EVALUATING THE USE OF A HUMANOID ROBOT TO TEACH DISCRETE TRIAL TRAINING PROCEDURES TO INDIVIDUALS WITHOUT ABA EXPERIENCE THROUGH BEHAVIOR SKILLS TRAINING

by

KAROLINE RENEE KENVILLE

A dissertation submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY IN EDUCATION: EARLY CHILDHOOD EDUCATION

2025

Oakland University
Rochester, Michigan

Doctoral Advisory Committee:

Jessica Korneder, Ph.D., BCBA-D, LBA-Chair
Michael Kranak, Ph.D., BCBA-D,
Ambika Bhargava, Ph.D.
Wing-Yue Geoffrey Louie, Ph.D.

ACKNOWLEDGMENTS

This dissertation is dedicated to the strong, resilient women who are single mothers—those who carry the weight of their children's futures while healing from the past. To the women who have survived domestic violence and still rise, who protect, nurture, and persevere despite unimaginable challenges—you are living proof of courage in its purest form. This work is for the mothers breaking generational cycles of silence, poverty, and lack of education. You are not just changing your own story—you are creating new legacies for your children and for the generations yet to come. To the mothers who rise early, work tirelessly, and sacrifice endlessly to create better lives for their children—your perseverance is the foundation of hope and change. I started this journey in those shoes and by God's grace, I've prevailed. May this dissertation stand as a tribute to your strength, your healing, and your relentless pursuit of a better life. You are seen, you are valued, and your journey matters.

Karoline R. Kenville

ABSTRACT

EVALUATING THE USE OF A HUMANOID ROBOT TO TEACH DISCRETE TRIAL TRAINING PROCEDURES TO INDIVIDUALS WITHOUT ABA EXPERIENCE THROUGH BEHAVIOR SKILLS TRAINING

by

Karoline Renee Kenville

Adviser: Jessica Korneder, PhD, BCBA-D, LBA

The purpose of this study was to investigate the effectiveness of a humanoid Nao robot in training individuals with no prior experience in Applied Behavior Analysis (ABA) to implement Discrete Trial Training (DTT) procedures using the Behavior Skills Training (BST) model. Despite the widespread use of BST as an effective training method, its time-intensive nature poses challenges for scalability and consistency. Additionally, there is limited literature on the use of robotic technology to facilitate ABA training, particularly in training novice behavior technicians in DTT with a robot simulating a child with Autism Spectrum Disorder (ASD). This study utilized a nonconcurrent multiple baseline across participants design to assess the impact of robot-assisted BST on procedural accuracy. Nine undergraduate students from a large public university in the Midwest with no previous exposure to ABA participated in the study. Training took place in a therapy room within a university-affiliated ASD clinic. The intervention involved four steps, instructions, modeling, rehearsal, and feedback that were delivered with the assistance of a humanoid Nao robot programmed to respond as a child learner. The dependent variable was the participants correct implementation of DTT procedures, which included manding, imitation, receptive instructions, tacting, and emotion labeling, measured as the percentage of accurate steps completed during sessions. Results indicated that all participants reached mastery criteria, achieving at least 80% accuracy in DTT implementation following the BST intervention. The use of the Nao robot contributed to consistent delivery of training across participants and supported procedural integrity throughout the teaching process. These findings demonstrate that humanoid robots may serve as an effective and scalable tool in training novice ABA staff, particularly when traditional training resources are limited. Evaluating the Use of a Humanoid Robot to Teach Discrete Trial Training Procedures to Individuals Without ABA Experience Through Behavior Skills Training Implications of this research suggest that integrating robotic assistance into ABA training programs may enhance training efficiency, procedural consistency, and accessibility. Future research should explore long-term skill retention, generalization to live learners, and cost-benefit analysis of robot-assisted training in clinical and educational settings.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

Overview

Behavior analytic theories approach early childhood development differently than other theories such as Jean Piaget's Cognitive Development Theory or Lev Vygotsky's Sociocultural Theory. The cognitive development theories in early childhood education have strengths yet are missing a collaboration with behavior analytic approaches and vice versa. Cognitive theories, such as those developed by Piaget (1952) and Vygotsky (1978), offer valuable insights into how children think, reason, and make sense of the world. They emphasize the role of internal processes, social interaction, and developmental stages. However, they often lack specific, measurable strategies for teaching and behavior change. As advanced by Skinner (1957), behavior analysis focuses on observable behavior and uses evidence-based methods to shape learning and development through reinforcement and environmental manipulation. By integrating both approaches, educators and practitioners can gain a more complete understanding of a child including how they think and behave. A well-rounded approach could lead to more effective interventions and support in early childhood settings. Behavior analysis emerged as a field within child development in the early 1990s, according to Henry Schlinger (1992), but before then, child development theories were largely dominated by cognitive approaches like those of Piaget and Vygotsky. Bandura’s theories of early childhood development, attempts to bridge the gap between cognitive theories and behaviorism in his social learning theories. Pioneers like Sidney Bijou and Donald M.

Baer (1978) sought to bridge the gap between behavior analysis and traditional child development theories. Bijou's 1961 book *The Behavior Analysis of Child Development* introduced behavioral principles to early childhood development, however many behavior analysts have not sufficiently incorporated research from other fields (Schlinger, 1992). A few exceptions include Gewirtz (1972, 1991), who worked to merge social learning and behavior theories.

Typically, behavior analytic theories emphasize environmental factors in behavior development and may neglect social learning and emotional development. There are attempts to bridge the gaps addressed by the work of Gewirtz and Bandura. When early childhood development theories are absent within behavior analytic approaches it limits the effectiveness of interventions by disconnecting professionals from valuable insights. Schlinger (1992) argues that integrating behavior analytic theory with other developmental theories offers a more cohesive, efficient approach and framework for understanding and supporting child development.

However, merging behavior analytic theories with other child development approaches presents challenges. Behavior analytic theories focus on observable behavior shaped by the environment, but often overlook emotional regulation and social learning, which are central in many early childhood classrooms. Without a strong understanding of early childhood development, behavior analytic interventions may lead to inappropriate goals, which may negatively impact children's learning and growth.

Schlinger (1992), suggests that integrating early childhood development theories into behavior analysis would strengthen behavioral analytic approaches, particularly in early intervention settings. A deeper understanding of child development is essential for professionals to select appropriate curriculum, set relevant, achievable goals, and implement interventions that address challenging behaviors and promote positive educational experiences.

As mentioned above, while much research in child development focuses on cognitive, social and emotional theories, behavior analytic theory provides a functional understanding of why children engage in specific behaviors and how these behaviors are influenced by the environment. For example, behavior analytic theories allow for an understanding of motivation for engagement in behaviors and/or in various behaviors. It allows for an opportunity to teach appropriate replacement behaviors that could have a long-lasting effect on overall outcomes for the child. Piaget's theories, for example, focus on cognitive and emotional development, explaining concepts like object permanence and egocentrism without considering environmental influences on behavior (Piaget, 1947).

Integrating behavior analytic theories with developmental theories expands the understanding of child development beyond cognitive processes, providing a more comprehensive view. This fusion can enhance early intervention practices, improving the understanding of emotional regulation, attachment, and behavior modification strategies, ensuring interventions are holistic, efficient and effective. Addressing the professional development needs of staff is an essential step toward ensuring successful integration of these theories into practice.

In summary, behavior analytic approaches emphasize environmental factors and observable behavior patterns but often overlook social learning and emotional development. The work of theorists such as Vygotsky, Bandura, and Piaget are emphasized in a curriculum that would be implemented in a Montessori Classroom, for example. Although behavior analysis has significantly contributed to understanding early childhood behavior, its lack of integration with other developmental theories has led to gaps in the educational setting, especially concerning emotional and social growth. An integrated approach combining insights from cognitive and emotional development theories is especially important when addressing the needs of children who have developmental delays, such as ASD that creates a complexity in learning. ASD is considered a spectrum disorder, which means it includes a range of related conditions and may also involve individual symptoms and traits. According to DSM-5, ASD is a developmental disability that affects how people interact with others, learn and behave. ASD can have persistent deficits on social emotional reciprocity, social interactions, repetitive behaviors, interest and activities. ASD can include a language and intellectual impairment, behavioral barriers to learning and often presents itself in early childhood. Often early childhood developmental programs have limited resources to support the complexity of the child's unique needs. Staff development and cross training in various approaches might be a solution to bridge the gap and be a start for integration and combination of all early childhood developmental theories.

Prevalence in ASD

In 2018, the CDC reported that 1 in 44 children have been identified with ASD (Center for Disease Control and Prevention [CDCP], 2020) and ABA is one of the few recognized evidenced based treatments for ASD (American Psychiatric Association, 2022). Zablotsky et al. (1998) published a national study on the prevalence and trends of developmental disabilities among children in the United States from 2009 to 2017. In the form of a natural health survey, these data were collected to identify parents who reported their child being diagnosed with a developmental delay. From 2009 to 2011 and 2015 to 2017, there was an overall significant increase in the prevalence of developmental disabilities for children between the ages of 3 and 17. Data collected from 2015- 2017 noted that there was an increase in ASD diagnosis, moving the developmental prevalence to every 1 and 6 children (about 17% of children). The study found that boys are 4 times more likely than girls to be diagnosed with a developmental disability, particularly with an ASD diagnosis. There are many theories as to why there are increases to an ASD diagnosis which could be attributed to several factors, such as growing awareness of ASD and treatment for ASD, improved screening and changes to diagnostic criteria and reporting processes. It is unclear to the full extent of why there are continued increases in ASD diagnosis and further investigations are needed to better understand this phenomenon. As a result of early diagnosis, there are more children with ASD in early childhood education who require additional accommodation and support, inside and outside of the classroom (Shaw et al. 2022).

ASD in the Classroom

The increasing rates of children with ASD have had a profound impact on treatment availability in early childhood classrooms for children who require additional support. In the National Library of Medicine, Siller, Morgan, Wedderburn, Fuhrmeister, and Rudrabhatla (2021) described barriers to inclusive early childhood education for children with ASD. They mentioned that the age at which the child is first diagnosed in the community and the diverse presentation/support needed for the children with ASD are common concerns. The impact of an ASD diagnosis in early childhood classroom routines through modifications with individualized support, re-arrangement of the environments and applying evidence-based interventions for children to overcome obstacles and be successful in an early childhood classroom is critical. Early childhood programs play a critical role in helping identify early signs of ASD and support in leading families towards diagnostic testing with Head Start being a major provider of inclusive early childhood education services in Michigan. Early childhood teachers play a significant role in social and professional support during a period where parents might start to first recognize concerns about their child and help to navigate the diagnostic process and ASD specific resources. Often, early childhood education teachers will begin to implement individualized academic instruction and make classroom modifications prior to a child having an ASD diagnosis.

Interventions and Recommended Practices

With increased diagnosis in young children with ASD the obstacles can vary across each diagnosis which can make it difficult to meet all required modifications for appropriate intervention, thus making it more complex to address everyone's needs. Researchers advocate for creating supportive and engaging environments with well organized, stimulating environments which would be critical in minimizing behavioral issues (Bredekamp & Copple, 2016). Furthermore, research by Bredekamp & Copple (2016) describes the classroom as being designed learning spaces that are inviting, organized, and rich with age-appropriate materials that stimulate curiosity and that support the development of cognitive, social, emotional and physical development. The Division of Early Childhood (DEC) stresses the importance of family involvement as essential for behavioral expectations and helps strengthen the overall approach to behavior management. Creating a family-centered practice allows for family involvement that helps support consistency between the home and the school.

Positive Behavioral Interventions and Support (PBIS) is a proactive, school-wide approach to promote positive behavior by establishing clear systems of expectations, reinforcement, and support. It is built around the focus on teaching children's appropriate behaviors and provides positive reinforcement for meeting those expectations. Within PBIS, educators are expected to teach explicitly through roles and stories. Such as reading a book about sharing then practicing it. It is expected to be modeled throughout the day by the teachers and reinforced positively with praise, stickers, or tokens when children show the targeted behaviors. An example would be if a child helps a friend pick up toys. The teacher notices and says, *"Thank you for being kind and helping your friend clean up! That was a great choice!"* The child receives a sticker for their behavior, which goes on a chart toward a small class reward (like choosing a story or game).

There are many overlapping strategies between behavior analysis and early childhood when addressing behavior in the classroom. Early childhood professionals seek to promote positive behavior, teach social and emotional skills, and support the child's development by creating a nurturing environment. Some strategies include the teacher using social stories to describe appropriate behavior in socials situations. Social stories work to help create a visualization of the appropriate actions within a social situation (e.g., how to join friends who are already playing together) to help increase comprehension and expectations around that social situation. Offering choices in both an early childhood and behavior analytic strategy that shares control between the student and the teacher. In this strategy, the child's choice was included in the academic instruction which may decrease the need for challenging behaviors. Simultaneously, it increases the opportunity to learn decision making and responsibility. Social stories and providing choices are strategies used in a behavior analytic setting and an early childhood classroom.

When applying behavior analytic theories in early childhood development, it is essential for an educator to fully understand the scope of child development and the theories behind it. Child development is not just talking about theories; it also includes addressing milestones and incorporates developmentally appropriate skills.

Applied Behavior Analysis

Interventions derived from Applied Behavior Analysis (ABA) are evidence-based and rooted in the scientific study of behavior, utilizing empirically validated principles to produce meaningful and socially significant behavior change. Often, people with ASD have various (challenging) behaviors that are barriers to learning. Replacement behaviors can be used to replace challenging behaviors with more appropriate behaviors. Challenging behaviors may include aggressive behaviors, non-compliance, and/or avoidance of work. Some examples of replacement behaviors might be teaching functional communication skills or requesting a break (Copper, 2011).

ABA is a science that focuses on understanding why people engage in various behaviors and focuses on modifications to the environment to either decrease or increase behaviors. For families affected by ASD, ABA is used for early evidenced-based interventions of children to reach goals that will increase the quality of life for the child and their family (Fisher, et al. 2020). An individualized approach to ABA therapy is essential, as each child's needs are different and require therapy to be tailored to these individualized needs.

Discrete Trial Training in ABA

Discrete Trial Training (DTT) is a specific ABA-based intervention to help support children with ASD acquire new skills (or new replacement behaviors). These new skills are also referred to as acquisition targets. Each acquisition trial consists of a targeted academic instruction and a correct response from the child followed by reinforcement. An error correction is provided if the response from the child is incorrect, or if no response occurs. An error correction begins with representing the academic instruction paired with an immediate prompt and followed by a high probability sequence. High probability sequence is a method used to gain instructional control or gain compliance by using easier or already learned tasks prior to delivering the challenging task. High probability sequences increase motivation to respond to an academic instruction and ensure that an individual’s next response is associated with the targeted instruction. The trial then ends with representing the target and followed with either error correction or reinforcement. Common practice in ABA suggests that to acquire (master) a target behavior, an individual must correctly respond to 80% of the total acquisition trials presented during a session over two consecutive sessions, across two different people, in two different environments. Once a target meets this criterion for mastery, the target is no longer considered in acquisition. The target would then be considered a maintenance trial. The maintenance trials can be used within high probability sequences. For a child to make effective, efficient, and lasting changes, it requires a skilled practitioner to fully understand the importance of skill acquisition in

ABA. To ensure optimal outcomes, this entire process must be individualized based on the learner's unique needs, strengths, and rate of progress. Due to the increasing prevalence of ASD, there is a high need for skilled practitioners.

Significance

To fully understand the significance of the research question outlined later in this text, it is important to explore the depth of the prevalence of ASD, the demand for practitioners, training, staffing, and requirements needed to meet service needs. In discussing the significance, I will provide information on the Board-Certified Behavior Analysist (BCBA) role and the structure of therapy, focusing on staffing needs and staff expectations in education and training.

ABA is a field that requires a BCBA to be eligible to implement the treatment (BACB, 2022). A BCBA is governed by the Behavior Analyst Certification Board (BACB) and requires a master's degree or higher with a certified course sequence that must be approved by the BACB for certification. The intensity of these requirements to implement ABA and the growing number of individuals with an ASD diagnosis limit the availability of qualified professionals to deliver this service (American Psychiatric Association, 2022).

According to the BACB, there are only 37,859 BCBA's in the United States as of June 2020 (BACB, 2022). Even though the number of BCBAs continues to grow, there still is a significant shortage of skilled practitioners to deliver effective, efficient, and quality ABA therapy (American Psychiatric Association, 2025). It is important to note the educational and training that is required of a BCBA, as they are the professionals that guide the ABA programming. Each ABA program has a BCBA who leads the program and trains therapists to help deliver the interventions. The therapists working under the BCBA are often bachelor-level therapists. These therapists are typically newly graduated, and/or new to the profession. Considering this, there are significant training needs for these entry level staff, and BCBA's are often tasked with the responsibility of training. The need for services is significantly greater than the availability of BCBAs or trained therapists. BCBAs are then required to engage in supervision over staff members such as Registered Behavior Technicians (RBT). Training RBT for a position in ABA can be very time consuming. It is encouraged by the BACB for technicians to receive their (RBT) certification to learn the basic concepts of ABA. According to the BACB, an RBT candidate must complete at least 40 hours of training and complete a competency assessment before taking the RBT exam. After a technician passes the RBT exam, the BACB requires the RBT to maintain certification annually. To maintain certification, a person must continue on-going supervision, pass an annual competency evaluation, and adhere to the ethical code of conduct outlined by the BACB. To obtain 40 hours of training, often ABA providers use online training programs. When using a training program online, the ABA provider will often compensate the employees for their time spent in in-person training as well as the online training course, that often can be costly. Rochat & Charania, (2019) published an article that discusses concerns regarding the adequacy of training in ABA even with the RBT certification established by the BACB. As a result, some professionals may lack the necessary knowledge to effectively address complex, multi-dimensional child development issues, such as emotional regulation, social skills, and language development. This gap in training may hinder the ability to provide well-rounded, individualized care, especially for children with ASD. This lack of continuity and expertise can lead to inconsistent implementation of treatment plans, potentially diminishing the effectiveness of interventions (Rochat & Charania, 2019).

In many cases, a BCBA is tasked with conducting the 40 hours of training required for behavior technicians, which can be extremely time-consuming and often feels unrealistic, especially when trying to manage an already established caseload and meet ongoing supervision requirements. When training is not sufficient, the integrity of the delivery of the ABA is at risk (Rochat & Charania, 2019). For example, with lack of sufficient training, children in ABA programs may not receive quality services, thus limiting the chance for the child to have an opportunity to reach their fullest potential (Smith & Jones, 2017). In addition to focusing on receiving the fullest potential, a poorly trained therapist could inadvertently reinforce challenging behaviors, stall the child's learning, and impact adequate data collection, misinterpretation of behavior, or make learning an aversive activity (Rochat & Charania, 2019; see also Smith & Jones, 2017). Staff training and development has an impact on the outcome of services and quality of life for the child.

Traditional staff training methods in ABA often rely on presentations, webinars, training videos, and lectures. While these approaches offer flexibility, accessibility, and cost-effectiveness for a wide audience, they often lack opportunities for real-time clarification, hands-on practice, and deeper engagement with the material. Additionally, such formats provide limited means to assess knowledge retention and the practical application of newly acquired skills (Kranak et al., 2019). Based on the staff training needs, what improvements can the field of applied behavior analysis do to increase staff training for more efficient and effective results to be applied in practice? Given these limitations, it is essential to consider how the field of ABA can improve staff training methods to ensure more efficient, effective, and sustainable implementation in practice.

Research Question

Given the variety of theories in early childhood development, it can be challenging to determine the best approach. This dissertation will explore the application of behavior analytic theories in staff development and training for ABA programs in early intervention. As the number of ASD diagnoses rises, the demand for skilled practitioners has increased. The challenge lies in meeting this demand without compromising the integrity of the practice, while effectively integrating early childhood theories to enhance support for the developing child. To address these challenges and opportunities, the following research question will be examined. Can a humanoid Nao robot effectively train individuals with no prior experience in ABA to implement DTT procedures? How does the use of a humanoid Nao robot in a behavior skills training (BST) framework impact the procedural accuracy of trainees during training?

CHAPTER TWO

LITERATURE REVIEW

Theorical Framework

To receive early intervention services, children must first undergo an evaluation for developmental delays. A developmental delay refers to a condition in which a child is mentally, cognitively, or physically less developed than their peers or what is typical for their age (American Psychiatric Association, 2022). These delays may manifest in infancy or later, and can stem from genetic factors, inherited cognitive impairments, or severe medical conditions. Developmental delays can significantly impact a child's ability to learn, retain information, and develop the skills necessary for independent living, a high quality of life, and social, emotional, and mental growth (American Psychiatric Association, 2022).

The Individuals with Disabilities Education Act (IDEA), established in 1986, aims to support the development of infants and toddlers with disabilities, reduce potential developmental delays, and decrease the need for later special education services. Part C of IDEA specifically addresses early intervention for children from birth to age three, focusing on fostering social engagement, independence, functional communication, play skills, social compliance, cognitive abilities, and skill generalization. Early diagnosis of ASD can occur as early as 18 months, which means there are approximately 18 months remaining before a child age out of early intervention services under Part C due to the age limit. This limited timeframe can create a barrier to continued care following diagnosis and early educational support. It is important to note that IDEA also provides Early

Childhood Special Education (ECSE) services for children aged three and older, facilitating continued support beyond early intervention. For this research, it will be essential to discuss key topics including early intervention, ASD, the theoretical framework of Applied Behavior Analysis (ABA), and evidence-based practices.

Early Intervention

According to CDC, early intervention services are crucial for babies and young children with developmental delays and disabilities. These services may include speech therapy, occupational therapy, and behavioral therapies like ABA. Early intervention is most effective when provided in the first five years of life, which are critical for brain development (Crain, 1999). The CDC (2018) states that early intervention is not only more effective but also less costly than later interventions. Consistency in care is key for these interventions to have a lasting impact, as supported by research from the National Association for the Education of Young Children (NAEYC, 2022). Despite the growing need for qualified professionals, the CDC highlights a significant shortage of trained experts in early childhood development and intervention. Collaboration among professionals is essential to provide comprehensive care for children in early intervention programs.

In Michigan, the Early On program, under Part C of IDEA, provides state-funded services in education, physical therapy, occupational therapy, speech therapy, and family counseling to infants and toddlers. These services are typically delivered to home or public schools until age 3. To work in Early On, professionals require a bachelor's degree in early childhood education or a related field, along with ongoing education and training. However, ABA services are not currently provided under this program, even though they are covered by Medicaid or private insurance for children with ASD. It is unclear why ABA has not been integrated into Early On, but simplifying the training for professionals might facilitate its inclusion. It is hypothesized that factors related to philosophical difference are a leading influence on the lack of integration early on.

Autism Spectrum Disorder (ASD)

ASD is a developmental disorder characterized by deficits in social communication and interaction, along with restricted and repetitive behaviors (Hansen, 2013). Communication challenges can include difficulties with social reciprocity, nonverbal behaviors, and understanding relationships, while restricted behaviors may involve repetitive movements, echolalia, or rigid routines. These barriers can cause significant impairments in a child's quality of life and independent living skills (Hansen, 2013).

Skinner: The Start of Applied Behavior Analysis

B.F. Skinner, an American behavioral psychologist, was identified as one of the most influential psychologists in the 20th century in behavioral approaches to child development (Schlinger, 1992). Due to his discoveries in the analysis of the effects of consequences on behavior, Skinner identified procedures that evolved to demonstrate a clear and orderly reliable functional relationship between the behavior and various environmental changes and environmental events (Cooper et al., 2001). He was successful in this experimental analysis through the process of replication and the development of ABA. Skinner's success in the experimental analysis of behavioral theories in child development became the basis for ABA. During his experimental analysis, Skinner manipulated the environment to identify variables that may evoke behavior. Excluded in the theories by Watson, Skinner believed that Radical Behaviorism seeks to understand all human behavior, including the why and how of a behavior. Radical Behaviorism, which aimed to explain all human behavior—including thoughts and language—by analyzing observable behavior and its environmental causes. Skinner spent over two decades developing his theory of verbal behavior, which became foundational in the field of Applied Behavior Analysis (ABA) (Sundberg & Michael, 2001). Skinner's analytic framework sought to explain how language is learned, not as an innate ability, but as a set of behaviors shaped by the environment. In his book Verbal Behavior (1957), Skinner defined verbal behavior as behavior that is reinforced through the actions of another person, rather than through direct interaction with the physical environment. For example, a child saying "milk" and receiving milk from a parent demonstrates verbal behavior maintained by social reinforcement. Skinners' analytic framework looked to understand verbal behavior and theories of how language is acquired. Skinner defined verbal behavior as established and maintained by reinforcement that is mediated by another person. He believed that verbal behavior was shaped by the environment, and that controlled relations included the speaker's motivational state, stimulus circumstances, past reinforcement and genetic composition (Crain, 1999; Sundberg & Michael, 2001). Skinner identified language in stages, which worked like building blocks in verbal behavior (Cooper et al, 2011).

The verbal operants in language development are structured in stages that follow developmental skills (Cooper et al., 2011). It should be noted that children can acquire the domains of verbal behavior (i.e., verbal operants) simultaneously. Multiple language, verbal behavior targets can be addressed at one time. For example, a child can learn to tact a bird (e.g., “A bird!”), echo someone saying “bird”, mand (i.e., request) a bird and answer a question about a bird, “What flied in the sky?” (i.e., intraverbal) at the same time. Skinner believed that a child must complete each stage of verbal behavior for successful communication (Sundberg & Michael, 2001; Cooper et al, 2001).

Manding (i.e., requesting) is identified as the first stage. In this stage the child would begin communication requesting for items they desire. The second stage is identified as tact (i.e., labeling). Tact(ing) is when the child can begin labeling things in the environment. Echoic, the third stage is when the child begins to echo or repeat language. Intraverbal, the fourth stage is when the child can engage in social exchanges and conversation skills with appropriate reversals in communication. Textual, the fifth stage of language development is identified as when a child can generalize language by reading written words. Transcription, the final stage of Skinner’s verbal operant in understanding language development in early childhood. Transcription is when a child can take written words to spell or write the words. (Cooper et al, 2001). Unlike Bandura who argued that language development takes place primarily through the process of observation and imitation, Skinner argued that children learn language as parents selectively reward or punish during the stages of language development. In addition, children who may apply language rules rather than simply repeating reinforced words.

Often, children diagnosed with ASD who have a deficit in social communication have not yet developed one or more of these domains (Cooper et al., 2001). In the delivery of ABA therapy, children diagnosed with ASD are taught each domain of verbal behavior through the process of reinforcement and motivating operations (Sundberg & Partington, 2001; Cooper et al., 2001, Crain,). On the contrary, Noam Chomsky published a critique of behaviorism in 1959 "The Case Against B. F. Skinner" outlines Chomsky's concerns with Skinner's ideas on behaviorism, focusing on how Skinner lacks discussion about freedom and dignity (Chomsky, 1959). Through the process of reinforcement, Chomsky (1959) states that freedom and dignity are removed through control and attempting to change their mind. Chomsky (1959) criticized Skinner for the limitations of behaviorism as it does not address the internal state including impulses, feelings, purposes, state of mind and personality. B.F. Skinner's work laid the foundation for Applied Behavior Analysis by demonstrating that human behavior could be understood, predicted, and modified through the systematic application of reinforcement principles. Skinner's work was highly empirical, and data driven. His experiments were carefully designed and conducted, providing concrete evidence to support his theories. This emphasis on observation and measurement helped establish behaviorism as a scientific discipline. His emphasis on observable and measurable behavior led to interventions that are both evidence-based in a variety of settings, including education, developmental disabilities, and behavioral health (Cooper, Heron, & Heward, 2020).

Evidence-Based Practices in Developmental Disabilities

Evidence-based practices are interventions that have been rigorously tested through research and clinical experience (Cooper, 2011). These practices are scientifically validated through repeated studies and clinical trials. The following sections discuss evidence-based interventions for children with developmental disabilities, including ASD. ABA is a widely recognized evidence-based approach used to teach new skills and replacement behaviors to children with ASD. ABA addresses challenging behaviors, such as aggression or noncompliance, by teaching more appropriate behaviors, like functional communication or requesting a break (Cooper, 2011). ABA focuses on understanding why a child engages in specific behaviors and modifies the environment to either increase or decrease those behaviors, ultimately enhancing the child's quality of life (Fisher et al., 2020). DTT is a specific ABA intervention used to teach new skills or replacement behaviors (acquisition targets). Each trial consists of a targeted academic instruction followed by reinforcement for a correct response, or a prompt if the response is incorrect (Lovaas, 1987). High probability sequences are often used to increase motivation by preceding difficult tasks with easier, learned ones. To master a skill, a child must respond correctly to 80% (or more) of trials across two consecutive sessions, with the target moving to maintenance once this criterion is met (Lovaas, 1987).

This dissertation aligns with the theoretical framework of ABA and early intervention by addressing the need for effective and efficient training in evidence-based procedures. The needs of young children with ASD and the complexity of interventions, such as ABA, have been presented. It has also been stated that there is a need for effective teachers/interventionists. Therefore, robots as teachers, trainers or a proxy child is being explored. Given the increasing demand for skilled professionals in early intervention, there is a pressing need for innovative solutions that can enhance service delivery and training quality. The integration of behavior analytic techniques with robotic technology presents a promising avenue to address this challenge. Robots can offer consistent, controlled, and engaging learning environments that support the acquisition and generalization of key developmental skills in children with ASD. Moreover, using robots in both practice and training can enhance the scalability and precision of interventions, potentially improving outcomes for children and families while alleviating pressure on an overburdened workforce. This leads to the hypothesis that incorporating robotics into early behavior analytic interventions may significantly enhance their effectiveness and accessibility.

Robots Research with ASD

Robots have the potential to facilitate efficient training and generalization by adhering to evidence-based training approaches in ABA for children with ASD. Leiman et al. (2021) explored the use of a parrot-like robot to teach turn-taking skills to children with ASD. In a single-subject design, the robot engaged children in a card game, either with a therapist or independently. The results indicated that interactions with the robot led to larger effect sizes in turn-taking behaviors compared to interactions with a human therapist. Therapists reported that the robot's engaging nature facilitated the therapy process and suggested incorporating additional functionalities and games to enhance learning and generalization of turn-taking tasks. In addition, Clabaugh et al. (2019) investigated the use of an in-home socially assistive robot to support children with ASD. The robot utilized a hierarchical human-robot learning framework, adapting its interactions based on each child's learning patterns. Over a month-long intervention, children aged 3 to 7 years engaged with the robot in personalized math games. Results demonstrated significant improvements in targeted skills and long-term retention. Caregivers reported increased eye contact, initiation of communication, and responsiveness to others. The robot's adaptability and the high level of engagement were highlighted, suggesting its potential as a valuable tool in home-based interventions for children with ASD.

Robots can be integrated into traditional ABA practices, such as DTT, to assist with behavioral interventions. For example, robots can deliver commands, prompt correct responses, and provide reinforcement. The use of robots can also help maintain a high level of motivation and engagement, especially for children who find human trainers less engaging. Werry, et. Al. (2001) conducted a study exploring the use of robots in therapy for children with ASD. During this study, they focused on how robotic systems could be integrated into interventions designed to improve communication, social interaction, and behavioral skills in children with ASD. In this research, the authors evaluated the potential for a robot to serve as a motivational and instructional tool during ABA therapy. They found that robots could be effective in encouraging children to engage in activities, providing consistent feedback, and reinforcing learning behaviors. The robot's ability to model behaviors and present prompts or cues in a predictable manner was beneficial in keeping children engaged during therapy sessions. In addition, robots could be designed to meet individual needs and help children practice social skills, such as turn-taking, making eye contact, and responding to prompts.

In research conducted by Baraka et al., (2019) a Nao humanoid robot was programmed with behaviors characteristic of ASD, based on the Autism Diagnostic Observation Schedule-2nd edition (ADOS-2), a diagnostic tool for ASD. Each programmed behavior varied in severity, including speech, eye contact, gestures, and verbal responding. The robot could be programmed with a total of 256 customized behavioral profiles for training and staff development. The robot possesses multiple senses that can be programmed to respond in various ways, akin to sensor receptors that react to touch and movement. A robot that can be programed to mimic an individual with an ASD allows the trainee to experience the robot that simulates some possible barriers in working with a child in ABA.

Incorporating robots into a training process can save valuable time by delivering consistent, standardized interactions and support. Robots like the humanoid Nao replicate human behaviors, gestures, and vocalizations, allowing them to reliably engage individuals in training scenarios. This consistency ensures that all participants receive uniform instruction, reducing variability often present in human-led training. By integrating robots into the training model, the workload on BCBAs is alleviated, freeing them to focus more on individualized care and complex cases. This research proposes leveraging humanoid robots such as Nao to enhance therapist training in ABA, providing an efficient, evidence-based solution that optimizes resource allocation and improves overall training effectiveness.

Robots in ABA Therapy

While there is a growing body of literature on the use of robots with children and in mental health settings, limited research exists on their application in ABA staff training, particularly for those working with children with ASD. Current studies primarily focus on therapeutic outcomes for children rather than on how robots might be used to train or support ABA practitioners. This gap highlights the need for further empirical investigation into the feasibility, scalability, and effectiveness of using robots in real-world ABA staff development contexts.

While the use of robots in ABA therapy sessions is still developing, their application in ABA staff training remains largely unexplored. This gap highlights the need for further research to evaluate their potential in enhancing staff competence and improving training efficiency, especially in response to the growing demand for ABA services for individuals with ASD. In this section, existing research on the use of robots in therapeutic settings will be reviewed to provide context for their possible role in future staff training.

Recent research has explored the use of robots in ABA therapy to teach social skills to children with ASD (Korneder et al., 2021). Robots can help children practice social interactions such as eye contact, gestures, and body language, which are often challenging for children with ASD. These robots can also support the generalization of learned skills across various settings (Korneder et al., 2021).

In a literature review, Saleh et al. (2021) categorized robots used in autism intervention into three main types: social robots, therapeutic robots, and assistive robots. Social robots are designed to engage individuals in social contexts, helping them practice social behaviors such as eye contact, conversation, and joint attention. Therapeutic robots are employed in structured therapy to assist with emotional regulation, learning tasks, and behavior management. Assistive robots help with daily activities and provide routine-based support to individuals with ASD. Saleh et al. (2021) highlighted several studies that showed robots can improve various aspects of social interaction and communication with individuals with ASD. For example, these robots were noted to increase interactions by promoting eye contact, turn-taking, and more sustained attention and motivation. Future directions suggested in the literature review by Saleh et al. (2021) recommend that robots should be complementary tools in therapy rather than replacements for human caregivers, with an emphasis on integrating robotic support within broader, human-centered therapeutic approaches.

The primary goal of the study conducted by Valadao et al. (2016) was to analyze how robotic interventions can be used to improve social skills in children with autism, promoting social interactions, emotional regulation, and communication. This research involved observational methods to collect data on the children's responses, including eye contact, social engagement, and participation in tasks. The results indicated improvements in eye contact, joint attention, and social engagement, and the children were more likely to engage in activities during the robot-mediated sessions compared to traditional therapy approaches.

These studies contribute to the growing body of research indicating that humanoid robots hold significant promise as tools for training individuals in autism interventions. By providing a novel and engaging platform, robots can support the acquisition and practice of essential skills in a consistent and motivating manner. However, further research is necessary to explore how robotic technology can be effectively integrated into ABA training protocols, to maximize its impact on practitioner skill development and early childhood outcomes within the field of autism intervention.

Research in Training Methods

To further the understanding of methods used in this research, it will be important to discuss the training methodology to be used in supporting staff training in ABA. BST is considered a gold standard for training, addressing the limitations of traditional methods by focusing on applying knowledge and assessing skill competency (Kranak et al., 2019). The BST model begins with the trainer providing clear written instructions in BST, followed by an evaluation of performance. The trainer then demonstrates expectations, guides the trainee through role-playing, and provides feedback to ensure mastery of the skills. Revisions are made as needed to help the trainee achieve competency in all steps (Kranak et al., 2019). Research supports the effectiveness of BST in improving staff performance across various ABA content areas. While the training duration may vary based on individual performance, mastery often requires several sessions. Some trainees achieve mastery after the initial attempt, while others may need repeated practice to reach competency.

Many ABA professionals combine BST with additional methods, such as video modeling for self-evaluation (Aherne & Beaulieu, 2018). In a study by Aherne and Beaulieu (2018), BST was implemented with new hires at a behavioral health agency providing in-home services. The study found that baseline performance ranged from 55% to 77%, but after BST implementation, procedural integrity increased to nearly 90%.

Overall, the current research supports the concept that a robot, when integrated into ABA practices, can offer a powerful tool for both intervention and possibly in staff training. The robot had the ability to engage children and deliver structured interventions while ensuring consistency. They could be a promising asset in the field of ABA, particularly for children with ASD. As research continues to grow, the application of robots in ABA is likely to expand, further enhancing the effectiveness of treatment and training.

CHAPTER THREE

METHODS

Overview

Given the limited literature on the use of robots in training advanced ABA methods, this research explores how robots can expand training opportunities in ABA using the BST model. As technology continually evolves, the goal is to identify effective ways to provide staff training in ABA using robots. Integrating robots into training could help maintain the integrity of ABA by supporting efficient training for complex models like BST. Notably, current research has not significantly focused on training new behavior technicians to implement DTT procedures with a robot simulating a child. This gap makes it unclear how effective robots can be in enhancing ABA programming, improving procedural integrity, and supporting staff training outcomes. Despite the effectiveness of the BST model, it has been shown to be time-consuming (Shapiro & Kazemi, 2017). Therefore, this research investigates whether a humanoid Nao robot, simulating a child, can assist in training new staff members. This study aims to demonstrate the efficacy of the humanoid Nao robot in facilitating staff training using the BST model. The following research question guided this study: 1) Can a humanoid Nao robot effectively train individuals with no prior experience in ABA to implement DTT procedures? 2) In what ways does the use of a humanoid Nao robot in a BST framework impact the procedural accuracy of trainees during training?

Participants and Setting

The participants for this study (*n* = 9) included individuals 18 years of age or older who had no experience or exposure to ABA techniques and were undergraduate students at a university in the Midwest. Participants were excluded if they had experience or exposure to the field of ABA. It was important to identify individuals who did not have any exposure to ABA to ensure 1) previous exposure was not a variable that aided in new skills learned, and 2) the results of the training were a direct reflection of the skills learned with the humanoid Nao robot.

The participants were recruited at a large, public, R2 university in the Midwest and had no prior connection to this research. Four of the participants had experience working with a humanoid robot; one student was interested in working in the field of ABA; three participants were pursuing a degree in social work; the 6^h participant had no experience in ABA or robots and was pursuing a degree in biology. Each participant followed the same training procedure with the same materials and in the settings. This study took place in a therapy room within an ASD clinic at a university in the Midwest. The therapy room had a desk, a double-sided mirror, and two chairs, a camera and materials needed for the DTT trials.

Materials

The materials for this research consisted of a humanoid Nao robot, which was programed and used to mimic a child with ASD, as well as materials to perform the DTT targets. The humanoid Nao robot was controlled remotely through Wi-Fi and has seven sensors and bidirectional microphones and 2D cameras for sensing the environment. Movement of the humanoid Nao robot was made possible with its 58 cm in height, two degrees of freedom (DOF) in head, five DOF in each arm, and one DOF in each hand. The robot stood on two feet with six DOF on each leg. There are speakers inside the robot that produce verbal responses. The DTT target materials included a small toy car, a small ball, a book, a juice box, playdough, a data sheet and paper with definitions used for the training procedure, a laptop with training videos, and a video recording system.

Experimental Design

This research used multiple baselines across participant's design. A multiple baseline across participants design provides the opportunity to support replication and consistency across multiple participants. Nonconcurrent multiple baseline methods allowed for flexibility in the recruitment of the participants and for careful visual analysis of the effects of the intervention. Nonconcurrent multiple baseline methods enabled the assessment of how each participant responded to the training at their own pace, providing more nuanced and reliable conclusions about the effectiveness of the humanoid Nao robot in ABA training. Considering that a nonconcurrent design was used in this research, participants did not begin their baseline at the same time. For example, Participant 1 started with baseline data collection, whereas Participant 2 started baseline data collection after Participant 1's baseline data had been established. Participant 3 started baseline data collection after Participant 2's baseline data was established, and so on. During the introduction, the intervention was staggered to each participant at different times, following the collection of baseline data. For example, once Participant 1 had achieved mastery criterion, Participant 2's intervention phase began. It was important to stagger the intervention because it allowed for the comparison of each participant's performance after the intervention was introduced, while helping to eliminate potential confounding variables.

Independent Variable

The independent variable in this study was BST. BST is a structured and systematic approach to teaching new skills and involves four critical steps (see figure 1). The first step is instructions in BST on the expectations and key components of the training (Appendix 1). The second step is that an individual fluent in the key components models the expectations to the learner. The third step allows for the learner to rehearse the key components and expectations that were instructed and modeled. The fourth step requires feedback from the rehearsal step (step 3) so that the learner can make appropriate modifications to meet the expectations. The BST steps remained consistent throughout the intervention with video modeling and a list of key terms. This allowed all participants to be presented with the same materials, without error or inconsistencies throughout the training. The humanoid Nao robot was programed to maintain consistency across participants during the intervention process (see figure 2)

Figure 1

BST visual

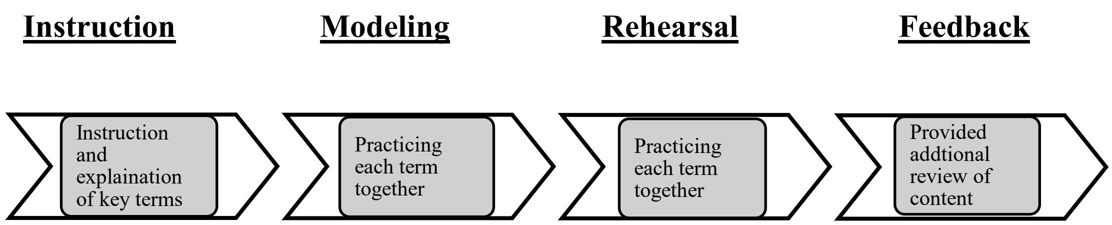
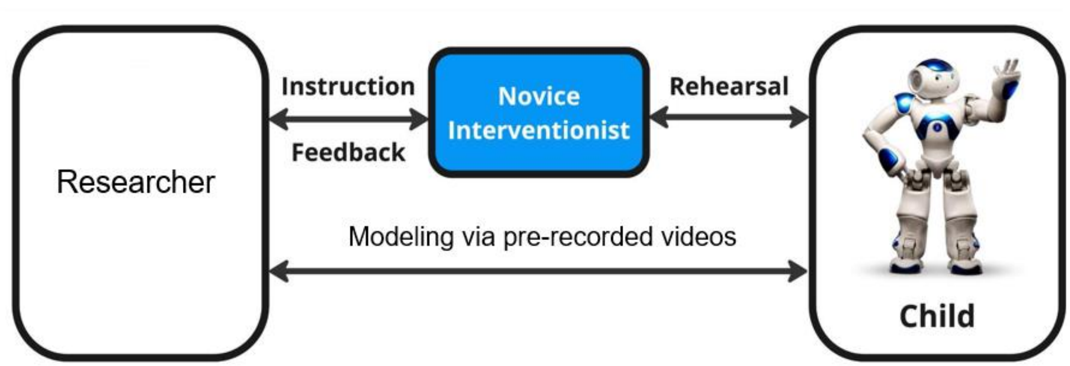


Figure 2

Using BST and a robot to simulate a child.



DTT included a direction to follow, the response of the child-simulated robot and the delivery of reinforcement. Each DTT session consisted of 15 acquisition trials. Acquisition trials are skills a child may need to learn and tend to follow developmental milestones. A mini preference assessment is when the child is presented with a limited selection of items or activities to choose from right before a teaching session to identify the most preferred or motivating item to work for. Within each acquisition trial, the participant presented the robot with a mini preference assessment (see Appendix 2). During this research, the participant held up two preferred items and asked the robot which one the robot wanted to work for. The robot chose one of the items. Next, the participant delivered the academic instruction to evoke a response. If correct, the robot was provided with a reinforcer. Descriptive praise is when the participant used verbal praise statements to the robot describing the correct behavior emitted by the robot. An example is saying: "Nice, work telling me this is a car!" Descriptive praise was used as reinforcer after each correct response from the robot.

If an error or incorrect response occurred, the learner was taught to begin the process of error correction. Error correction, a method of teaching, often uses a high probability (HP) sequence to increase motivation in learning. A HP sequence in an error correction typically follows an incorrect response and tend to be simple skills already in the child's repertoire. HPs are often implemented to increase motivation in children by exposing them to easier tasks for successful responding before the delivery of more complex skills. Error correction often includes repeating the complex skill, prompting the correct response to support the teaching of a new skill. For this research, error correction was implemented in five steps after an error had occurred. Error correction included a redirection such as “Let’s try again.”, representing the demand with a prompt to support a correct response from the robot, a HP target, representation of the academic instruction for an opportunity for independent responding and ended on social (verbal) reinforcement.

When a response was incorrect by the robot, the participant started the steps of an error correction. Error correction is a strategy used to provide feedback, re-teach the corrective behavior to help the learner encounter the correct or preferred response.

Dependent Variable

This research was designed to measure acquisition targets in the areas of manding (requesting), imitation, receptive instruction, tacting (labeling) and emotions. Correct implementation of the targets by the participant was defined as following the DTT steps with at least 80% accuracy. This measure reflected the accuracy with which the participant (or robot) executed each component of the DTT sessions, including correctly responding to instructions in BST, engaging in reinforcement procedures, and following error correction protocols. Participant performance percentages were calculated by dividing the total number of correct delivery of trials to the robot, correct delivery of error correction and correct delivery of reinforcement, with the number of opportunities presented throughout the session.

Interobserver Agreement

Interobserver agreement (IOA) data were collected through repeated reviews of recorded sessions by the same researcher at different times. During these video reviews, the researcher gathered data while having the ability to pause and re-evaluate behaviors as needed, ensuring careful and accurate scoring. This method allowed for detailed analysis that may not have been possible during live sessions. Once the data from the video recordings were fully collected, they were compared to the data recorded in real time during the study. Although traditionally IOA involves multiple observers, this approach was deemed acceptable in this study due to resource constraints and the advantages of video review, such as enhanced accuracy and the ability to verify responses retrospectively.

Procedural Fidelity

In BST, procedural fidelity is critical because the training involves multiple components that must be implemented in a specific sequence and with precision. Each step has a distinct purpose, and any deviation from the prescribed procedure can reduce the training's effectiveness, resulting in incomplete skill acquisition or inaccurate behavior change. Consistency in materials and delivery across all phases of BST is essential to maintain high procedural fidelity. Procedural fidelity was ensured by using standardized materials, such as pre-recorded training videos, which guaranteed that all participants received identical instruction. During training sessions, the researcher remained with the participant to monitor correct implementation of protocols in real time. Additionally, all sessions were video recorded to allow for detailed review and measurement of procedural fidelity after the intervention. Fidelity was measured by systematically reviewing these recordings to verify that each BST step was delivered accurately and in the correct order. This video-based fidelity assessment was appropriate because it allowed for precise, objective evaluation and the opportunity to pause and reexamine components, reducing potential errors or oversight that can occur during live observations.

Data Collection Procedure

A robot was programmed to simulate a child and respond to the participant creating opportunities to practice DTT implementation. Data collection involved the correct delivery of the implementation of targets within a DTT program, which also included the measurement of establishing motivation, delivery of the academic instruction to the robot, implementing the error correction, delivering the reinforcer and providing descriptive praise. In addition, the robot was programmed to enact random errors, to measure the participant's ability to correctly implement the error correction procedure within the DTT process.

For baseline, the participant was presented with written definitions of how to implement DTT. During the baseline condition, the participant was provided with a one-page document that described the definition of important key terms related to ABA and DTT. The participant was told to implement DTT based on the written definitions that were provided to the best of their ability. The terms in this document contained key definitions related to ABA and DTT.

Intervention Data Collection

Data were collected based on the correct implementation of the DTT targets and averaged into a percentage based on the opportunities presented. Each participant received the same number of opportunities to implement DTT correctly. For each correct response, the researcher recorded a plus sign (+) on the data sheet. For each incorrect response, the researcher recorded a minus sign (-) on the data sheet. Baseline measures established a starting point, and during the intervention phase, the researcher assessed the percentage of growth achieved after the training (Appendix 3). Subsequently, the researcher evaluated the percentage of accuracy in the post-intervention phase. The data collected were compiled and graphed using Excel. This graphical representation provided a visual analysis of each participant's accuracy in implementing DTT, allowing for a comprehensive assessment of the intervention's effectiveness.

Data Analysis

Data across all phases were analyzed through visual analysis of trends and to ensure stability. Each correct response was counted as a single response and the responses were collected to achieve a percentage. A percentage was collected by identifying the number of valid responses by the total number of responses available. Each participant had the same number of opportunities to respond to the robot. This process was completed across all stages of this research, including the pre-experimental procedure, baseline, intervention, and post measures.

General Procedures

Before each session, the researcher ensured the cameras were working and ready to record. When the participant sat down, the researcher began recording. Transitions in the training meant that the researcher was required to provide directions on when to move to the next training slide without providing any contextual feedback that would interfere with the training. The researcher remained neutral during the training process to avoid influencing participant behavior. While the participant engaged with the humanoid Nao Robot, the researcher recorded data on their delivery of DTT.

Pre-experimental Procedure

During the pre-experimental procedure of this study, it was required to collaborate with the department of engineering to ensure the proper functionality of the humanoid Nao robot. The pre-experimental procedure of this study allowed the researcher to run through all the outlined steps to ensure accurate dissemination and address any potential issues that could arise. During the pre-experimental procedure, it was determined that, to effectively meet the requirements of the feedback component of BST for efficiency, the modeling videos needed to be segmented. The researcher divided each section of the original modeling video into individual videos based on specific topics. This organization allowed the researcher to quickly access the relevant content during the feedback portion of BST. It should be noted that there were no changes that needed to be made to the research design after the pre-experimental procedure.

Baseline

The participant began by reviewing and signing the consent forms. Once completed, the participants were provided with a list of terms, a data sheet and the session materials. When the robot was on and ready, the researcher recited the following statements: “At this time I cannot answer any questions, to the best of your ability please use these items to teach the robot what these items are. You may use this data sheet. Please let me know when you are completed and the robots name is Salt.” Once the participant indicated they were finished, the researcher calculated the baseline data.

Behavior Skills Training (Intervention)

The first step in the BST sequence was instruction (in BST), which included a list of key terms, a review of a data sheet, and a video recording explaining each term with examples of how to apply them. To begin, the researcher provided the participants with a list of key terms and data sheets to read on their own. Once the participant indicated to the researcher that they had completed the reading, the researcher transitioned to the computer to show the participant the video recording of the key terms. The video also provided examples of the key terms. Once the participant indicated completion of the video, the researcher moved on to the next video.

Modeling, the second step in BST, was the next part of the intervention. The next video featured an individual demonstrating how to apply the key terms and model the DTT requirements. The video included quick pauses at pivotal points to pair the key term with the corresponding action being modeled. Once the participant identified that they had finished watching the video, the researcher set the computer aside and brought out the same materials used in the baseline phase, preparing the robot for the next step.

Rehearsal, the third step in BST, was then implemented. During this step, the participants practiced the skills they had learned from the instruction in BST and modeling steps. They used the materials from baseline and engaged with the robot. The participant was provided with the same key list of terms and data sheet to refer to while working with the robot. The researcher gathered data on the implementation of each step in the DTT trials. When the participant indicated they were finished, the researcher set aside the materials, analyzed the data, and provided feedback if the participant did not meet the mastery criterion of 80% or higher.

For participants who did not meet the mastery criterion, the researcher reviewed each data point to pinpoint areas for improvement. Feedback was provided by reviewing the relevant portion(s) of the modeling video(s) along with the key terms list. This procedure ensured consistency in feedback across all participants. Once the participant had completed the feedback review, the researcher presented the materials and robot again to repeat the rehearsal step. The Feedback and Rehearsal phases were repeated until the participant reached 80% or higher in correct implementation of the DTT trials. One training session was defined as the completion of all four steps in the BST training model.

Post-BST

Post the BST interventions, evaluation of the BST data was completed. The participant's ability to perform the targeted skills was assessed. This assessment was completed through measuring for maintenance of skill after the intervention and measurement of whether the skills learned could be transferred from the use of the robot to a child. After post measurements, evaluation of the data collected was required to identify the effects of the intervention and if the skills learned were effectively transferred and maintained.

Generalization and Maintenance

After the training, the researcher measured for maintenance of the skills learned through a process of a randomized maintenance check and generalization measure. Maintenance checks measure the participants' ability to retain previously acquired skills and perform it once the training is removed. The maintenance check with generalization was essential to answering the research question on whether a humanoid Nao robot could train an individual to perform DTT accurately and be able to generalize the skills to clinical setting with a child active participating in ABA therapy. The maintenance and generalization checks began after the participant mastered the training, by reaching the mastery criterion of 80% or higher. The participant was required to repeat the same procedure that was implemented during the intervention with a child from the ABA Clinic, and was provided with a data sheet, and the same procedural materials. Instead of using the robot, the maintenance and generalization phase was conducted with a child in an already established ABA program at a university-based center. The participants met master of the maintenance check after implementing the procedure at 80% accuracy or higher. All data were safely and securely stored at the university in a locked research lab and later used for analysis while in the lab.

CHAPTER FOUR

RESULTS

Group One

Group one had three participants and was the first group to participate in this study. Group one completed the study before group 2 began.

The baseline data for group one's first participant resulted in an average of 23% accuracy in the delivery of the DTT targets (see Figure 3). Upon the introduction of the intervention in the fourth session, there was a notable increase in the accurate implementation of the DTT targets with the robot. The first intervention phase resulted in 55% correct implementation. After the first introduction of the intervention phase, the first participant met mastery criterion at 88%.

Within group one, participant two's baseline data were collected with an average of 8.3% accuracy in the delivery of the DTT targets (see Figure 3). Upon the introduction of the intervention, there was a notable increase in the accurate implementation of the DTT targets with the robot. The first intervention phase resulted in 79% correct implementation. After the introduction of the second intervention phase, the participant met mastery criterion at 96%.

The data for group one's third participant were collected with an average of 21.8% accuracy in the delivery of the DTT targets (see Figure 3). This metric was a higher baseline compared to the others in this group. Upon the introduction of the intervention, accurate implementation of the DTT targets with the robot and resulted in meeting mastery criterion with one intervention phase. After the introduction of the intervention phase, the participant met mastery criterion at 96% of correct implementation of the DTT targets and procedure.

Figure 3

Group 1 baseline and intervention data

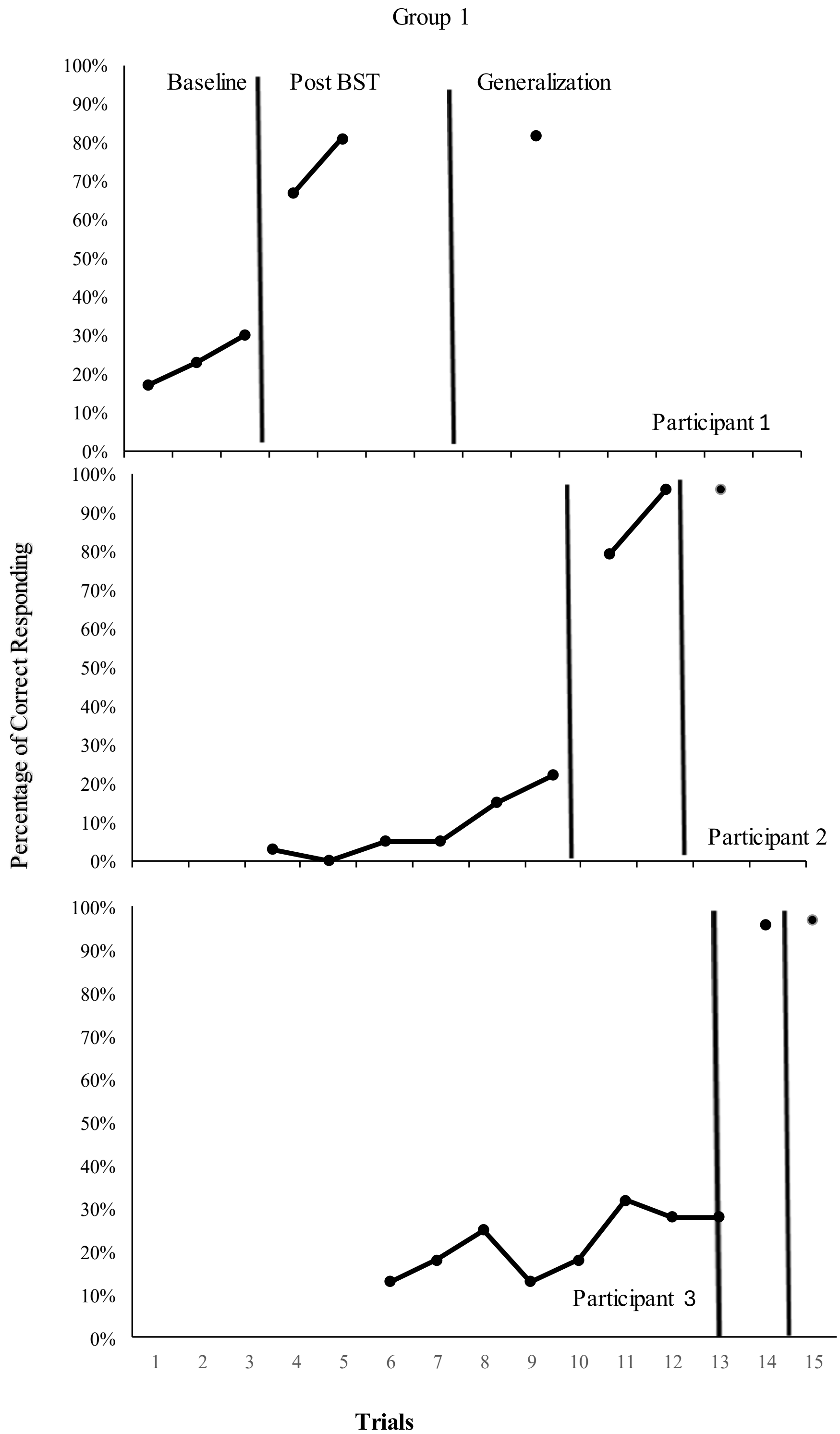
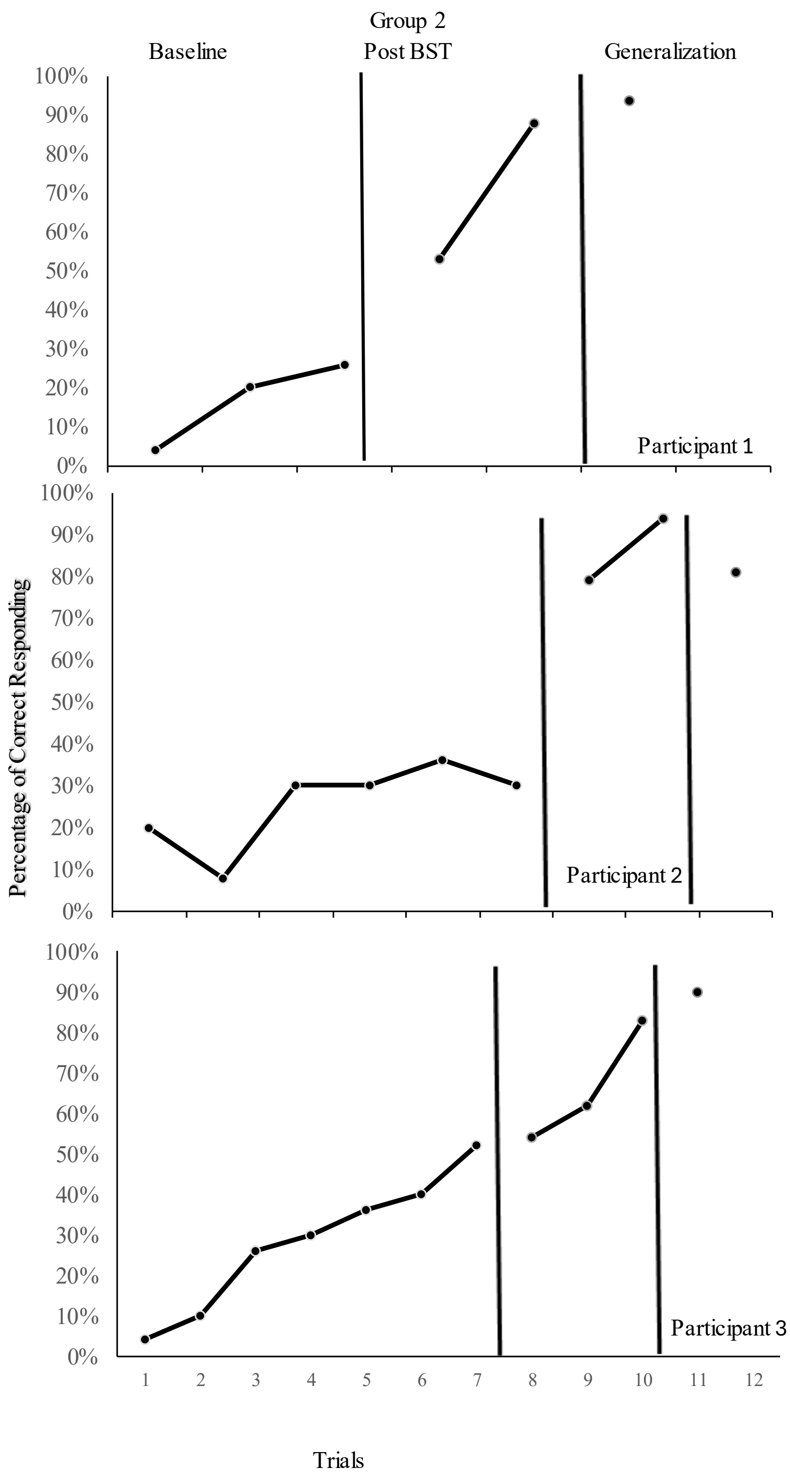


Figure 4

Group two baseline and intervention data



Group Two

After group one had completed the intervention and mastery phase, group 2 began baseline data collection. Group 2 followed the same process and procedures as group 1.

The data were analyzed through visual analysis of the results. The data for group two, first participants; baseline data were collected with an average of 16% accuracy in the delivery of the DTT targets (see Figure 4). Upon the introduction of the intervention in the fourth session, there was a notable increase in the accurate implementation of the DTT targets with the robot. The first intervention phase resulted in 53% correct implementation. Participant one in group two needed two intervention phases before meeting mastery criterion. During the first intervention phases, participant one responded at 53% accuracy. After introduction of the second intervention phase, participant one met mastery criterion at 88% accuracy.

The data for group two, second participant; two baseline data were collected with an average of 25% accuracy in the delivery of the DTT targets (see Figure 4). These baseline data were the highest baseline average across all participants, across three groups. Upon the introduction of the intervention, there was a notable increase in the accurate implementation of the DTT targets with the robot. The first intervention phase results in 79% correct implementation. After the introduction of the intervention phase, the participant met mastery criterion at 94%. The data for group two, third participants; baseline data were collected with an average of 23% accuracy in the delivery of the DTT targets (see Figure 4). This baseline was a higher as compared to the other participants; however, the participant needed up to three interventions to reach mastery. The first intervention resulted in being 50% correct. The second intervention showed little progress of 62% accuracy in the implementation of the DTT targets. In the third phase, the participant met mastery criterion at 83%.

Group Three

After group two had completed the generalization phase of the study, then group 3 began the baseline. The data were recorded in baseline and the intervention began, following the same process and procedure as group one and two.

Notably, the baseline for group three's participants had the lowest and most stable of the three groups; however, no clear explanation for these findings is evident. The data for group three, first participants; baseline data was collected, with an average of 0% accuracy in the accuracy of delivery of the DTT targets (see Figure 5). Upon the introduction of the intervention, there was a notable increase in the accurate implementation of the DTT targets with the robot. The first intervention phase resulted in 73% correct implementation of the DTT targets. The data for group three, second participant; needed four intervention phases before reaching mastery at 93% of correct implementation of the DTT targets. The data for group three, second participant; baseline data was collected, with an average of 0% accuracy in the delivery of the DTT targets (see Figure 5). Upon the introduction of the intervention, there was a notable increase in the accurate implementation of the DTT targets with the robot. The first intervention phase resulted in 76% correct implementation. After the second intervention phase, group three, participant two met mastery criterion at 83%. Within group three, participant three averaged a baseline of 2% and only needed one intervention phase to meet mastery criterion at 86%.

It is important to note how quickly the participants achieved mastery. One participant achieved mastery after three intervention phases four participants achieved mastery after two intervention phases, and one after one intervention phase.

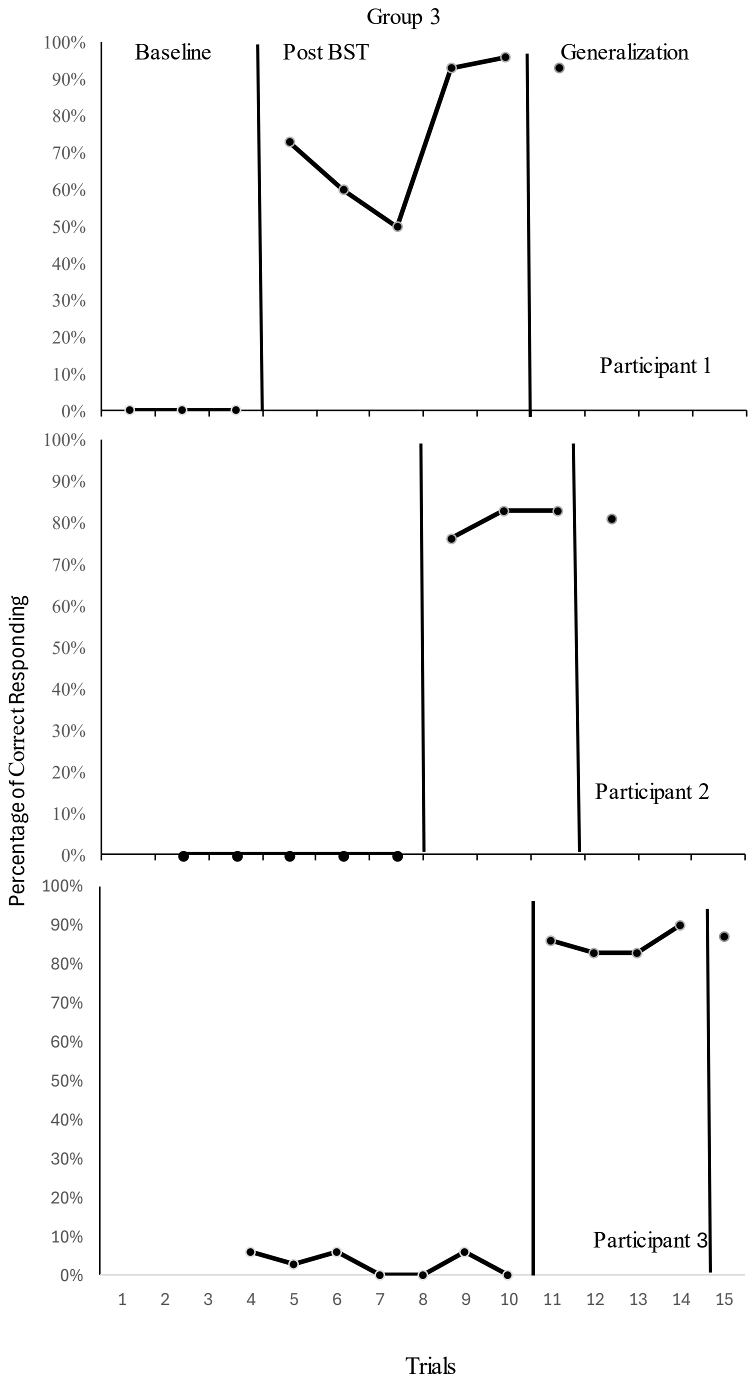
This finding suggests the intervention caused an increase in accuracy of the delivery of the DTT trial after the training and these changes likely would not have occurred naturally based on the baseline trend and complexity of skills needed.

Generalization

Generalization was attempted first with group one. During the first attempt with group one participant one, generalization was not successful due to barriers related to the child's behaviors and external factors in the environment. These barriers resulted in a second attempt and additional time between the intervention and generalization measurements. The second attempt with group one participant one, at generalization resulted in 82% accuracy. During generalization, group one participant two responded with 96% accuracy, and participant three responded with 97% accuracy (see figure 3). For group one, participants two and three responded at 96% accuracy in the correct implementation of the DTT targets. The generalization data were the same as the intervention data. Group two generalization occurred approximately two weeks after the intervention phase. Group two, participant one responded with 94% accuracy. Group two, participant two responded with 81% accuracy, and group two, participant three responded with 90% accuracy (see figure 4). The data for group two first and third participants had an increase in accurate implementation in of the DTT targets in the generalization phase compared to the intervention phase. Participant one had a 6% increase and participant three had a 7% increase. Participant two had a 9% decrease in accurate responding in the generalization phase compared to the intervention phase. Group three generalization occurred approximately 1 week after the intervention phase. Group three participants responded with 93% accuracy. Group three, participant two responded with 81% accuracy, and participant three responded with 87% accuracy. For each participant in group three, it has a slight decrease in generalization. Overall, the data indicates a high level of generalization, with accuracy rates ranging from 81% to 97%. This suggests that the targeted skills were maintained and effectively transferred beyond the original training context for all participants (see figure 5).

Figure 5

Group 3 baseline and intervention data.



Interobserver Agreement (IOA)

Interobserver agreement data were collected after the completion of the generalization sessions. Video recordings of each session were reviewed, and data collection was recorded based on what was captured on the video. The data collected from the video recordings of the sessions were compared to the data collected during the live session. The results of the IOA indicated 97% accuracy in the data collected across all groups and participants during the implementation of the intervention. Errors in the IOA were related to instances when the humanoid Nao robot experienced a technical error and shut down in the middle of the intervention and during recording of the data during error correction.

CHAPTER FIVE

DISCUSSION

With the growing demand for trained staff in ABA, one common concern is the need to expedite the training process to meet service demands. This expediency often leads to shortened training programs or the use of shortcuts, which can negatively impact service delivery outcomes. When service outcomes are compromised, it affects the quality of care and undermines the integrity of ABA practices. Utilizing robots in staff training for ABA can improve the consistency of training, ensuring adherence to the highest standards of care.

Implications of Findings

With the increasing number of individuals diagnosed with ASD (as discussed in Chapter 2) and the shortage of trained staff qualified to work with this population, there are significant challenges in addressing the needs of those diagnosed with ASD. Staff training is crucial to ensure continuity of care and maintain the integrity of ABA as an evidence-based approach. Incorporating robots into the training process offers high-quality, consistent, and reliable training across participants, which directly addresses concerns about well-trained staff implementing treatment strategies effectively. Using evidence-based training methods, such as BST, in combination with evidence-based treatment approaches, enhances the quality of care and, in turn, produces more significant outcomes, thereby improving the quality of life for individuals receiving treatment.

This research, which integrates BST and the Nao humanoid robot to help train individuals to provide DTT for skill acquisition in children with ASD, presents strong potential for broader application across other developmental domains. For example, similar methodologies could be adapted to address developmental delays in areas such as language acquisition, motor coordination, executive functioning, and emotional regulation. By tailoring DTT targets and reinforcers, the approach could support a wider population of children with developmental disabilities beyond ASD, including those with intellectual disabilities or speech-language impairments. Furthermore, integrating this research with other theorical frameworks could deepen the impact. Example, Bandura's Social Learning theory could use robots to demonstrate behaviors for imitation when focusing on observational learning. The results of this study demonstrate that BST is an effective method for teaching DTT implementation skills, even when using a humanoid robot to simulate a child. All nine participants achieved the mastery criterion, defined as implementing DTT steps with at least 80% accuracy across training sessions, by their third exposure to the BST procedure. Furthermore, generalization, the ability to apply learned skills in new contexts or with different materials—was also achieved, with some participants showing increased accuracy during the generalization phase compared to the initial intervention phase.

Core Success

This study demonstrated that integrating BST with a humanoid robot is an effective, scalable, and innovative solution to training ABA staff in DTT implementation. All participants met the mastery criterion rapidly, with strong generalization outcomes, underscoring the robustness of the training model. The consistent delivery across participants ensured high procedural fidelity, while the use of robotics reduced human resource demands—highlighting a potentially transformative solution to workforce shortages. Furthermore, the study opens the door to broader application across developmental areas and integrates well with behavioral learning theory, advancing both practice and research in ABA. Importantly, this study shows that incorporating the Nao humanoid robot into the training process can reduce the need for intensive human oversight while maintaining high procedural fidelity. The robot provided consistent practice opportunities, allowing staff to efficiently acquire and generalize essential intervention skills in a shorter time frame. These findings suggest that robotic-assisted training could be a scalable and resource-efficient solution for preparing staff in applied behavior analysis (ABA) without compromising the quality-of-service delivery. These findings could help expedite the delivery of care to better support individuals who are waiting for ABA service. Not only could this method shorten the trajectory of training but also allows for ensuring consistency across the training program. The training was implemented in the same way across all participants without variation; thus, the findings consistently show that the BST model is effective when using a robot. The consistency across the participants plays a vital role in the results and outcomes which ensure accurate comparison outcomes and interval validity.

While previous research has primarily focused on how humanoid robots can be used during ABA sessions directly with children with ASD, there is limited research exploring their role in staff training. This study contributes to filling that gap by demonstrating how the Nao humanoid robot can support consistent, efficient, and high-fidelity training for individuals working in ABA settings. By extending the application of robotic technology to staff development, this research broadens the field’s understanding of how robots can enhance not only child-focused interventions but also the infrastructure of ABA service delivery through scalable and standardized training models.

Core Limitations

These are inherent weaknesses or flaws in the design or execution that could affect the validity or generalizability of the results. They are often unavoidable in early-stage research or pilot studies but should be transparently acknowledged. One core limitation in this study worthy of further discussion is the single-subject multiple-baseline design across participants. First, a drawback of single-subject designs is that the findings may not generalize to a broader population, as they typically involve a small number of participants. Moreover, regarding multiple baseline design across participants, it does not allow for measurement of the skills across-settings and across many different children in the generalization phase. Furthermore, the findings may not be consistent across different environments, and across different children, as the varying contexts can influence participant behavior and the effectiveness of the intervention. A multiple baseline design across participants could limit addressing the immediate needs of a behavioral health clinic and delay the evaluation of training effectiveness due to the time required to complete the multiple baseline design.

Limitations to this research and the multiple baseline design were related to an unstable baseline among participants in groups one and two. The baseline for some of the participants showed a slight ascending trend. The slight ascending baseline can create a misleading impression of the intervention effectiveness and seem to appear as the behavior is changing due to natural progression and/or external factors. This impact can make it difficult to determine whether the intervention itself was effective.

As Kazdin (2011) noted, an ascending baseline can be problematic because it may seem like behavior is changing naturally. The challenge was determining whether the trend would have continued without the intervention or if external factors, such as the intervention, could cause the change (Cooper et al., 2020). Given the slight ascending baseline, it was hypothesized the trend would have slowly continued without the intervention, but most likely not be able to reach mastery without the intervention. In other terms, the ascending baseline could be due to inadvertent learning of the intervention through the continued exposure to the baseline process (Kazdin, 2011). Based on the data and significant changes in the trend after the intervention, the data show that intervention is what improved responding accurately to the delivery of the DTT targets.

To address the design limitations in future work, a multiple probe design might be helpful when staff training is required in stages, allowing it easier to monitor progress and adjust intervention as needed without waiting for extended periods of time. A multiple-probed design might support having fewer sessions to gather data and with limited resources for staff training. Instead of waiting for a stable baseline across all conditions, a multiple probe design uses intermittent data collection points, allowing for quick evaluation of training effectiveness to address the immediate needs

Multiple baseline designs across participants have many advantages, such as increased internal validity and control with external variables by allowing for a clear comparison of behavior changes. Multiple baseline designs across participants allow researchers to observe the effects of the training and the generalization of skills. A multiple baseline design across participants posed some challenges related to variability in learning rates, skills and backgrounds. Multiple baseline designs are intensive resources that require more time and monitoring across participants. There were difficulties in establishing a stable baseline for some of the participants as mentioned in our limitations

Logical Limitations

These are practical, situational, or logistical limitations that do not necessarily reflect flaws in the study design but could affect outcomes. These can be mitigated in future studies. Minor limitations in this research were related to technical issues in the recording stage. For example, for one participant, the robot needed to be rebooted. Limitations were also related to scheduling of participants and recruitment of child participants. Three participants wanted to ask the researcher questions and expressed frustration during the baseline stage due to not understanding what to do. This frustration was challenging because the independent observer could not engage in expanding on expectations during baseline. Finally, during generalization, there were barriers in establishing instructional control with no prior history of pairing between the participant and the child. Overall, these minor limitations could be mitigated in future work by ensuring the participant is aware of the possible duration of the baseline and allowing for the participant to pair with the child prior to the generalization phase.

While the use of a robot to simulate child responses offered consistency and innovation in training delivery, it may not fully reflect the complex and often unpredictable nature of real-life interactions with children diagnosed with ASD. As such, generalizing the skills acquired through robot-assisted training to live clinical environments may require additional supervision or practice with actual clients.

Furthermore, the scope of training in this study was limited to a defined set of DTT skills, including manding, imitation, tacting, receptive instruction, and emotional recognition. Although these are essential developmental domains, the study did not address other critical components of ABA practice, such as behavior reduction procedures, accurate data collection, or caregiver collaboration, all of which are integral to comprehensive service delivery. Additionally, the outcomes were assessed only during and immediately following the intervention. Without long-term follow-up, it remains unclear whether the improvements in DTT implementation were maintained over time, limiting conclusions about the durability and sustained effectiveness of the training model.

Future Research Directions

Future research should explore the extent to which staff trained using robot-assisted instruction combined with BST are able to generalize their skills to real-world settings involving children diagnosed with ASD. Assessing performance across a range of learner profiles and naturalistic environments will enhance our understanding of the training model's ecological validity.

In addition, future studies should broaden the focus beyond DTT to include essential areas of ABA such as functional behavior assessments, behavior intervention planning, data collection procedures, and parent training. This expansion would better prepare practitioners for the complex and diverse demands of clinical practice.

Long-term maintenance of training effects should also be investigated. Follow-up assessments are critical in determining whether the skills acquired through robot-assisted training are sustained over time and whether ongoing support or booster sessions are necessary to maintain implementation fidelity.

Further exploration is warranted on the use of robot-assisted training in addressing barriers to implementation, particularly for challenging behaviors such as self-injury. Research should focus on how BST combined with robotic tools can support staff in implementing behavior intervention plans aimed at reducing high-intensity or complex behaviors.

This study was limited by a small sample size (n = 9), which restricts generalizability. Additionally, participants demonstrated the highest error rates during the error correction component of instruction. During the generalization phase, some clients had prior exposure to similar instructional tasks, resulting in fewer opportunities to implement error correction procedures, potentially skewing performance data.

These limitations suggest that future research should focus more intensively on error correction procedures and how staff can be trained to respond effectively to unpredictable and uncontrolled environmental events using robot-assisted tools. Incorporating a broader variety of generalization tasks, particularly for children with diverse skill sets and learning histories, will strengthen the external validity of findings.

Participant and Contextual Variables

Future research should also examine how individual differences among staff—such as previous experience, educational background, and learning styles—may impact training outcomes. The generalization and retention of skills may be influenced by these variables and understanding them could guide more personalized training approaches. Likewise, the influence of diverse client profiles on training outcomes warrants investigation. Adapting training to accommodate learners with a wide range of communication, cognitive, and behavioral characteristics would improve the relevance and applicability of robot-assisted instruction.

Implementation of Feasibility and Ethical Considerations

While the use of humanoid robots like NAO offers promising advantages for standardized instruction, issues such as cost, accessibility, and ethical considerations around automation in human service settings must be addressed. Research should explore the feasibility of integrating robotic tools into community-based clinics, schools, and home settings. Additionally, staff perceptions, acceptability, and potential over-reliance on technology should be evaluated to ensure that robots are viewed as supplements to, rather than replacements for, human supervision and mentorship.

Using video recordings for IOA can be a helpful tool in behavioral observation; however, having the same individual collect the original data and complete the IOA scoring introduces limitations. This approach eliminates the independence between observers, which is essential for validating the reliability of data collection. When the same person scores both data sets, there is an increased risk of observer bias, unintentional data alignment, and repeated recording errors, all of which can falsely inflate agreement levels. Additionally, without a second observer, there is no opportunity to detect or correct inconsistencies, reducing the overall credibility of the findings. For IOA to serve its purpose, it is critical that data be scored independently by at least two trained observers to ensure objectivity and accuracy.

Conclusions

Given that behavior therapist is an entry-level position within the ABA field, establishing a solid foundation in intervention implementation is essential. The complexity of skills required for high-integrity performance demands robust and consistent training methods. The use of humanoid robots in ABA training could play a transformative role in both initial staff education and ongoing professional development. Such technology has the potential to enhance treatment outcomes by promoting consistency in training and reducing variability in service delivery.

While no single system can account for every individual difference in treatment delivery, certain ABA methodologies, such as DTT does require structured, clearly defined protocols. Consistent, high-quality training ensures staff alignment with best practices and helps safeguard treatment integrity. In addition, addressing training quality contributes to preventing staff burnout, a significant and growing concern in the field. As ABA continues to evolve, investing in innovative, scalable training solutions is not only beneficial—it is essential to meeting the needs of clients, staff, and the broader behavioral health system.

REFERENCES

Aherne, C. M., & Beaulieu, L. (2018). Assessing long-term maintenance of staff performance following behavior skills training in a home-based setting. *Wiley Advance Online Publication.*

American Psychiatric Association. (2022). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Publishing.

Baraka, K., Melo, F. S., & Veloso, M. (2018). Simulating behaviors of children with autism spectrum disorders through reversal of the autism diagnosis process. *Paladyn, Journal of Behavioral Robotics, 10423,* 753–765. doi: 10.1007/978-3-319-65340-2 61

Baraka, K., Melo, F. S., & Veloso, M. (2019). Interactive robots with model-based 'autism-like' behaviors: Assessing validity and potential benefits. *Paladyn, Journal of Behavioral Robotics, 10,* 103-116. https://doi.org/10.1515/pjbr-2019-0011

Bredekamp, S., & Copple, C. (Eds.). (2016). *Developmentally appropriate practice in early childhood programs serving children from birth through age 8* (4th ed.). National Association for the Education of Young Children (NAEYC).

Centers for Disease Control and Prevention. (2023). *Developmental disabilities monitoring network.* Retrieved July 8, 2024, from https://www.cdc.gov/ncbddd/developmentaldisabilities/features/birthdefects-dd-keyfindings.html

Clabaugh, C., Mahajan, K., Jain, S., Pakkar, R., Becerra, D., Shi, Z., Deng, E., Lee, R., Ragusa, G., & Matarić, M. (2019). Long-term personalization of an in-home socially assistive robot for children with autism spectrum disorders. *Frontiers in Robotics and AI, 6,* 110-128. https://doi.org/10.3389/frobt.2019.00110

Cooper, J. O., Heron, T. E., & Heward, W. L. (2020). *Applied behavior analysis* (3rd ed.). Pearson.

Courtemanche, A. B., Turner, L. B., Molteni, J. D., & Groskreutz, N. C. (2021). Scaling up behavioral skills training: Effectiveness of large-scale and multiskill trainings. *Behavior Analysis in Practice, 14*(1), 36–50. https://doi.org/10.1007/s40617-020-00480-5

Fisher, W. W., Piazza, C. C., Bowman, L. G., Hagopian, L. P., Owens, J. C., & Slevin, I. (2020). Evidence-based practices for children and adolescents with autism spectrum disorder: Review of the literature and practice guide. *Journal of Autism and Developmental Disorders, 50*(9), 3179–3203. https://doi.org/10.1007/s10803-019-04147-4

Indeed. (2024). *Job search.* Retrieved July 8, 2024, from https://www.indeed.com

Kazdin, A. E. (2011). *Single-case experimental designs: Methods for clinical and applied settings* (2nd ed.). Oxford University Press.

Korneder, J. A., Louie, W.-Y. G., Pawluk, C. M., & Abbas, I. (2021). Robot-mediated interventions for teaching children with ASD a new intraverbal skill. *Assistive Technology: The Official Journal of RESNA, 34*(8), 707–716. https://doi.org/10.1080/10400435.2021.1930284

Kranak, M. P., Shapiro, M. N., Sawyer, M. R., Deochand, N., & Neef, N. A. (2019). Using behavioral skills training to improve graduate students' graphing skills. *Behavior Analysis: Research and Practice, 19*(3), 247–260. https://doi.org/10.1037/bar0000131

Lovaas, O. I. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychology, 55*(1), 3–9. https://doi.org/10.1037/0022-006X.55.1.3

Rabbitt, S. M., Kazdin, A. E., & Scassellati, B. (2014). Integrating socially assistive robotics into mental healthcare interventions: Applications and recommendations for expanded use. *Science Robotics, 1*(1), eaah4258. https://doi.org/10.1126/scirobotics.aah4258

Rochat, T., & Charania, M. (2019). Addressing the training and supervision needs of early interventionists: A comparison of ABA and non-ABA approaches. *Journal of Early Intervention, 41*(4), 299–314. https://doi.org/10.1177/1053815119880916

Shaw, K. A., Williams, S., Patrick, M. E., Valencia-Prado, M., Durkin, M. S., Howerton, E. M., Ladd-Acosta, C. M., Pas, E. T., Bakian, A. V., Bartholomew, P., Nieves-Muñoz, N., Sidwell, K., Alford, A., Bilder, D. A., DiRienzo, M., Fitzgerald, R. T., Furnier, S. M., Hudson, A. E., Pokoski, O. M., Shea, L., … Maenner, M. J. (2025). Prevalence and Early Identification of Autism Spectrum Disorder Among Children Aged 4 and 8 Years - Autism and Developmental Disabilities Monitoring Network, 16 Sites, United States, 2022. *Morbidity and mortality weekly report. Surveillance summaries (Washington, D.C. : 2002)*, *74*(2), 1–22. https://doi.org/10.15585/mmwr.ss7402a1

Soleiman, P., Moradi, H., Mahmoudi, M., Teymouri, M., & Pouretemad, H. R. (2021). Teaching turn-taking skills to children with autism using a parrot-like robot. *arXiv*. https://doi.org/10.48550/arXiv.2101.12273

Saleh, M. A., Hanapiah, F. A., & Hashim, H. (2021). Robot applications for autism: A comprehensive review. *Disability and Rehabilitation: Assistive Technology, 16*(6), 580–602. https://doi.org/10.1080/17483107.2019.1685016

Shapiro, M., & Kazemi, E. (2017). A review of training strategies to teach individuals implementation of behavioral interventions. *Journal of Organizational Behavior Management, 37*(1), 32–62. https://doi.org/10.1080/01608061.2016.1267066

Siller, M., Morgan, L., Wedderburn, Q., Fuhrmeister, S., & Rudrabhatla, A. (2021). Inclusive early childhood education for children with and without autism: Progress, barriers, and future directions. *Front Psychiatry, 12,* 754648. https://doi.org/10.3389/fpsyt.2021.754648

Smith, T., & Jones, L. (2017). *Behavior analysis in practice: Issues and solutions in the field of applied behavior analysis.* ABA Publishing.

Valadao, C. T., Goulart, C., Rivera, H., Caldeira, E., Bastos Filho, T. F., Frizera-Neto, A., & Carelli, R. (2016). Analysis of the use of a robot to improve social skills in children with autism spectrum disorder. *Research in Biomedical Engineering, 32*(3), 161–175. https://doi.org/10.1590/2446-4740.01316

Werry, I. R., Dautenhahn, K., & Harper, D. (2001). Using robots in therapy for children with autism. *Proceedings of the International Conference on Robotics and Automation.*

Zablotsky, B., Black, L. I., Maenner, M. J., Schieve, L. A., Danielson, M. L., Bitsko, R. H., Blumberg, S. J., Kogan, M. D., & Boyle, C. A. (2019). Prevalence and trends of developmental disabilities among children in the United States: 2009-2017. *Pediatrics, 144*(4), e20190811. https://doi.org/10.1542/peds.2019-0811

APPENDIX

Date: 7-18-2025

IRB #: IRB-FY2021-50
Title: Evaluation of Evidence-Based Training Strategies on Staff Performance
Creation Date: 8-16-2020
End Date:
Status: Approved
Principal Investigator: Michael Kranak
Review Board: OU IRB
Sponsor: Rutgers, The State University of New Jersey

Study History

Submission Type Initial	**Review Type** Expedited	**Decision** Approved
Submission Type Modification	**Review Type** Expedited	**Decision** Approved
Submission Type Modification	**Review Type** Expedited	**Decision** Approved
Submission Type Modification	**Review Type** Expedited	**Decision** Approved
Submission Type Modification	**Review Type** Expedited	**Decision** Approved
Submission Type Modification	**Review Type** Expedited	**Decision** Approved

Key Study Contacts

Member Michael Kranak	**Role** Principal Investigator	**Contact** kranak@oakland.edu
Member Michael Kranak	**Role** Primary Contact	**Contact** kranak@oakland.edu
Member Jessica Korneder	**Role** Investigator	**Contact** korneder@oakland.edu
Member Wing-Yue Louie	**Role** Investigator	**Contact** louie@oakland.edu
Member Kelly Adamek	**Role** Investigator	**Contact** kadamek@oakland.edu
Member Karoline Kenville	**Role** Investigator	**Contact** kkenville@oakland.edu