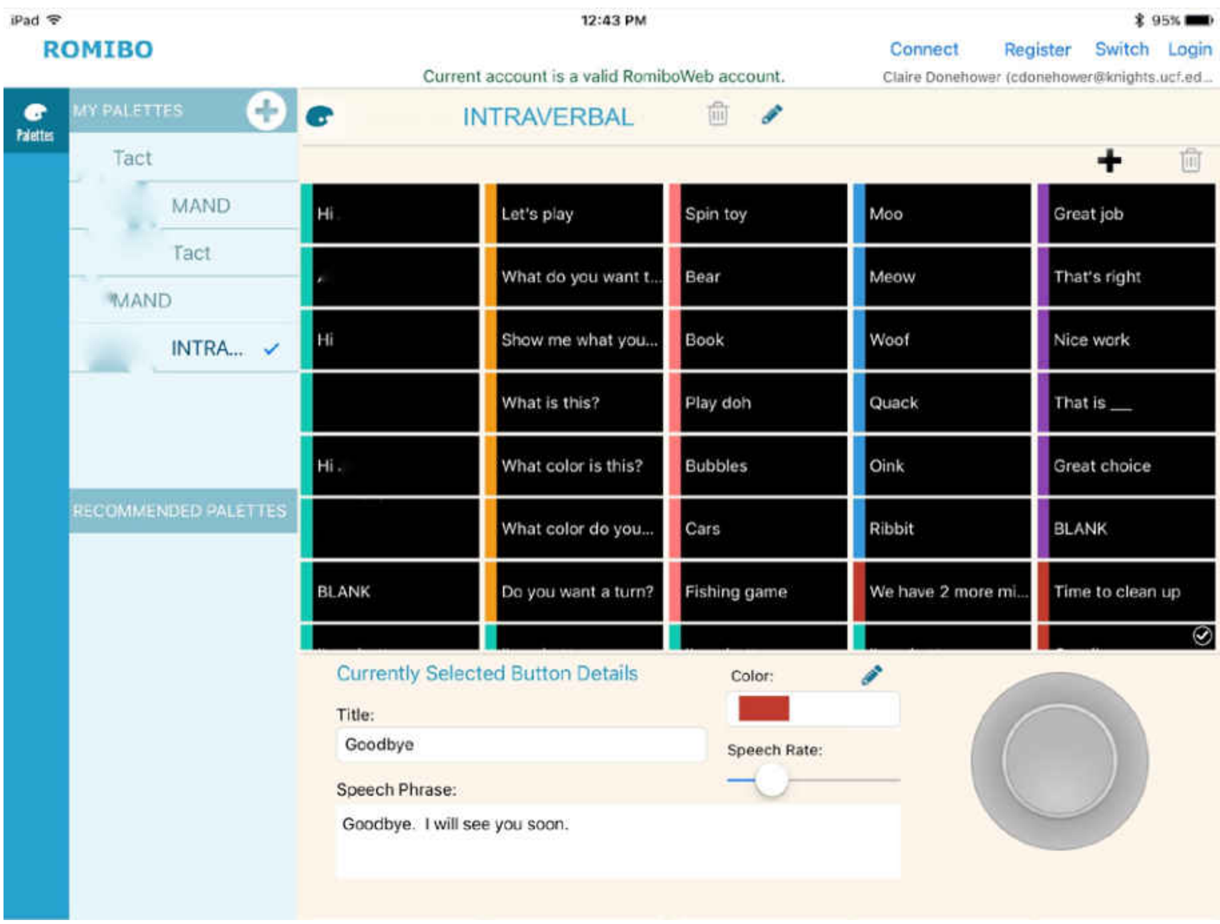


Figure 13. Sample Intraverbal Palette

## Procedural Fidelity

A rubric was developed to assess the implementation of the intervention (see Appendix H). An interobserver was identified and trained on the intervention and the scoring procedures for the rubric. The interobserver was a doctoral student with a bachelor's degree in Psychology and master's degree in Special Education of Severe Disabilities. She also had seven years experience as a 1:1 instructor for students, ages 1-18, with ASD and one year of experience as a behavior specialist in an inclusive elementary school setting. The interobserver was provided with training materials prior to the intervention phase, including the following: (a) a brief summary of the literature; (b) information regarding study methods; (c) a description of the intervention for all three target skills; and (d) the rubric and scoring procedures.

### Pre-study Treatment Fidelity Check

Prior to beginning the intervention phase, the researcher delivered the intervention for all three target skills in a role-play scenario. The interobserver scored the instructional delivery on the treatment fidelity rubric. The treatment fidelity rubric was broken down into three components: set-up and wrap-up, praise for target behavior, and robot vs. human interactions. The criteria for setting up and wrapping up each session was set at 100%, the criteria for the robot delivering praise statements for each occurrence of the target behavior was set at 80%, and the criteria for robot vs. human interactions was set at >50%. If the researcher met criteria during the first role-play, she was cleared to begin the intervention with participants. If the researcher did not meet criteria, she repeated the role-play until she did meet criteria.

### Treatment Fidelity Checks During Intervention Phase

In the intervention phase, an interobserver assessed the researcher's instructional delivery every 3 sessions (What Works Clearinghouse, 2014). If the researcher did not meet criteria for any of the components on the treatment fidelity rubric, she reviewed the rubric and repeated the role-play from the pre-study treatment fidelity check.

## Reliability

### Interobserver Agreement

One member of the research team coded all sessions and an independent rater coded 30% of the sessions, every third session, to calculate interobserver agreement (What Works Clearinghouse, 2014). Interobserver agreement (IOA) was calculated using a total agreement method. Both observers coded all three behaviors (i.e., mand, tact, and intraverbal) for all sessions and the frequency counts for the full sessions were compared. The lower frequency count was divided by the higher frequency count and then multiplied by 100.

## Social Validity

A social validity survey was given to all parents and teachers of the participants (see Appendix D). This survey evaluated the perceptions of the stakeholders related to the following: (a) the social desirability of the goals of the interventions, (b) the acceptability of the procedures used in each intervention, and (c) the importance or desirability of the outcomes of the intervention (Wolf, 1978). The survey is comprised of nine items ranked on a Likert scale (i.e., strongly disagree, disagree, neutral, agree, strongly agree) and is a modified version of the Treatment Evaluation Inventory – Short Form (Kazdin, 1980).

## Data Analysis Procedures

For studies that employ a single-subject design, it is typical for researchers to analyze the data using a combination of visual analysis techniques and descriptive statistics (Gall, Gall, & Borg, 2007). Visual analysis, descriptive statistics, and non-regression type effect size measures were used to interpret the data and answer the two research questions. Percent of non-overlapping data (PND) and Tau-U were used for this study and are both measures of effect size.

Visual analysis is the process by which researchers examine a graphical representation of data and attend to six features of the data including: (1) level, (2) trend, (3) variability, (4) immediacy of effect, (5) overlap, and (6) consistency of data patterns across similar phases (Fisher, Kelley, & Lomas, 2003; Kazdin, 1982; Kennedy, 2005; Kratchowill et al., 2010; Morgan & Morgan, 2009; Parsonson & Baer, 1978).

Percent of non-overlapping data represents the degree to which data points do not overlap between conditions. "The PND can range from 0 to 100; a PND greater than 90% reflects a highly effective treatment, a PND of 70-90% is considered a fair treatment outcome, and a PND of less than 50% indicates unreliable/ineffective intervention" (Gast, 2010, p. 441). Percent of non-overlapping data is calculated locating the highest point in the baseline phase, identifying the number of points in the intervention phase that fall above this point, and dividing this number by the total number of data points in the intervention phase (Parker, Vannest, & Davis, 2011).

Tau-U is a non-parametric measure of non-overlap and trend and has greater statistical power than other non-overlap measures (Parker, Vannest, & Davis, 2011). Tau-U scores are equivalent to non-overlap of all pairs (NAP) and range from 0-1. Scores from 0 to .65 are be interpreted as a small effect, .66 to .92 can be interpreted as a medium effect, and .93 to 1.0 can be interpreted as a large effect (Parker & Vannest, 2009). The Tau-U procedure also allows the researcher to control for an undesirable trend in the baseline phase. To calculate Tau-U, a web based calculator for single case research analysis, was used (Vannest, Parker, & Gonen, 2011).

# CHAPTER 4: RESULTS

## Overview of Data Analysis

The purpose of this study was to examine the impact of a robot-assisted social – communication intervention on the manding, tacting, and intraverbal skills of young learners with ASD. The study was designed to answer the following questions:

Research Question 1: To what extent does social-communication instruction mediated through a surrogate interactive robot impact manding skills of preschool students (age 3) with ASD?

Research Question 2: To what extent does social-communication instruction mediated through a surrogate interactive robot impact tacting skills of preschool students (age 3) with ASD?

Research Question 3: To what extent does social-communication instruction mediated through a surrogate interactive robot impact intraverbal skills of preschool students (age 3) with ASD?

Research Question 4: To what extent do stakeholders find the goals, procedures, and outcomes of a social-communication intervention mediated through a surrogate interactive robot?

Alex Results

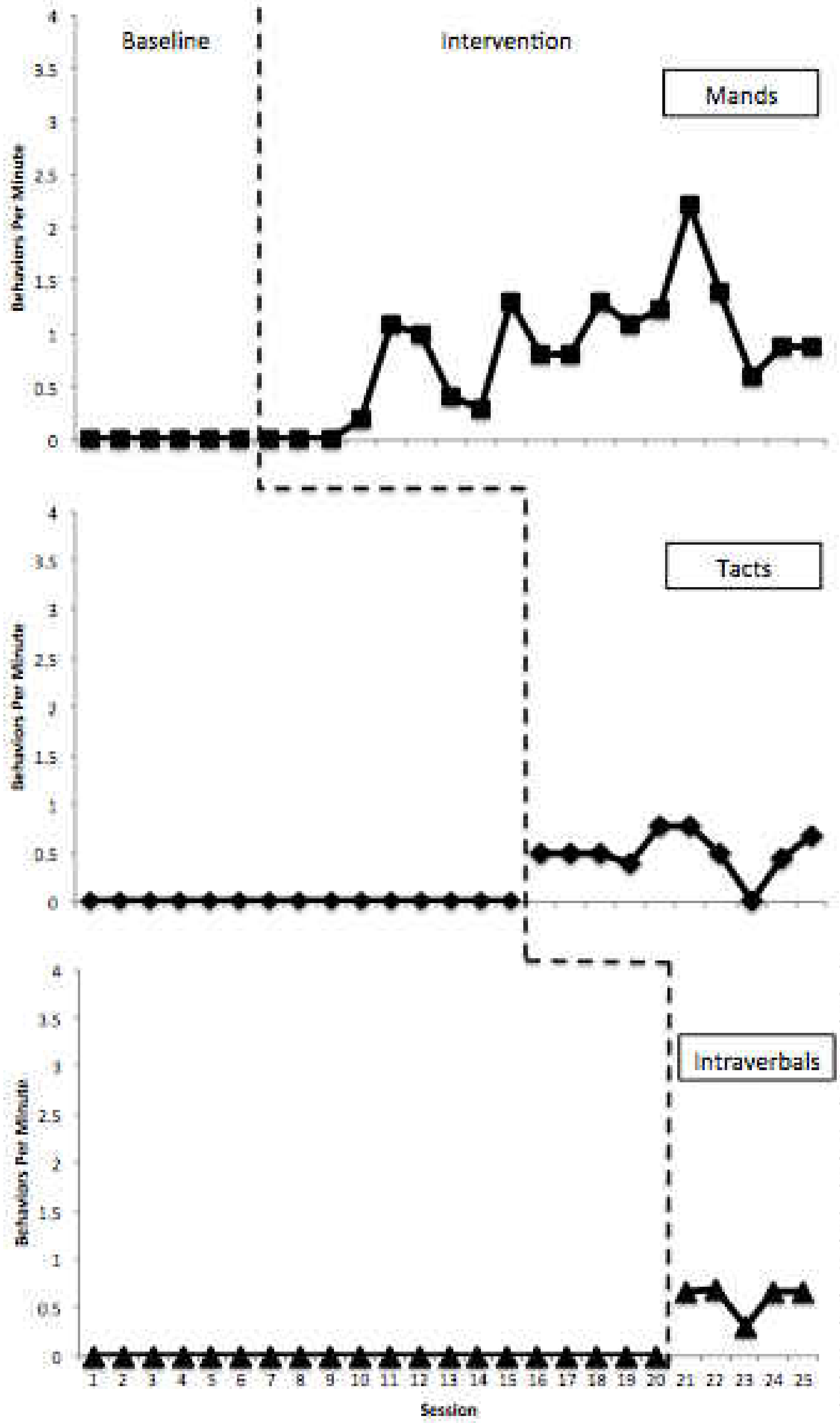


Figure 14. Alex Results

## Visual Analysis and Descriptive Statistics

A visual analysis of six features of the data including: (1) level, (2) trend, (3) variability, (4) immediacy of effect, (5) overlap, and (6) consistency of data patterns across similar phases (Fisher, Kelley, & Lomas, 2003; Kazdin, 1982; Kennedy, 2005; Kratchowill et al., 2010; Morgan & Morgan, 2009; Parsonson & Baer, 1978) was completed for the three target behaviors across all four participants.

### Level

Alex demonstrated zero rates of all three target behaviors prior to moving into intervention. All three behaviors increased during the intervention phase for that behavior. The mean level of each condition is shown in Table 11.

Table 11

Mean Level by Condition for Alex

| Behavior | Mean Level in Baseline | Mean Level in Intervention |
|---|---|---|
| Mand | 0 | 0.82 |
| Tact | 0 | 0.51 |
| Intraverbal | 0 | 0.60 |

### Trend

Alex demonstrated zero mands per minute (i.e., flat trend) during baseline, which shifted to an increasing trend in this behavior during intervention. With the other two target behaviors, tact and intraverbal, Alex demonstrated zero behaviors per min during baseline and flat trend in these during intervention.

Variability

For the purposes of this study, low variability will be defined as 80% of the data points in a given condition falling within 20% of the median. Moderate variability will be defined as 80% of the data points in a given condition falling within 20-50% of the median. Finally, high variability will be defined as 80% of the data points in a given condition falling over 50% of the median. There was no variability in the data for any of the target behaviors in the baseline condition for Alex. Once in the intervention phase, 80% of the data points for manding fell within a 78% range of the median, which represents high variability for this target behavior. Eighty percent of the data points for tacting fell within a 50% range of the median, which represents high variability for this target behavior. Finally, 80% of the data points for intraverbals fell within a 4% range of the median, which represents low variability for this target behavior.

Immediacy of Effect

Alex's manding skills were not immediately impacted by the intervention but his tacting and intraverbal skills were significantly different when comparing the last three data points in each baseline condition and the first three data points in each intervention condition (see Table 12).

Overlap

Percent of non-overlapping data was calculated by locating the highest point in the baseline phase, identifying the number of points in the intervention phase that fall above this point, and dividing this number by the total number of data points in the intervention phase (Parker, Vannest, & Davis, 2011). Alex's data reflected 100% PND for all three target behaviors.

Table 12

Immediacy of Effect by Condition for Alex

| Behavior | Last 3 Baseline Data Points | First 3 Intervention Data Points |
|---|---|---|
| Mand | 0, 0, 0 | 0, 0, 0 |
| Tact | 0, 0, 0 | 0.5, 0.5, 0.5 |
| Intraverbal | 0, 0, 0 | 0.67, 0.7, 0.3 |

<u>Consistency of Data Patterns</u>

All three target behaviors for Alex had no variability during baseline and increased in both level and variability as they were moved into the intervention phase.

## Measures of Effect Size

Percent of non-overlapping data was calculated during a visual analysis of the data but also serves as a measure of effect size. For single case design research, a PND greater than 90% indicates a large effect size (Gast, 2010) and in Alex's case, there was 84% PND for mands, 90% PND for tacts, and 100% PND for intraverbals.

Tau-U is a non-parametric, robust measure of non-overlap and was calculated for the three target behaviors across each participant. An analysis of the Tau-U results suggests medium to large effects for all target behaviors and the weighted average. The Tau-U for mand was .83, tact was .89, and intraverbal was 1.0.  The Tau-U result for the weighted average condition was .90, with 90% confidence intervals between .63 and 1. This result indicates that 90% of data showed improvement between baseline and intervention phases. Alex's results by behavior and an interpretation of the statistic can be found in Table 13.

Table 13

Tau-U Results for Alex

| Behaviors | Tau-U | Interpretation |
|---|---|---|
| Mand | 0.83 | Medium effect size |
| Tact | 0.89 | Medium effect size |
| Intraverbal | 1.0 | Large effect size |
| Weighted Average | 0.90 | Medium effect size |

Andrew Results

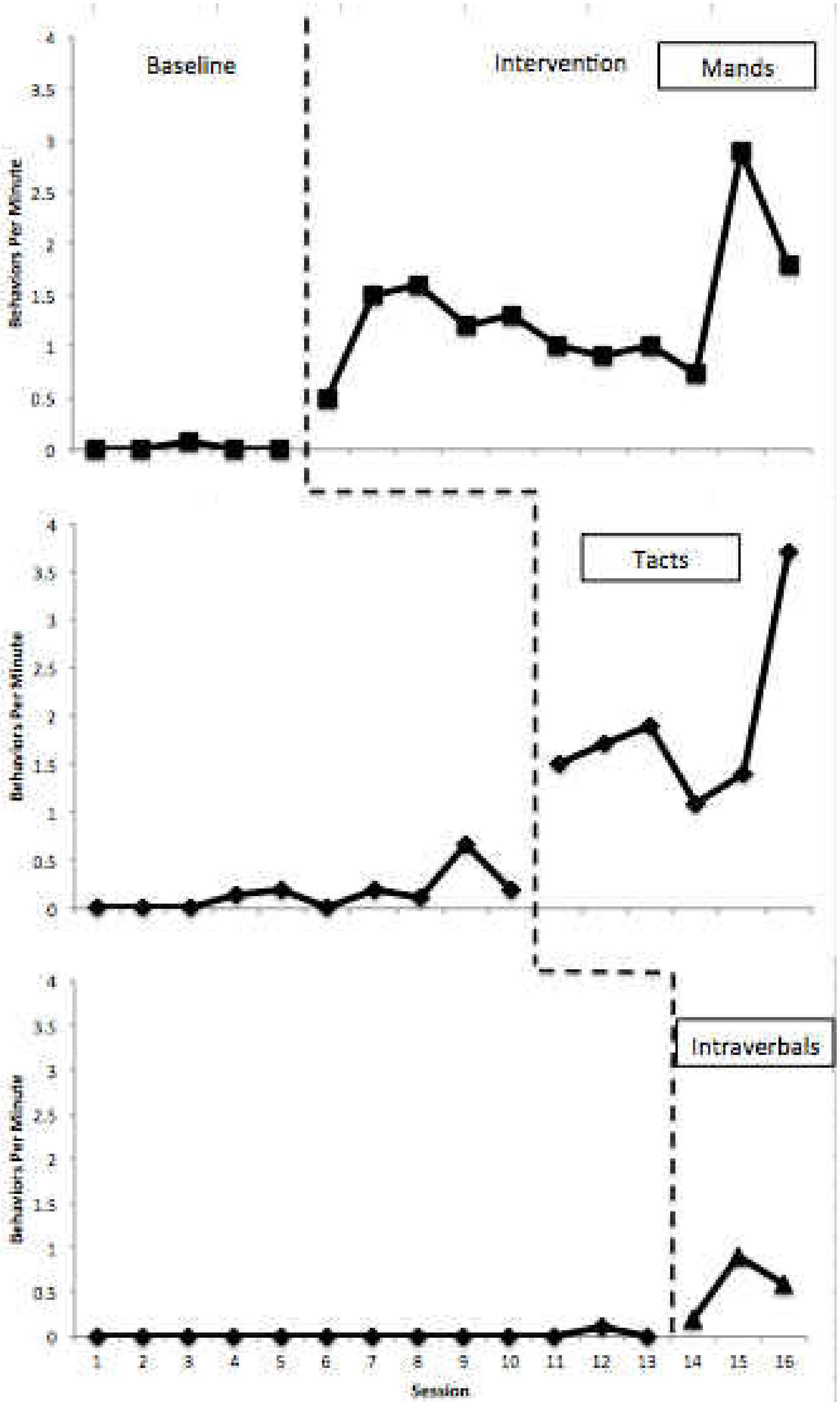


Figure 15. Andrew Results

## Visual Analysis and Descriptive Statistics

Level

Andrew demonstrated low rates of manding (i.e., 0 to .07 per minute); tacting (i.e., 0 to .67 per minute); and intraverbals (i.e., 0 to .1 intraverbals per minute) during the baseline condition. All three behaviors increased during the intervention phase for that behavior. The mean level of each condition is shown in Table 14.

Table 14

Mean Level by Condition for Andrew

| Behavior | Mean Level in Baseline | Mean Level in Intervention |
|---|---|---|
| Mand | 0.01 | 1.31 |
| Tact | 0.15 | 1.88 |
| Intraverbal | 0.01 | 0.56 |

Trend

Andrew demonstrated pre-intervention stability, and therefore a flat trend, for all three target behaviors. Once the behaviors were moved into their respective intervention phases, the data reflects an increasing trend for all three behaviors. The steepest trend was for tacts per min, followed by mands and then intraverbals.

Variability

There was low variability in the data for any of the target behaviors in the baseline condition for Andrew. Once in the intervention phase, 80% of the data points for manding fell within a 42% range of the median, which represents moderate variability for this target behavior. Eighty percent of the data points for tacting fell within a 32% range of the median, which represents moderate variability for this target behavior. Finally, 80% of the data points for intraverbals fell within a 70% range of the median, which represents high variability for this target behavior.

<u>Immediacy of Effect.</u>

Andrew shows an immediate and significant change in all three target behaviors when comparing the last three data points in each baseline condition and the first three data points in each intervention condition (see Table 15).

Table 15

Immediacy of Effect by Condition for Andrew

| Behavior | Last 3 Baseline Data Points | First 3 Intervention Data Points |
|---|---|---|
| Mand | 0.07, 0, 0 | 0.5, 1.5, 1.6 |
| Tact | 0.1, 0.67, 0.2 | 1.5, 1.7, 1.9 |
| Intraverbal | 0, 0.1, 0 | 0.18, 0.9, 0.6 |

<u>Overlap</u>

Percent of non-overlapping data was calculated by locating the highest point in the baseline phase, identifying the number of points in the intervention phase that fall above this point, and dividing this number by the total number of data points in the intervention phase (Parker, Vannest, & Davis, 2011). Andrew had 100% PND for all three target behaviors.

Consistency of Data Patterns

In Andrew's case all three target behaviors had low variability during baseline and increased to moderate to high variability as they were moved into the intervention phase.

## Measures of Effect Size

Percent of non-overlapping data was calculated during a visual analysis of the data but also serves as a measure of effect size. For single case design research, a PND greater than 90% indicates a large effect size (Gast, 2010) and in Andrew's case, there was 100% PND for all target behaviors.

Table 16

Tau-U Results for Andrew

| Behaviors | Tau-U | Interpretation |
|---|---|---|
| Mand | 1.0 | Large effect size |
| Tact | 1.0 | Large effect size |
| Intraverbal | 1.0 | Large effect size |
| Weighted Average | 1.0 | Large effect size |

Tau-U is a non-parametric, robust measure of non-overlap and was calculated for the three target behaviors across each participant. Tau-U is a non-parametric, robust measure of non-overlap and was calculated for the three target behaviors across each participant. An analysis of the Tau-U results suggests large effects for all target behaviors and the weighted average. The Tau-U results for mand, tact, and intraverbals were all 1.0. The omnibus Tau-U result was also 1.0, with 90% confidence intervals between .68 and 1. This result indicates that 100% of data showed improvement between baseline and intervention phases. Andrew's results by behavior and an interpretation of the statistic can be found in Table 16.

Sam Results

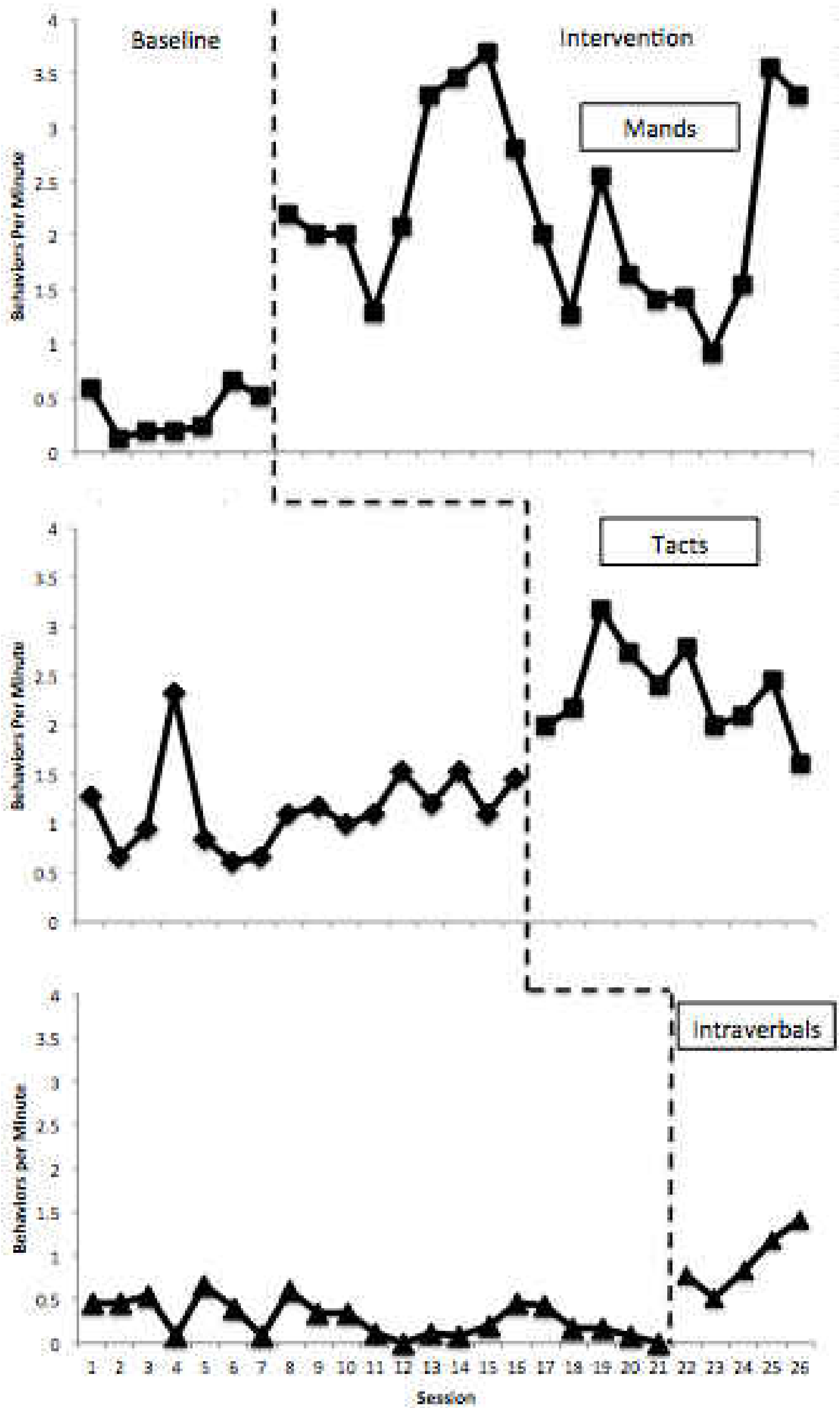


Figure 16. Sam Results

## Visual Analysis and Descriptive Statistics

Level

Sam demonstrated variable rates of all three target behaviors prior to moving into intervention. All three behaviors increased during the intervention phase for that behavior. The mean level of each condition is shown in Table 17.

Table 17

Mean Level by Condition for Sam

| Behavior | Mean Level in Baseline | Mean Level in Intervention |
|---|---|---|
| Mand | 0.37 | 2.23 |
| Tact | 1.16 | 2.34 |
| Intraverbal | 0.28 | 0.94 |

Trend

Sam demonstrated a slight increase in mands per minute during baseline sessions. During the intervention phase, the trend of the data points was flat. Similarly, he demonstrated a slight increase in tacts per minute during baseline sessions. For this target behavior, the trend line during the intervention phase was slightly decreasing. Conversely, Sam demonstrated a slight decreasing trend for intraverbals per minute during baseline and during intervention the data showed an increasing trend.

Variability

There was moderate to high variability in the data for any of the target behaviors in the baseline condition for Sam. Once in the intervention phase, 80% of the data points for manding fell within a 65% range of the median, which represents high variability for this target behavior. Eighty percent of the data points for tacting fell within a 21% range of the median, which represents moderate variability for this target behavior. Finally, 80% data points for intraverbals fell within a 31% range of the median, which represents moderate variability for this target behavior.

Immediacy of Effect

Sam's manding, tacting, and intraverbal skills were all immediately impacted by the intervention when comparing the last three data points in each baseline condition and the first three data points in each intervention condition (see Table 18). The immediate impact on tacting behaviors was the least significant.

Table 18

Immediacy of Effect by Condition for Sam

| Behavior | Last 3 Baseline Data Points | First 3 Intervention Data Points |
|---|---|---|
| Mand | 0.25, 0.67, 0.53 | 2.2, 1.4, 2.0 |
| Tact | 1.54, 1.1, 1.45 | 2.0, 2.18, 3.18 |
| Intraverbal | 0.18, 0.09, 0 | 0.78, 0.5, 0.82 |

Overlap

Percent of non-overlapping data was calculated by locating the highest point in the baseline phase, identifying the number of points in the intervention phase that fall above this point, and dividing this number by the total number of data points in the intervention phase (Parker, Vannest, & Davis, 2011). Sam's data reflected 100% PND for all three target behaviors.

Consistency of Data Patterns

In Sam's case all three target behaviors had moderate to high variability during baseline and moderate to high variability as they were moved into the intervention phase.

## Measures of Effect Size

Percent of non-overlapping data was calculated during a visual analysis of the data but also serves as a measure of effect size. For single case design research, a PND greater than 90% indicates a large effect size (Gast, 2010) and in Sam's case, there was 100% PND for all mands and intraverbals and 90% PND for tacts.

Table 19

Tau-U Results for Sam

| Behaviors | Tau-U | Interpretation |
|---|---|---|
| Mand | 1.0 | Large effect size |
| Tact | 0.94 | Large effect size |
| Intraverbal | 0.94 | Large effect size |
| Weighted Average | 0.96 | Large effect size |

Tau-U is a non-parametric, robust measure of non-overlap and was calculated for the three target behaviors across each participant.  An analysis of the Tau-U results suggests medium to large effects for all target behaviors and the weighted average. The Tau-U for mand was 1.0, tact was .94, and intraverbal was .94.  The Tau-U result for the weighted average condition was .96, with 90% confidence intervals between .71 and 1. This result indicates that 96% of data showed improvement between baseline and intervention phases. Sam's results by behavior and an interpretation of the statistic can be found in Table 19.

Jeffrey Results

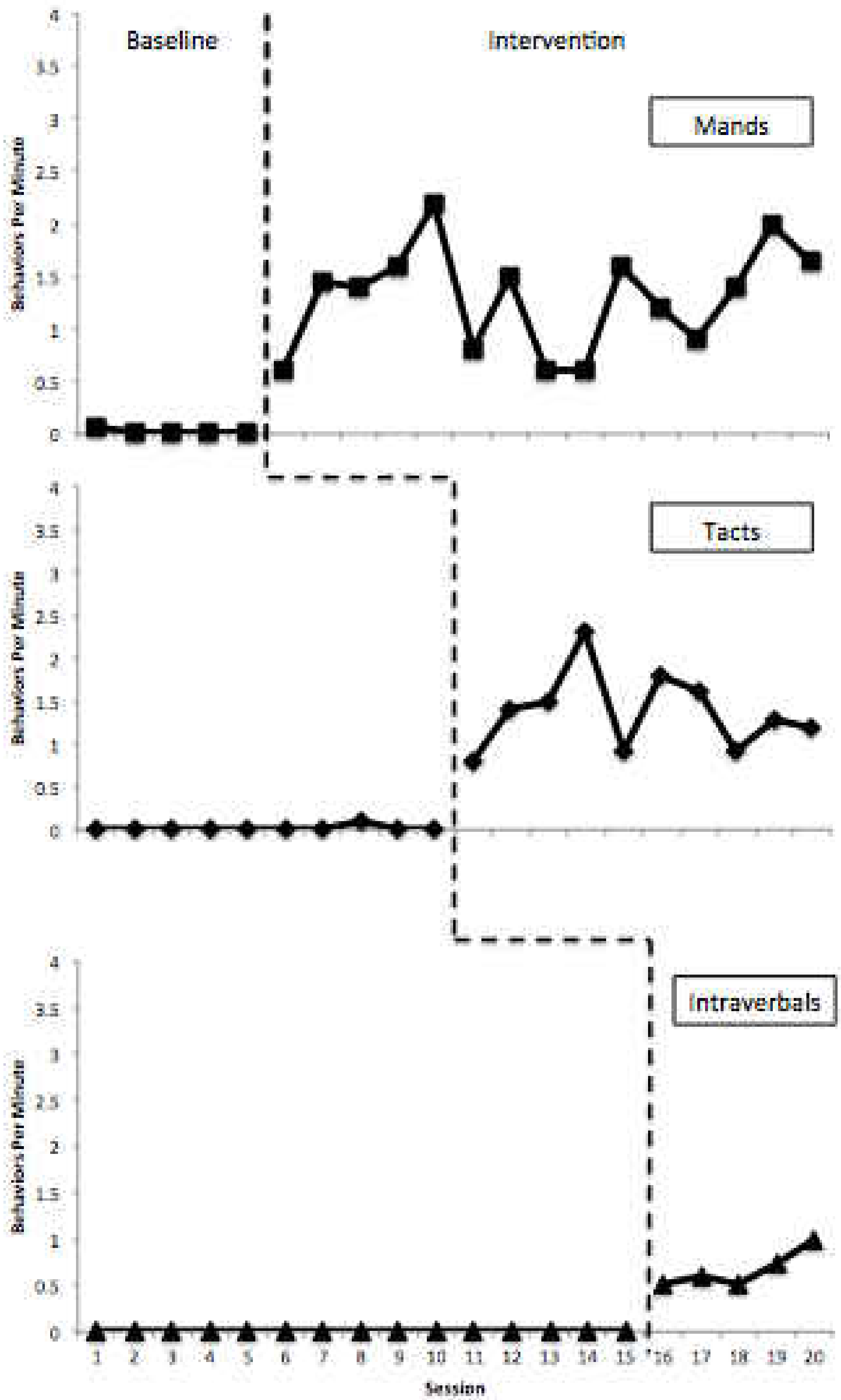


Figure 17. Jeffrey Results

## Visual Analysis and Descriptive Statistics

Level

Jeffrey demonstrated low rates of manding (i.e., 0 to .07 mands per minute) and zero rates of tacting and intraverbals during the baseline condition. All three behaviors increased during the intervention phase for that behavior. The mean level of each condition is shown in Table 20.

Table 20

Mean Level by Condition for Jeffrey

| Behavior | Mean Level in Baseline | Mean Level in Intervention |
|---|---|---|
| Mand | 0.01 | 1.30 |
| Tact | 0.01 | 1.37 |
| Intraverbal | 0 | 0.67 |

Trend

Jeffrey demonstrated pre-intervention stability for manding as 80% of data points in baseline fell within a 20% range of the median level for that behavior. In baseline, Jeffrey displayed zero to low rates of mands, tacts, and intraverbals (i.e., flat trend). Once moved into intervention, there was an slightly increasing trend in his mands and intraverbals and a flat trend in his tacts.

Variability

There was low to no variability in the data for any of the target behaviors in the baseline condition for Jeffrey. Once in the intervention phase, 80% of the data points for manding fell within a 57% range of the median, which represents high variability for this target behavior. Eighty percent of the data points for tacting fell within a 35% range of the median, which represents moderate variability for this target behavior. Finally, 80% of the data points for intraverbals fell within a 22% range of the median, which represents moderate variability for this target behavior.

Immediacy of Effect.

Jeffrey showed an immediate and significant change in all three target behaviors when comparing the last three data points in each baseline condition and the first three data points in each intervention condition (see Table 21).

Table 21

Immediacy of Effect by Condition for Jeffrey

| Behavior | Last 3 Baseline Data Points | First 3 Intervention Data Points |
|---|---|---|
| Mand | 0, 0, 0 | 0.6, 1.45, 1.4 |
| Tact | 0.1, 0, 0 | 0.8, 1.4, 1.5 |
| Intraverbal | 0, 0, 0 | 0.5, 0.6, 0.5 |

Overlap

Percent of non-overlapping data was calculated by locating the highest point in the baseline phase, identifying the number of points in the intervention phase that fall above this point, and dividing this number by the total number of data points in the intervention phase (Parker, Vannest, & Davis, 2011). Jeffrey had 100% PND for all three target behaviors.

Consistency of Data Patterns

In Jeffrey's case all three target behaviors had low to no variability during baseline and increased in level and variability (moderate to high) as they were moved into the intervention phase.

## Measures of Effect Size

Percent of non-overlapping data was calculated during a visual analysis of the data but also serves as a measure of effect size. For single case design research, a PND greater than 90% indicates a large effect size (Gast, 2010) and in Jeffrey's case, there was 100% PND for all target behaviors.

Tau-U is a non-parametric, robust measure of non-overlap and was calculated for the three target behaviors across each participant. An analysis of the Tau-U results suggests medium to large effects for all target behaviors and the weighted average. The Tau-U results for mand, tact, and intraverbal were 1.0. The Tau-U result for the weighted average condition was also 1.0, with 90% confidence intervals between .72 and 1. This result indicates that 100% of data showed improvement between baseline and intervention phases. Jeffrey's results by behavior and an interpretation of the statistic can be found in Table 22.

Table 22

Tau-U Results for Jeffrey

| Behaviors | Tau-U | Interpretation |
|---|---|---|
| Mand | 1.0 | Large effect size |
| Tact | 1.0 | Large effect size |
| Intraverbal | 1.0 | Large effect size |
| Weighted Average | 1.0 | Large effect size |

## Reliability

An independent scorer coded 30% of the sessions for each participant. Interobserver agreement (IOA) was calculated by dividing the smaller frequency count by the larger frequency count and multiplying by 100 resulting in a total percent agreement (Gast, 2010). Total percent agreement was calculated at 92% (range: 80-100%). Total percent agreement for Participant 1 was calculated at 93.9% (range: 83-100%), agreement for Participant 2 was calculated at 89% (range: 80-100%), agreement for Participant 3 was calculated at 92% (range: 84-100%), and agreement for Participant 4 was calculated at 94% (range: 89-100%).

## Fidelity

In the intervention phase, an interobserver assessed the fidelity of the researcher's instructional delivery every three sessions (What Works Clearinghouse, 2014). The treatment fidelity rubric was broken down into three components: set-up and wrap-up, praise for target behavior, and robot vs. human interactions. The criteria for setting up and wrapping up each session was set at 100%, the criteria for the robot-delivered praise statements for each occurrence of the target behavior was set at 80%, and the criteria for robot vs. human interactions was set at >50%.

Treatment fidelity for the set-up and wrap-up component of the rubric was calculated at 97% (range: 50-100%). Treatment fidelity for the robot-delivered praise statements was calculated at 99% (range: 87-100%). Treatment fidelity for the robot vs. human interactions was calculated at 58% (range: 50-67%). The treatment fidelity data have also been broken down by participant in Table 23.

Table 23

Treatment Fidelity by Participant

| | Set-up and Wrap-up | Robot-Delivered Praise Statements | Robot vs. Human Interactions |
|---|---|---|---|
| Alex | 100%<br>(range: 100%) | 100%<br>(range: 100%) | 50.2%<br>(range: 55-67%) |
| Andrew | 100%<br>(range: 100%) | 100%<br>(range: 100%) | 58.3%<br>(range: 55-61%) |
| Sam | 87.5%<br>(range: 50-100%) | 97%<br>(range: 87-100%) | 56%<br>(range: 51-62%) |
| Jeffrey | 100%<br>(range: 100%) | 100%<br>(range: 100%) | 57.5%<br>(range: 50-62%%) |

<u>Social Validity</u>

The social validity questionnaire was administered to the parents and teachers of participants and measured their perceptions of the goals, procedures, and outcomes of this intervention. The response rate was 100%. In general, teachers had positive perceptions of the robot-assisted intervention and parents had a positive or neutral perception of the intervention.

Table 24

Social Validity Results

| | Strongly Disagree or Disagree | Neutral | Agree or Strongly agree |
|---|---|---|---|
| I find this treatment to be an acceptable way of dealing with my child's social-communication deficits. | | Parents: 1 | Parents: 3<br>Teachers: 2 |
| I would be willing to use this procedure if I had to change my child's social-communication deficits. | | Parents: 1 | Parents: 3<br>Teachers: 2 |
| I believe that it would be acceptable to use this intervention without children's consent. | Parents: 1 | Parents: 2 | Parents: 1<br>Teachers: 2 |
| I like the procedures used in this intervention. | | Parents: 2 | Parents: 2<br>Teachers: 2 |
| I believe this intervention is likely to be effective. | | Parents: 2 | Parents: 2<br>Teachers: 2 |
| I believe my child will experience discomfort during the intervention. | Parents: 3<br>Teachers: 2 | | Parents: 1 |
| I believe this intervention is likely to result in permanent improvement. | | Parents: 2<br>Teachers: 1 | Parents: 2<br>Teachers: 1 |
| I believe it would be acceptable to use this intervention with individuals who cannot choose interventions for themselves. | Parents: 1 | | Parents: 3<br>Teachers: 2 |
| Overall, I have a positive reaction to this intervention. | | Parents: 2 | Parents: 2<br>Teachers: 2 |

All respondents found the treatment to be an acceptable way to address social-communication deficits in their children or students and would be willing to use the procedure to treat these deficits. Additionally, all of the respondents felt positive or neutral when asked if they liked the intervention and if they believed the intervention would be effective. Half of the respondents believed the robot-assisted intervention would result in permanent improvement and the other half felt neutral on this issue.

## Summary of Results

Overall, the manding, tacting, and intraverbal skills of all participants improved when the robot-assisted intervention was introduced. While there was variability in the effect that the intervention had on the trend of the data points from baseline to intervention, there was an increase in mean level for the three behaviors across all four participants. Additionally, using the two measures of effect size, PND and Tau-U, there was a medium to large effect size for the three target behaviors across all participants.

# CHAPTER 5: DISCUSSION

## Summary and Discussion of Results

Young children with ASD typically present with significant challenges in the area of social-communication skills. As they transition out of early childhood programs in into K-12, these deficits can impact the child's ability to participate meaningfully in school and community-based activities. Interactive technologies, such as robots, provide an alternative way to deliver highly effective and engaging instruction in social-communication skills starting at an early age. The existing research on robotics and early childhood education, robotics and ASD, and robotics and communication skills is limited but promising. Despite this foundation, there is a void in the research when looking at the use of robots to teach social-communication skills to young children with ASD. Social-communication skills - including mands, tacts, and intraverbals - represent a critical instructional domain for this population of learners. In this study, the researcher addresses this critical area of need for three year-old students with ASD.

The existing research on using robots to teach social-communication skills to early childhood learners with ASD is extremely limited and focuses heavily on teaching joint attention and other pre-linguistic communication skills. During the systematic literature review, only eight empirical manuscripts were found that focused on robot-assisted social-communication instruction for young learners with ASD (Bekele et al., 2016; Peca et al., 2015; Pop et al., 2013; Pop et al., 2014; Simut et al., 2016; Tapus et al., 2012; Wainer et al., 2015). These eight studies focus on three skill sets for this population: (a) joint attention and pre-linguistic communication skills, (b) imitation and physical interaction, and (c) play and social skills with five of the eight existing studies focused on the effects of robot-mediated or robot-assisted interventions on the joint attention or pre-linguistic communication skills of early learners with ASD. The existing research showed mixed results related to skill acquisition when using robot-mediated or robot-assisted instruction, but consistently reported that participants were highly engaged with the robots when they were present.

This study contributed to this body of work by addressing more advanced, but developmentally appropriate communication skills (e.g., manding, tacting, and intraverbals) for this population of learners. The findings were significant because all participants in this study, showed significant improvements in manding, tacting, and intraverbal skills when the robot-assisted intervention was introduced. While there was some inconsistency in the patterns of responding (e.g., trend, immediacy of effect, variability) from baseline to intervention across behaviors and participants, there was consistently an increase in mean level for the three behaviors across all four participants. Additionally, using the two measures of effect size, PND and Tau-U, there was a medium to large effect size for the three target behaviors across all participants.

There were some important features of the data that need to be addressed. First, for all participants, the target behaviors increased in level when the robot-assisted intervention was introduced, but for some participants the trend of the behavior shifted from increasing or flat to decreasing when the intervention was introduced. One possible explanation for this behavioral pattern is that as the participants were moved into the second and third leg of the intervention, the robot was attempting to elicit a variety of verbal behaviors in the same time frame (i.e., 10-15 mins). This may have resulted in a slight decreasing trend as more behaviors were moved into the intervention phase.

Second, for most participants, intraverbal skills showed the least significant change from baseline and in many cases required the most prompting from the robot. Intraverbal skills can be challenging to teach to students without solid mand and tact repertoires. In most cases, formal intraverbal training seems to be most effective when the child can easily emit a number of different mands and tacts, and demonstrates receptive discrimination skills (Sundberg, 2006).

## Technical Demands and Challenges

Throughout the course of the study, there were some challenges associated with the robot and other study materials. The robot used for this study had a fragile internal wiring system that would periodically malfunction if a participant grabbed or bumped the robot roughly. Compounding this issue further was the fact that the company that manufactured the robot was a small start-up with no infrastructure to support clients in identifying and solving technical issues associated with the robot. At several points throughout the study, the company was contacted twice during the study to assist when there were issues logging into the application and when the speaker on the robot was not functioning properly. There was no response to these inquiries regarding technical issues, leaving the researcher to solve the issues independently. This could present a significant issue in a larger study. Other robots with similar capabilities should be considered for future research in this area.

Additionally, the iPad that controlled the robot connected to the iPhone that served as the robot's eyes through Bluetooth. This connection could easily be disrupted if a participant touched the robot's eyes repeatedly or hit the home button on the iPhone. One participant, Alex, touched the eyes repeatedly during most sessions. This created a scenario where the iPhone (eyes and voice) would disconnect from the iPad (operator) and the connection would need to be reset. The process or resetting could take 30 s to 1 min. During that timeThese technical issues could lead to disruptions in the intervention sessions, which may have impacted the participants' behavior during sessions.

All of these technical demands and challenges serve as barriers to the successful use of the Romibo robot in classrooms at this point. Therefore, other robots and or future updates and improvements to Romibo should be monitored for both feasibility and appropriateness in the classroom environment.

Also, at present Romibo is not able to record or analyze interactions despite the fact that an iPhone, which has recording and analyzing capabilities, serves as the eyes of the robot. This technical feature would be useful to both researchers and practitioners. If the robot were able to record sessions, perform analytics internally, and display them back to the teacher in real time, this could make the use of robots in the classroom more

## Treatment Fidelity

The robot-assisted intervention used in this study utilized a combination of automated responses from the robot and supplemental prompts or cues from the human operator. One benefit of the robot selected for this study was the open-source programming app where users can share or create palettes or control panels. For the purposes of this study, palettes were created by the researcher to address the specific target skills and could be customized if needed for a specific participant. For example, if one participant consistently required a specific prompt to make a request or label a preferred item, that prompt could be programmed into the palette and therefore become an automated response. The ability to customize and adapt the automated responses improves the ease of implementation for the operator as more appropriate automated responses are available, but also represents a challenge with regards to treatment fidelity across participants.

## Social Validity

The parents and teachers of the participants were asked to complete a survey detailing their perceptions of the goals, procedures, and outcomes used in the robot-assisted intervention. On the whole, all participants felt positive or neutral about the intervention and its outcomes however, the teachers had more positive perceptions about the robot-assisted interventions than the parents. It is important to note that because the intervention was implemented in school, the teachers had more exposure to the intervention than parents, which likely contributed to the disparity in scores on the social validity survey.

School districts are investing heavily in educational technologies and regularly spend about 36% of their budget on technology (Piccano & Spring, 2013). Initially, schools set out to have a computer in every classroom, but more recently schools have started purchasing tablets and other devices for every student and investing in educational software and electronic curricula. Simultaneously, parents and educators are adjusting to the presence of technology in the classroom. Many parents and teachers, including those surveyed for the purposes of this study were open to exposing their children or students to novel technologies in an educational setting. Other educators fear that emerging technologies will negatively alter the role of the teacher and eventually replace teachers altogether.

While there is no doubt that technology is changing the landscape of PK-12 education, robots like the one used in the present study are not designed to take the place of educators. Instead, these technologies are a powerful tool that can be used in combination with traditional instructional practices to provide engaging and customized learning environments for students.

The New Media Consortium (2017) discussed how the pervasiveness of technology in the classroom is requiring us to rethink the role of educators. The primary role of teachers will shift from the provider of knowledge to the constructor of educational experiences and environments using a variety of approaches including technology-based learning (New Media Consortium, 2017). Teachers in technology-enabled classrooms and schools will be successful if they engage in ongoing professional development related to digital competencies and adapt quickly to new technologies while maintaining a solid foundation of evidence-based instructional practices.

## Implications of Analysis

Children and adults with ASD struggle with a variety of social-communication challenges that impact their ability to participate fully in school, family, and community-based activities. These skills also may negatively impact their ability to transition successfully to adulthood. Highly effective and engaging instruction in social-communication skills should begin at an early age and continue through K-12 and beyond. At present, school-based social-communication interventions are minimally effective and produce insufficient outcomes (Bellini, Gardner, & Markoff, 2014; Bellini, Peters, Benner, & Hopf, 2007). Given the existing research on robotics and the findings from this study, there are several implications for practice and future research.

The present study served as the initial exploration into teaching social-communication skills (i.e., mands, tacts, and intraverbals) to young children with ASD using a robot-assisted intervention. By introducing robots into early childhood learning environments, students, teachers, and families are being exposed to this technology in a new environment and with a new population of learners. Their presence in an educational environment pushes our field to look more closely at programming robots to teach other skills, programming robots to provide individualized accommodations, and teaching early childhood learners with and without disabilities how to program and code at a basic level. For society as a whole, the increased presence of technologies, more specifically robots, in the classroom normalizes their presence in the school environment and challenges us all to think about how best to prepare children for the global, technological market that they will be entering after graduation. The promising results of this study indicate that robot-assisted interventions warrant further exploration in applied settings like schools, after school programs, and home-based settings.

## Implications for Practice

Four primary recommendations emerged from this research related to practice in the field of special education. First, practitioners need to integrate technologies within evidence-based instructional practices. Second, practitioners need to monitor the emergence of technologies not specifically designed for educational purposes for their appropriateness in the classroom. Third, practitioners need to customize technology-mediated interventions for individual students as needed. Fourth, teacher professional development will need to keep pace with emerging technologies and directly support the integration of technology and evidence-based instructional practices.

The United States Department of Education (2016) stated, “when carefully designed and thoughtfully applied, technology can accelerate, amplify, and expand the impact of effective teaching practices” (p. 2). Students with and without disabilities should have access to technologies to support their learning and these technologies should be integrated with evidence-based instructional strategies. Existing literature on robotics and education provided support for the use of this technology with early childhood learners and learners with disabilities to teach a variety of skill sets including social-communication skills.

Technologies like robots, which were not originally intended for educational purposes, have the potential to engage learners in new ways and provide additional practice opportunities for children who present with social-communication deficits. It is important that teachers, administrators, and parents monitor emerging technologies and "think outside the box" about ways that technologies can be used to level the playing field between students with and without disabilities. As the technologies evolve and the interactions become more automated, it is likely that the demands on and involvement of the operator (e.g., teacher, therapist, or parent) will lessen. This, in turn, will result in more flexible use of the technology in classroom and home-based settings.

Students with ASD are a heterogeneous group and therefore it is important that the use of any technology-based intervention is monitored appropriately and the technology or teaching strategy is customized to meet the needs of each student. This recommendation aligns closely with the Pyramid Model for Supporting Social Emotional Competence in Infants and Young Children, which indicates that educators should provide intensive and individualized services to students with the most severe deficits in this area. When looking specifically at the use of robotics with this population of learners, it is important to consider that each platform or user interface will have a different mechanism for customizing and automating responses. More sophisticated and automated technologies will impact the customizability and the role of the operator in the intervention.

Finally, professional development experiences for educators will need to focus not only on the features and functions of new technologies, but also on the integration of these technologies into the existing evidence-based instructional practices in the classroom. As the role of the teacher shifts, so must the skills they possess in order to facilitate a productive learning environment for their students. Educators today need to be able to deliver technology-based and traditional instruction, construct learning environments that encourage creative inquiry and digital literacy, and provide opportunities for students to direct their own learning (New Media Consortium, 2017). Preparation for new teachers and professional development for all teachers will need to support these skill sets.

## Implications for Future Research

Additional studies regarding the response of young students with ASD and other developmental disabilities to robot-assisted interventions are warranted. The results of the present study in combination with results from other studies on using robotics to teach communication skills to young learners with ASD provide a basis for further exploration of this type of intervention. It will be important to expand the current research to include group design studies comparing robot-assisted social-communication interventions to other common instructional practices in early childhood programs.

This line of research should be extended to include students who are chronologically and developmentally older and younger than the participants in this study. Groups of students at different ages and different developmental levels will likely have different social-communication profiles and may respond differently to robot-assisted interventions. Similarly, the participants in this study were children with a formal diagnosis of ASD, but this type of intervention may be effective with children who have other cognitive, developmental, or language-related disorders.

This study focused on three verbal operants (i.e., mand, tact, and intraverbal). Previous work has addressed the impact of robot interactions on joint attention, body awareness and appropriate physical touch, positive affect, interaction initiations, responses, frequency of utterances, play skills, engagement in play, and social skills. Future research should focus on other verbal operants and social-communication skills. Additionally, this study used the principles of verbal behavior and the VB-MAPP curriculum as the basis for the intervention. However, future research could use other research-based instructional strategies or curricula to develop novel robot-assisted interventions.

This study utilized a robot-assisted intervention, which included automated cues and responses from the robot and supplemental human prompts and cues. As robots and the user interfaces associated with them become more sophisticated, it should become possible to have a higher ratio of automated responses and lower ratio of human prompts and cues. Future research could look how students with ASD respond as the ratio of robot to human interactions shifts in interventions like the one described in this study. More research is needed on the features of the robot and the interaction that are more or less engaging and reinforcing for students with ASD.

## Limitations

Studies that utilize a multiple baseline design across behaviors have some inherent limitations. First, all three target behaviors are monitored repeatedly and concurrently which can present difficulties related to data collection (e.g., time commitment, complexity of coding; Gast, 2010). While coding multiple behaviors during a single observation presented a challenge for observers, the intervention sessions were video-recorded so they could be watched multiple times if needed.

Second, a lengthy baseline condition may result in the inadvertent extinction of the target behaviors addressed in the second and third leg of the intervention (Gast, 2010). The length of the baseline condition for the first target skill (i.e., mands) ranged from 5-7 sessions. The length of the baseline condition for the second target skill (i.e., tacts) and third target skills (i.e., intraverbals) were significantly lengthier ranging from 10-16 sessions and 13-21 sessions respectively. Therefore, the second two target behaviors (i.e., tact and intraverbal) were at risk of inadvertent extinction.

Third, maturation or naturally occurring changes (e.g., skill acquisition) over time could be mistaken as intervention effect (Kratchowill et al., 2010). This study took place over 12 weeks in two classrooms where traditional instruction and related services (e.g., speech-language pathology, occupational therapy) were being delivered. As a result, it is reasonable to assume that some learning and skill acquisition occurred over that time.

Fourth, the small number of participants ($N = 3$) in this study also represents a limitation, as it reduces generalizability to other students with ASD or other developmental disabilities including those of different ages and with different social-communication profiles. This study also had several methodological limitations include the omission of a maintenance phase due to time constraints with the end of the school year. Also, although the results did show an increase in the target behaviors in the intervention setting, this study did not address generalization of skills into the classroom, home, or community setting.

Fifth, baseline data was collected in a group setting and the intervention was delivered in a 1:1 setting. The goal was to collect baseline data in the participants' natural environment during regularly scheduled activities in order to provide the most accurate information on their present rates of the target behaviors. However, the difference between the conditions could have influenced the number of opportunities to respond afforded each participant.

Finally, the parents did not have any direct exposure to the intervention or to their child's interactions with the robot. This likely influenced their responses on the social validity questionnaire and therefore caution should be taken when interpreting those results.

## Conclusions

In 2014, the prevalence of ASD in the United States was estimated to be an average of 1 in 68 children. For individuals with ASD, language and communication deficits typically present in early childhood. Children with ASD often hit developmental milestones later than their peers and take longer to develop the same skills and for many, social-communication skills never fully develop (Gleason & Ratner, 2016). Adults with ASD typically experience difficulty obtaining and maintaining employment and social skills deficits are frequently cited as barriers to improved outcomes (Burke, Andersen, Bowen, Howard, & Allen, 2010; Cimera & Cowan, 2009). The total annual cost to society for supporting an individual with ASD across the lifetime is estimated at $3.2 million (Ganz, 2008). By improving critical social-communication skills and, in turn, the individual's ability to find and maintain employment, the cost to society could be significantly reduced.

The role of technology in education is continuing to expand each year. In the NMC/CoSN Horizon Report: 2016 K-12 Edition and the NMC/CoSN Horizon Report Preview: 2017 K-12 Edition, robotics is highlighted as a technology that is one year or less from widespread use in classrooms (Adams Becker et al., 2016; New Media Consortium, 2017). The 2017 K-12 Report Preview also notes, "it is also clear that some students with spectrum disorders are more comfortable working with robots to develop better social, verbal, and non-verbal skills."

This study was an initial attempt to investigate the impact of a robot-assisted intervention on the social-communication skills of young children with ASD. This study has shown that while there was some variation in how participants responded to the intervention, all four participants demonstrated an increase in the three target behaviors when the robot-assisted intervention was introduced.

Emerging technologies, including robots, are readily available for supporting teachers and parents in creating and adapting more engaging content for learners with and without disabilities.  We have to continue to look deeper at which technologies are most appropriate for teaching specific skill sets to students with different learning profiles.

## APPENDIX A: IRB APPROVAL LETTER

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

## Approval of Human Research

From: **UCF Institutional Review Board #1**
**FWA00000351, IRB00001138**

To: **Claire L. Donehower and Co-PI: Eleazar Vasquez**

Date: **February 28, 2017**

Dear Researcher:

On 02/28/2017 the IRB approved the following human participant research until 02/27/2018 inclusive:

| | |
|---|---|
| Type of Review: | IRB Continuing Review Application Form<br>Expedited Review |
| Project Title: | Project Romibo |
| Investigator: | Claire L Donehower |
| IRB Number: | SBE-16-12097 |

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 02/27/2018, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation.
Participants or their representatives must receive a copy of the consent form(s).

All data, including signed consent forms if applicable, must be retained and secured per protocol for a minimum of five years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained and secured per protocol. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Gillian Amy Mary Morien on 02/28/2017 01:12:03 PM EST

IRB Coordinator

# APPENDIX B: CONSENT FORM

University of Central Florida

**Informed Consent from Parent for a Child in a Non-Exempt Research Study**

**Using Robots to Improve the Social Skills of Young Children with Developmental Delays**

**Research Site:** **University of Central Florida/UCP Bailes**


**Principal Investigators:**
Claire Donehower, Doctoral Student, UCF

**Co-Investigators:**

Dr. Eleazar Vasquez, Professor of Child, Family and Community Sciences, UCF
Dr. Matthew Marino, Professor of Child, Family and Community Sciences, UCF

**Research Associates:**
Matthew Taylor, Doctoral Student
Faith Ezekiel-Wilder, Doctoral Student


Dear Parent or Guardian:

Your child is being invited to participate in a research study that will examine the effects of social skills intervention that targets social initiations, responses, and asking. This study will involve your child engaging with an interactive robot called Romibo in structured interactions. All equipment will be provided.

The research team conducting this research is led by Claire Donehower, Doctoral Student; Dr. Eleazar Vasquez, Professor of Child, Family, and Community Sciences; and Dr. Matthew Marino, Professor of Child, Family, and Community Sciences

**What you should know about participating in a research study:**

- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you or your child take part is up to you.
- You should participate in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you.
- Feel free to ask all the questions you want before you decide.

**Purpose of the research study:** The purpose of this study is to examine the effects of a social skills training program for young children with ASD that utilizes an interactive, fully programmable, and customizable robot.

**What you will be asked to do in the study:** During this study, your child will be asked participate in 15-20 minute sessions with the robot twice weekly for 10 -12 weeks. You will be asked to fill out a rating scale at the beginning and end of the study window. The approximate time to complete this survey is 15-20 minutes.

**Location:** The study will be conducted in the school setting. All necessary equipment will be provided.

**Time required:** This study will take place over the course of 10 -12 weeks and will require approximately 15-20 minute time commitment from your child twice weekly. We also estimate that it will take you 15-20 minutes to complete the parent survey.

**Videotaping:** All sessions of interactions will be videotaped. If you do not agree to be videotaped, you will not be able to participate in the study. If you have any questions please discuss this with the researcher. Videotapes will be kept in a locked, safe place and only the research team will have access to the recording. The video will be used to collect data on the frequency of social behaviors.

**Risks:** There are no reasonably foreseeable risks or discomforts involved in taking part in this study. Potential risks may include breach of confidentiality, which is always a risk in data collection. This study is voluntary, and at any time you may opt to discontinue participation in this study.

**Benefits:** We cannot promise any benefits to you or your child from taking part in this research. Your child may benefit from exposure to a social skills intervention package. Further, you might benefit indirectly by learning more about how this social skills intervention is implemented and gain insight on social supports that may be helpful for your child.

**Confidentiality:** We will limit your personal data collected in this study. Efforts will be made to limit your personal information to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the Institutional Review Board and other representatives of UCF. Data will be coded with a personal identification number to keep names confidential. Records of your participation including, but not limited to, consent forms, observation data, and videos will be maintained for at least six years after the study and then destroyed to protect your child's confidentiality.

**Study contact for questions about the study or to report a problem:** If you have questions, concerns, or complaints, or think the research has harmed you in any way please contact: Claire Donehower, Doctoral Student, cdonehower@knights.ucf.edu, (443) 844-9013.

**IRB contact about your rights in the study or to report a complaint:** Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following reasons:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

**Withdrawing from the study:** Participants may decide not to continue the research study at any time. The research team will destroy all data associated with participants who do not complete the studies unless that data is relevant to aspects of the interaction that this action leads us to determine should be changed to improve the system. The research study supervisor can remove you from the research study without your approval. Possible reasons for removal include failure to attend the practice sessions, failure to follow instructions of the research staff, or if the research supervisor decides the research study is no longer in your best interest. We will tell you about any new information that may affect your health, welfare or your choice to stay in the research.

By participating in the research study, you agree to the following:

□ I have read the procedure described above

□ I voluntarily agree to take part in the research

□ I agree that my child will take part in the research

□ I agree that my child will be audiotaped

□ I agree that my child will be videotaped

Your signature below indicates your permission for the child named below to take part in this research.

**DO NOT SIGN THIS FORM AFTER THE IRB EXPIRATION DATE BELOW**

________________________________________
Name of participant

________________________________________ ____________________
Signature of parent or guardian — Date

- ☐ Parent
- ☐ Guardian (See note below)

________________________________________
Printed name of parent or guardian

________________________________________ ____________________

**Note on permission by guardians:** An individual may provide permission for a child only if that individual can provide a written document indicating that he or she is legally authorized to consent to the child's general medical care. Attach the documentation to the signed document.

# APPENDIX C: DEMOGRAPHIC QUESTIONNAIRES

## Demographic Questionnaire

**Start here.**

Date: _____________________________________________

1. Child's name:
2. Child's date of birth:
3. Your name:
4. Your relationship to child:
   - ☐ Parent
   - ☐ Other: _____________________________________________
5. Child's ethnicity:
   - ☐ Hispanic or Latino
   - ☐ Not Hispanic or Latino
   - ☐ Prefer not to answer
6. Child's race:
   - ☐ American Indian or Alaska Native
   - ☐ Asian
   - ☐ Black or African American
   - ☐ Native Hawaiian or Other Pacific Islander
   - ☐ White
   - ☐ Prefer not to answer
7. What is your total household income?
   - ☐ Less than $30,000
   - ☐ $30,000 to $49,000
   - ☐ $50,000 to $69,000
   - ☐ $70,000 to $89,000
   - ☐ $90,000 to $109,000
   - ☐ $110,000 to $129,000
   - ☐ $130,000 to $149,000
   - ☐ $150,000 or more
   - ☐ Prefer not to answer
8. Does your child have any formal diagnosis of a disability (e.g., developmental delay, Autism Spectrum Disorder, intellectual disability)
   - ☐ Yes – please specify:__________________________________________________
   - ☐ No
9. Who does the child live with?
   - ☐ Both parents
   - ☐ Mother
   - ☐ Father
   - ☐ Other: ________________________________________________
   - ☐ Prefer not to answer

10. Does the child have any siblings living in the home?
    - ☐ No siblings
    - ☐ 1 sibling
    - ☐ 2-3 siblings
    - ☐ 4 or more siblings

11. What languages are spoken in the home? (please check all that apply)
    - ☐ English
    - ☐ Spanish
    - ☐ Other: ________________________________________________

12. What type of school is your child enrolled in?
    - ☐ Public school
    - ☐ Charter school
    - ☐ Private school
    - ☐ Home school
    - ☐ Other (please describe):______________________________
    - ☐ Not sure

13. What type of classroom is your child placed in?
    - ☐ Inclusive (students with and without disabilities together in the classroom)
    - ☐ Self-contained (only students with disabilities in the classroom)
    - ☐ Other (please describe):______________________________
    - ☐ Not sure

14. How frequently would you say that your child interacts or plays with other kids in **school**?
    - ☐ Frequently
    - ☐ Sometimes
    - ☐ Rarely
    - ☐ Never
    - ☐ Other (please describe):______________________________
    - ☐ Not sure

15. How frequently would you say that your child interacts or plays with other kids in **the community**?
    - ☐ Frequently
    - ☐ Sometimes
    - ☐ Rarely
    - ☐ Never
    - ☐ Other (please describe):______________________________
    - ☐ Not sure

16. How frequently do you read to your child?
- ☐ Almost every day
- ☐ 3-4 times a week
- ☐ 1-2 times a week
- ☐ Never
- ☐ Other (please describe):______________________________
- ☐ Not sure

17. How frequently does your child use a computer or tablet (e.g., iPad)?
- ☐ Frequently
- ☐ Sometimes
- ☐ Rarely
- ☐ Never
- ☐ Other (please describe):______________________________
- ☐ Not sure

18. Has your child ever interacted with a robot?
- ☐ Yes
- ☐ Not
- ☐ Other (please describe):______________________________
- ☐ Not sure

**Please share any unique experiences or things you would like us to know about your child or family.**

| |
|---|
| |

***Thank you for your time in completing this questionnaire.***

## Cuestionario demográfico

**Comience aquí**

Fecha: ______________________________________________

1. **Nombre del niño/a:**

2. Fecha de nacimiento del niño/a:

3. Su nombre:

4. Su relación con el niño/a:

- ☐ Padre/madre
- ☐ Otra: ______________________________________________

5. Origen étnico del niño/a:

- ☐ Hispano o latino
- ☐ No hispano ni latino
- ☐ Prefiero no responder

6. Origen racial del niño/a:

- ☐ Nativo americano o nativo de Alaska
- ☐ Asiático
- ☐ Negro o afroamericano
- ☐ Nativo de Hawaii u otras islas del Pacífico
- ☐ Blanco
- ☐ Prefiero no responder

7. ¿Cuál es el ingreso total de su hogar?

- ☐ Menos de $30.000
- ☐ De $30.000 a $49.000
- ☐ De $50.000 a $69.000
- ☐ De $70.000 a $89.000
- ☐ De $90.000 a $109.000
- ☐ De $110.000 a $129.000
- ☐ De $130.000 a $149.000
- ☐ $150.000 o más
- ☐ Prefiero no responder

8. ¿El niño/a tiene un diagnóstico formal de discapacidad (por ejemplo, retraso en el desarrollo, trastorno del espectro autista, discapacidad cognitiva)

- ☐ Sí – indicar cuál:____________________________________________________
- ☐ No

9. ¿Con quién vive el niño/a?

- ☐ Ambos padres
- ☐ Madre
- ☐ Padre
- ☐ Otra: __________________________________________________
- ☐ Prefiero no responder

10. ¿El niño/a vive con otros hermanos en su casa?
- ☐ No vive con hermanos
- ☐ 1 hermano/a
- ☐ 2-3 hermanos
- ☐ 4 o más hermanos

11. ¿Qué idiomas se habla en casa? (Tilde todos los que correspondan)
- ☐ Inglés
- ☐ Español
- ☐ Otro: ________________________________________________

**12.** ¿En qué tipo de escuela está inscripto/a el niño/a?
- ☐ Escuela pública
- ☐ Escuela charter
- ☐ Escuela privada
- ☐ Estudia en casa
- ☐ Otro (describir):______________________________
- ☐ No estoy seguro/a

**13.** ¿En qué tipo de aula está el niño/a?
- ☐ Inclusiva (en el aula los niños con y sin discapacidades están juntos)
- ☐ Auto-contenida (en el aula solo hay niños con discapacidades)
- ☐ Otro (describir):______________________________
- ☐ No estoy seguro/a

**14. ¿Con qué frecuencia diría que el niño/a interactúa o juega con otros niños en la escuela?**
- ☐ Con frecuencia
- ☐ A veces
- ☐ Rara vez
- ☐ Nunca
- ☐ Otro (describir):______________________________
- ☐ No estoy seguro/a

**15. ¿Con qué frecuencia diría que el niño/a interactúa o juega con otros niños en la comunidad?**
- ☐ Con frecuencia
- ☐ A veces
- ☐ Rara vez
- ☐ Nunca
- ☐ Otro (describir):______________________________
- ☐ No estoy seguro/a

**16.** ¿Con qué frecuencia le lee al niño/a?
- ☐ Casi todos los días
- ☐ 3-4 veces por semana
- ☐ 1-2 veces por semana
- ☐ Nunca
- ☐ Otro (describir):______________________________
- ☐ No estoy seguro/a

**17.** ¿Con qué frecuencia el niño/a usa una computadora o tableta (por ejemplo, iPad)?
- ☐ Con frecuencia
- ☐ A veces
- ☐ Rara vez
- ☐ Nunca
- ☐ Otro (describir):______________________________
- ☐ No estoy seguro/a

**18.** ¿El niño/a alguna vez interactuó con un robot?
- ☐ Sí
- ☐ No
- ☐ Otro (describir):______________________________
- ☐ No estoy seguro/a

**Comparta sus experiencias o lo que nos quiera contar sobre su niño/a o su familia.**

| |
|---|
| |

***Gracias por el tiempo que dedicó a completar este cuestionario.***

# APPENDIX D: SOCIAL VALIDITY SURVEY

Modified Treatment Evaluation Inventory – Short Form

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| I find this treatment to be an acceptable way of dealing with my child's social-communication deficits. | | | | | |
| I would be willing to use this procedure if I had to change my child's social-communication deficits. | | | | | |
| I believe that it would be acceptable to use this intervention without children's consent. | | | | | |
| I like the procedures used in this intervention. | | | | | |
| I believe this intervention is likely to be effective. | | | | | |
| I believe my child will experience discomfort during the intervention. | | | | | |
| I believe this intervention is likely to result in permanent improvement. | | | | | |
| I believe it would be acceptable to use this intervention with individuals who cannot choose interventions for themselves. | | | | | |
| Overall, I have a positive reaction to this intervention. | | | | | |

(Kazdin, 1981)

# APPENDIX E: DATA COLLECTION INSTRUMENT

**Dissertation Curriculum-Based Measurement**

| | |
|---|---|
| **Participant Number:** | |
| **Date:** | |
| **Time:** | |
| **Baseline or Intervention:** | ☐**Baseline** ☐**Intervention** |
| **Activity or Lesson:** | |

Directions: Tally the number of mands, tacts, and intraverbals during each minute of the observation. Complete three observations for each participant at pretest and again at posttest.

| **Time** | **Mands** | **Tacts** | **Intraverbals** |
|---|---|---|---|
| **0:00 to 0:59** | | | |
| **1:00 to 1:59** | | | |
| **2:00 to 2:59** | | | |
| **3:00 to 3:59** | | | |
| **4:00 to 4:59** | | | |
| **5:00 to 5:59** | | | |
| **6:00 to 6:59** | | | |
| **7:00 to 7:59** | | | |
| **8:00 to 8:59** | | | |
| **9:00 to 9:59** | | | |
| **10:00 to 10:59** | | | |
| **11:00 to 11:59** | | | |
| **12:00 to 12:59** | | | |
| **13:00 to 13:59** | | | |
| **14:00 to 14:59** | | | |
| **Totals** | | | |

| Notes/Comments |
| --- |
| |

| Operational Definitions |
| --- |
| **<u>MAND:</u>**<br>For the purposes of this study, a mand has occurred when the child **asks for what he or she wants using verbal language or verbal approximation**. An individual can **mand for an item, action, activity and they can mand to remove or end an item, action, or activity**.<br><br>**<u>EXAMPLES</u>:** Mands can be used to request many things; desired items ("skittles"), information ("What's your name?"), assistance ("Can you help me?"), missing items (given a direction to cut out a shape but not given scissors, the child says "I want some scissors"), actions ("tickle me"); and negative reinforcement (when told to do something that's not preferred the student might ask "Can I take a break"). |
| **<u>TACT:</u>**<br>For the purposes of this study, when the child is tacting they are **labeling items, actions, and attributes in their environment** (Sundberg, 2014). The individual **must be in the presence of the non-verbal stimuli** in order for the verbal behavior to be considered a tact.<br><br>**<u>EXAMPLES</u>:** Some examples of tacts are: saying "cookie" when you see a cookie; saying "cookie" when you smell a cookie; or, saying "cookie" when you taste a cookie. When we label actions or features of objects, we are also emitting tacts. We can also tact properties of our internal status such as labeling pain, fear, joy, and so forth. |
| **<u>INTRAVERBAL:</u>**<br>For the purposes of this study, intraverbals are a type of language where the child is **responding to the language of others** (Sundberg, 2014) and can include but is not limited to **answering questions and filling in the blanks**. Intraverbal behaviors allow the child to engage in conversations with others.<br><br>**<u>EXAMPLES</u>:** Some examples of intraverbals are singing songs, answering factual questions, and filling in the blanks. |

# APPENDIX F: TREATMENT FIDELITY RUBRIC

**Dissertation Treatment Fidelity**

| | |
|---|---|
| **Participant Number:** | |
| **Date:** | |
| **Time:** | |

Directions: Check “yes,” “no,” or “N/A” for each objective.

| **Set-up and wrap-up** | **Yes** | **No** | **N/A** | **Notes** |
|---|---|---|---|---|
| Intervention takes place in the designated setting. | | | | |
| Robot greets participant. | | | | |
| Robot terminates session appropriately with participant (e.g., gives 2 min warning, says goodbye) | | | | |
| **TOTAL** | | | | Percent: |

Directions: Please tally in the appropriate column each time the participant engages in the target behavior.

| Robot **provides praise statement** for target behavior | Robot **does not praise statement** for target behavior |
|---|---|
| | |
| Percent: | Percent: |

Directions: Please tally each time robot or human facilitator interacts with participant

| **Robot interaction** | **Human facilitator interaction** |
|---|---|
| | |
| Percent: | Percent: |

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