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Effects of Aquatic Therapy on Vagal Tone and Social Behaviors in Individuals with Autism Spectrum Disorder

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APPROVAL OF THE DISSERTATION COMMITTEE

This dissertation has been duly read, reviewed, and critiqued by the Committee listed below, which hereby approves the manuscript of Brittany Bell as fulfilling the scope and quality requirements for meriting the degree of Doctor of Philosophy in Psychology.

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Abstract

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Aquatic therapy has been shown to have behavioral benefits for participants with autism spectrum disorder (ASD) including social and swimming skills. The mechanism through which aquatic therapy has these effects has not been demonstrated. It is noted that several aspects of swimming programs such as deep breathing, physical exercise and cold exposure have been shown to increase vagus nerve activation (Mason et al.,2013; Presmanes et al., 2015; Yuan et al., 2001). Using a quasi-experimental block design, the present study evaluated the effect of aquatic therapy on vagal tone as well as behavior in participants with ASD (n=32) and without ASD (n=32). Measures consisted of social, swimming, emotional and cognitive tasks. Following the aquatic intervention participants with ASD demonstrated a statistically significant increase in vagal tone while typically developing participants displayed a significant decrease. The ASD group's increased interest in the aquatic intervention and dysregulated vagus nerve activation may account for the groups' difference in post-treatment vagal tone levels. The typically developing group's lack of interest in the perceived trivial activity may account for the decrease in post-treatment vagal tone levels. However, both groups displayed a statistically significant increase on each social, swimming, emotional and cognitive measure. Positive correlations between vagal tone and social skills measures were found in participants with ASD. This study indicated that aquatic therapy can increase vagal tone in participants with ASD while also increasing swimming, social, emotional and cognitive abilities in both participants with and

without ASD. Aquatic therapy is an intervention that can be replicated to treat individuals with ASD. It also has potential to be adapted for other mental disorders such as posttraumatic stress disorder.

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CHAPTER 1

Introduction

Autism Spectrum Disorder and Background on Swimming

Drowning is the leading cause of death of children with autism spectrum disorder (ASD). While drowning is the second leading cause of death of all children in the United States, children with autism spectrum disorder are 160 times more likely to drown than a typically developing child (AJPH, 2019). Although these rates are alarmingly high, the public is generally unaware of this risk (Gleeson, 2016). In addition to actual drownings, 32% of parents of children with ASD have reported a “close call” with a near drowning incident (Gleeson, 2016). This higher risk may be due to several factors including engaging in eloping behaviors, having a higher attraction to water, inability to generalize, and a lack of specialized services for children with ASD.

Recent literature has addressed the risk of drowning for children with ASD. Aquatic interventions have proven successful in teaching swimming skills to individuals across the spectrum (Huettig & Darden-Melton, 2004; Pan, 2010). In addition to improving swim skills, the participants also displayed increases in social skills such as eye contact and communication, along with decreases in antisocial behavior such as stimming, the act of self-stimulatory behaviors such as hand-flapping, rocking, spinning or the repetition of words (Hettig & Darden-Melton, 2004; Pan, 2010). However, it is unclear why the aquatic interventions produced improvements in social skills.

The present study sought to explain how aquatic interventions produce improvements in socials skills of children with ASD. The researcher assessed vagal tone activity before and after the aquatic intervention to determine the association between vagal tone activation and the development of social skills in children with ASD. Vagal tone is dysregulated in individuals with

ASD. Activation of the vagus nerve in individuals with ASD is associated with an increase in socially appropriate behaviors (Bal et al., 2010; Kushki et al., 2013; Ming et al., 2005; Porges et al., 2013). Swimming incorporates several features which have been shown to activate the vagus nerve including exercise, deep breathing and exposure to cold temperatures (Makinen et al., 2013; Mason et al., 2013; Wang et al., 2010).

Why are Children with ASD at Risk for Drowning?

Children with ASD are at higher risk for drowning than typically developing children (AJPH, 2019). Behaviors such as elopement, attraction to water and difficulty generalizing skills contribute to this risk. In addition, there are limited specialized services to teach swimming and water safety skills to children with ASD.

Elopement

A characteristic which increases individuals with ASD's risk of drowning is elopement. Eloping consists of wandering or bolting from a situation without parental permission or notification (Perrin, et al.,2008). Children with ASD use elopement as a method to escape anxious situations and uncomfortable sensory stimuli (Boltz, 2006). It may also be used to explore or obtain a special interest item which separates them from others. This type of behavior is very common in children with ASD; 49% of children with ASD attempt to elope on a regular basis, and 50% of those who do elope go missing or enter dangerous situations (Anderson et al., 2002). When compared with their typically developing siblings, it was noted that 27% of the children with ASD eloped, while only 1% of the siblings eloped (Anderson et al., 2012). When children with autism elope, many of them encounter dangerous situations. Often these dangerous situations include encountering a source of water without supervision. Drowning accounts for 91% of deaths in children with ASD under age 14 (Li, 2017). It is also noted that the majority of the drowning instances were due to elopement or wandering near a source of water without supervision.

Attraction to Water

A second characteristic which increases a child with ASD's risk of drowning is his or her attraction to water. Humans are innately drawn to water and children with ASD are no exception. According to many parent reports, children with ASD are deeply drawn to water (Huettig & Darden- Melton 2004; Yilmaz, et al., 2004). This can range from fountains all the way to the ocean. There are several explanations as to why children with ASD have an increased attraction to water sources. First, the sight of a natural landscape such as a body of water or water feature is reinforcing. Being near such a landscape stimulates the reward circuitry similar to that of primary reinforcers such as food and sex, as well as strong secondary reinforcers such as money (Nichols, 2015). Water can also alleviate the overstimulation that many children with ASD experience (Talay-Ongan & Wood, 2000). Water may relieve overstimulation because water itself is visually stimulating to a child with ASD, that is, it will distract from other overbearing stimuli (Jake, 2003). In addition, the water provides hydrostatic pressure which is said to be both calming and soothing (Jake, 2003). It is sometimes referred to as "the ultimate hug" (Nichols 2015, p. 64). Lastly, being immersed in water places the body in a meditative state by altering the balance of catecholamines (Becker, 2009). Catecholamines are amines that act as neurotransmitters and hormones within the body. Catecholamines include dopamine, epinephrine and norepinephrine (Axelrod & Weinshilbourn, 1972). The catecholamine balance achieved during immersion creates a feeling of relaxation which is likely sought by children with ASD.

Lack of Generalization

Although some children with autism spectrum disorder are able to acquire swim and water safety skills, they may still be at risk of drowning because of a lack of generalizing the skills. Children with ASD often have trouble generalizing skills. Generalization is defined by the ‘‘occurrence of relevant behavior under different non-training conditions” (Stokes & Baer, 1977, p. 350). It has long been seen that children with ASD have an impaired ability to relate past experiences to novel stimuli (Rimland, 1964). This inability to generalize is thought to be due to poor categorization and enhanced discrimination (Plaisted, 2001). Because children with ASD have enhanced discrimination, especially with visual and auditory stimuli, they tend to have poor categorization which then leads to a lack of generalization of both verbal stimuli (Mottron, Peretz, & Ménard, 2000; O'Riordan & Passetti, 2006) and visual stimuli (Litrownik, McInnis, Wetzel-Pritchard, & Filipelli, 1978).

Swim and water safety skills are often learned in a controlled setting, such as a pool. However, to ensure safety, children with ASD need to generalize those skills to other bodies of water, including the ocean, lakes, rivers and streams. Generalizing skills includes assessing whether an environment is safe to swim in.

Even if a child with ASD is able to generalize swim skills in other bodies of water, he or she may be unable to assess the dangers associated with these settings such as tides and currents that were not present in the pool setting. They may also not realize that it is unsafe to swim when a lifeguard is not present. An individual with ASD's lack of judgment in novel situations may increase their risk of drowning (Gleeson, 2016; Moran et al., 2011).

Lack of Specialized Services

Lastly, the high rates of drowning in children with ASD are relatively unknown by the general public (Gleeson, 2016). Thus, the lack of awareness may be contributing to the high risk of drowning in children with ASD. This lack of awareness is also contributing to the absence of specialized swim programs for children with ASD (Gleeson, 2016). Swim lessons are easily accessible for typically developing children, but few centers offer adaptive lessons for children with autism spectrum disorder (NAA, 2012). Lessons tailored to the child's needs are necessary for individuals with ASD to learn how to swim and acquire water safety skills.

The risk for drowning in children with ASD has prompted the development of specialized aquatic programs. While the programs primary focus has been on developing swimming and water safety skills, improvements in social skills development were also noted. Aquatic interventions can address both the risk of drowning and social skills deficits in individuals with ASD.

The Positive Developmental Context of Aquatic Interventions

Aquatic interventions offer the opportunity to foster positive youth development. Positive youth development is a programmatic approach for supporting healthy, productive and engaged youth (Benson et al., 2007). Positive contexts have been an important factor in fostering positive youth development, and ultimately social skills. In aquatic interventions there may be two aspects which develop a positive context for fostering social development. These include the contexts of both nature and sports.

Nature

Our modern urban and suburban environments can be over stimulating for children with ASD. This overstimulation may interfere with positive youth development in children with ASD. Exposure to natural environments may be able to alleviate some of this overstimulation. When in nature, typically developing individuals report feeling a calm energy and stress reduction (Hartig, Mitchell, Vries & Frumkin, 2014; Thayer, 1996). Individuals with ASD reported this sense of calm specially in aquatic settings (Higashida, 2016). It is also evident that those who spend time outdoors tend to be display more open and outgoing behaviors (Nisbet et al., 2009; Tam, 2013). These characteristics are fostered by the natural environment and can explain the increase in social connectedness people experience while in nature (Hartig, Mitchell, Vries & Frumkin, 2014).

Since many aquatic facilities are located outdoors, they may offer the positive youth development benefits seen in nature. The water in a pool, mimics natural settings and provides sensory isolation similar to that experienced in natural pools or lakes (Nichols, 2015). Previous research has shown that outdoor aquatic sessions produced increases in appropriate social interactions and desire to engage with others in children with ASD (Best & Jones, 1972; Pan, 2006). It is likely that outdoor aquatic therapy provides a context which promotes social skills development in children with ASD.

Organized Physical Activities

Organized physical activities are a potential context for positive youth development. Sports and physical activity contexts have been shown to promote social skills, positive self-perception and peer relationships in youth (Fraser-Thomas et al., 2005). However, if the physical activity does not actively engage positive social interactions and behaviors, the full potential of the program will not be met (Danish et al., 2004). An emphasis on social interaction with peers fosters a context to build social skills. In addition to social interactions with peers during physical activity, children also often interact with non-parental adults during organized physical activities. Appropriate praise and support from adults during physical activities creates a warm environment for the child and promotes the positive effects of social relationships such as autonomy and positive self-perception (Coastsworth et al., 2009; Gano-Overway et al., 2009). In addition, warm social relationships help young individuals thrive and produce positive outcomes in areas of developmental and academic achievement (Benson et al., 2006; Bond et al., 2007; Gano-Overway et al., 2009).

Aquatic interventions display many of the characteristics used to describe the positive contexts created by organized physical activities above. Previous aquatic interventions have been shown to increase appropriate social skills and positive self-perception (Best & Jones, 1972; Hamilton, 1972). This is likely due to the social context with peers as well as the instructor. In many cases, the instructor encourages participation and engagement with others. The instructors also provided verbal praise to the children throughout the session when the participant followed directions and completed tasks. The physical activity and social interaction from sports could be creating a context which promotes social skills and positive self-perception.

Positive Contexts

Outdoor settings and physical activities often have a bidirectional relationship as physical activities are typically held outdoors, and those who are outdoors, tend to engage in physical activities (Ryan et al., 2010). Aquatic interventions employ both the positive context of nature and physical activity. In other words, aquatic interventions have dual agents in creating an optimal context for positive youth development. The context in which aquatic therapy is held likely fosters social skills development in children with ASD.

Aquatic Interventions for Children with ASD

Aquatic therapy is a relatively new intervention for treating autism spectrum disorder and there is limited research on the topic. Thus far aquatic programs have been successful in teaching water safety and preventing drowning. These programs also produced an increase in social skills in children with ASD but the mechanism behind this increase has not been assessed. Initial research in this area has focused on the acquisition of swimming skills and the physical benefits associated with it. Preliminary studies (Best & Jones, 1974; Jones & Best, 1975), used movement therapy, which involved swimming with four children with ASD, to examine the effectiveness of a physical activity program. It was concluded that physical activity may contribute to a child's physical development. The initial studies also found that there were reported improvements in participant's social, cognitive, motor, and behavioral development.

More recent research suggested that aquatic interventions provide an environment for children with ASD to engage in activities that they would have been physically unable to complete on land (Attwood, 1998). For instance, an individual with ASD may have difficulty with weight-bearing activities but is able to complete non-weight-bearing exercise such as swimming. It was also noted that swimming may increase a child's competence and proficiency of movement (Attwood, 1998). Aquatic interventions likely provide a more inviting environment to engage individuals with ASD in physical activity. The warm water (104ºF) in an aquatic intervention has been found to enhance muscle tone and allow for more efficient movement (Becker & Cole, 2004). In addition, the buoyancy in water enables individuals to perform movements they are not capable of on land (Hutzler et al., 1998). Incorporating aquatic activity into therapy for children with ASD is believed to foster language development as children verbalize their motor movements and activities in the water. Aquatic activity is also seen to aid in the formation of self-concept as children become more confident in themselves and their body movements (Best & Jones, 1972; Hamilton, 1972). The therapeutic use of water activities has also been seen to increase adaptive skills including communication and safety skills (Bachrach et al., 1978).

Several studies have assessed the effectiveness of swimming interventions for children with ASD and identified the programs' physical benefits. Previous research explored a single subject design in which a 9-year old child participated in a 10-week water exercise and swimming program (Yilmaz et al., 2004). This study assessed water intervention skills before and after the intervention. At the conclusion of the 10-week swimming program, the child's balance, agility, muscle strength and cardiovascular fitness had improved. Additionally, the child displayed a significant reduction in stereotypic behaviors such as hand flapping, echolalia and rocking (Yilmaz et al., 2004). An additional study assessed the acquisition of swimming skills in four children with autism spectrum disorder between the ages of 7–13. Each child displayed improvements in their swim skills throughout the intervention (Huettig & Darden-Melton, 2004). Additionally, parents reported that following the swimming intervention, they saw improvement in their child's social skills. One mother indicated that this was the first time their family had ever engaged in one activity all together as a family. Another parent shared that their child was interacting with other children at local swimming facilities and had even taken up water skiing.

Recent studies have also assessed the effect swimming interventions have on the social skills of children with autism spectrum disorder. Previous research surveyed 18 occupational therapists who provided aquatic therapy to children ages 4 to 10 with ASD. Therapists reported increases in initiation and maintenance of eye contact, attention and touch tolerance (Vonder Hulls et al., 2006). As expected, improvements in swim skills, muscle strength and water safety were also seen. The effectiveness of an exercise swimming program on the aquatic skills and social behaviors of 16 boys with high functioning ASD was assessed. The intervention yielded significant improvements in swim skills and a decrease in antisocial behaviors such as self-stimulatory behaviors throughout the 10-week program (Pan, 2010). These improvements were also maintained for up to 10 weeks following the intervention. The maintenance of both the swim and social skills may be due to the reintroduction to the aquatic setting each time the participants' skills are assessed. Qualitatively, parents reported improvements in their child's self-confidence, social as well as athletic performances.

Why Might Swimming Increase Social Skills?

Swimming interventions have proven effective in increasing social skills in children with ASD (Pan, 2010). There are several hypotheses to explain this occurrence. The increase in appropriate social behaviors may be influenced by hydrostatic pressure, sensory deprivation, as well as physiological changes that occur in water.

Hydrostatic Pressure

An aspect of swimming which may impact social skills development is hydrostatic pressure. Hydrostatic pressure applies an equal and consistent amount of pressure on all submerged parts of the body, and it provides resistance without exposing soft tissue to high stress (Fragala-Pinkham, Haley, & O'Neil, 2008; Getz, Hutzler, & Vermeer, 2006). Hydrostatic pressure has been thought to have a soothing and calming effect on individuals with ASD (Nichols, 2015). This effect is likely due to the pressure of the water outside of the body being greater than the pressure inside the body (Becker, 2007). During submersion, the body forces blood away from the extremities toward the heart and lungs. This signals the heart to work more efficiently, pushing a higher volume of blood with each heartbeat, ultimately circulating 30% more blood volume to the entire body. In order to manage the increased volume, the arterial blood vessels relax and create less resistance to blood flow (Nichols, 2015). At this time, catecholamine, a hormone that regulates arterial function, is released. During submersion, the body balances catecholamines which mimics the hormonal balance found during relaxation and meditation (Becker, 2007). Being in water decreases stress levels and elicits a feeling of relaxation (Nichols, 2015). Since individuals with ASD are typically overstimulated and relaxation techniques have been shown to decrease anxiety and increase social skills in those with ASD (Moree & Davis, 2010), the state of relaxation created by hydrostatic pressure may allow for attention needed to develop social skills. Several studies indicated that participants maintained the swim and social skills they acquired through an aquatic intervention (Hettig & Darden-Melton, 2004; Pan, 2010). When additional data was collected to assess maintenance, the participants were again in the pool setting and possibly again reaping the benefits of hydrostatic pressure.

Sensory Deprivation

Swimming provides the opportunity for sensory deprivation which may increase social skills. Individuals with ASD are often characterized as being over stimulated by sensory stimuli. Access to water can provide a space to reduce non-preferred sensory stimuli and replace them with preferred and relaxing stimuli. An adolescent with ASD describes his experience in and out of the water as the following:

> In the water it's so quiet and I'm so free and happy there. Nobody hassles us in the water, and it's as if we've got all the time in the world. Whether we stay in one place or we are swimming about, when we are in the water we can really be at one with the pulse of time. Outside of the water there's always too much stimulation for our eyes and our ears and it's impossible for us to guess how long one second is or how long an hour takes . . . We are outside the normal flow of time; we can't express ourselves and our bodies are hurtling us throughout life. If only we could go back to that distant, distant watery past – then we'd be able to live and contentedly and freely as you lot. (Higashida, 2016, p. 39)

When an individual enters the water, there are several notable shifts in sensory stimulation. First, is the reduction of auditory stimulation. While submerged, auditory stimuli are reduced if not muted, alleviating one source of overstimulation. There is also a change in physical stimulation, as the entire body receives and equal and constant pressure during submersion (Fragala-Pinkham, Haley, & O'Neil, 2008; Getz, Hutzler, & Vermeer, 2006). Lastly, the water provides a simple and appealing visual stimulus. Being in or near water elicits a meditative state and provides strong sensory reinforcers (Becker, 2007). Visually, the color of water could also be an indicator of human's connectedness to it, as many humans are drawn to the color blue (Angier, 2012). The color blue has been known to have calming properties and is associated with trust and confidence (Widrich, 2013). In addition, exposure to blue light has been shown to increase connectivity between the amygdala and hypothalamus which is responsible for processing voices (Vandewalle et al., 2010). The color blue also encourages greater attention to relationships. The multiple sensory stimuli from water provided an explanation as to how aquatic interventions yield social skills development. Previous studies found that swim and social skills were maintained for weeks after the initial treatment (Hettig & Darden-Melton, 2004; Pan, 2010). Since maintenance probes again took place in the water, the participants were likely again receiving the benefits of sensory deprivation post intervention.

Physiological Changes

Aquatic therapy may also yield physiological changes in children with ASD. Autism spectrum disorder is characterized by impairments in social interaction. The autonomic nervous system is theorized to act as a regulator for behavior and contribute to cognitive and affective responses. Emerging literature suggests that individuals with ASD have irregularities in autonomic functioning (Cheshire, 2012). Dysregulation of the autonomic nervous system in individuals with ASD includes decreased basal vagal tone (Bal et al., 2010; Kushki et al., 2013; Ming et al., 2005; Porges et al., 2013). The polyvagal theory emphasizes that the vagus nerve regulates social behaviors, which are compromised in individuals with ASD. The vagus nerve is also considered to link the autonomic nervous system and social behaviors such as social verbalizations and facial expressions (Porges, 2005), areas in which those with ASD have deficits. It is also seen that individuals with higher vagal tone levels have increased reports of connectedness to others (Kok & Fredrickson, 2010). This raises awareness of the role the vagus nerve plays in social interactions. It is hypothesized that activating the vagal nerve in individuals with ASD may increase both vagal tone levels and social skills.

There are several ways to increase vagal tone. The most effective method includes rocking the head back and forth to place the spine at a higher elevation than the head (Porges, 2005). This could explain why individuals with ASD engage in rocking behaviors in attempt to reach a state of increased vagal tone (Porges, 2005). However, this position can be uncomfortable and difficult to attain. Additional methods to increase vagal tone which can be accomplished through aquatic interventions are discussed next.

Cold Exposure. Cold exposure has been shown to activate the vagus nerve through vagus nerve pathways (Yuan et al., 2001). During aquatic activities individuals are often exposed to cool water temperatures. Makinen et al. (2013) found that regular exposure to cold (50º F) lowers sympathetic responses while increasing parasympathetic and vagus nerve activity.

Deep and Slow Breathing. Deep and slow breathing is known to increase vagal tone activation (Mason et al., 2013). Swimming, especially for exercise, is characterized by a face down, front crawl stroke with a bilateral alternating breath. This style of swimming allows for deep and slow breathing which mimics the deep diaphragm breathing that is recommended for increasing vagal tone. Diaphragm breathing has been shown to reduce anxiety and increase the PNS by activating the vagus nerve (Mason et al., 2013).

Meditation. Meditation has been shown to increase vagal tone activity and promote positive emotions and feelings toward oneself (Telles et al., 2013). During meditation, there is also a reduction in sympathetic or “flight or fight” activity as increases in the vagus nerve are noted (Kalyani, 2011; Kork et al., 2013). While submerged in water, the body produces a hormonal balance that is similar to the balance found during meditation or deep relaxation (Becker, 2007). Since submersion mimics meditation, it is possible that the vagus nerve is also being activated while in water.

Exercise. Exercise is an effective method for increasing vagal tone. There are numerous benefits of exercise, especially for individuals with ASD. Children with ASD are at higher risk for obesity than typically developing children (Presmanes et al., 2015). In addition to treating obesity, exercise stimulates the vagus nerve (Wang et al., 2010). Swimming is considered a mild to moderate exercise. As such, swimming is a type of exercise that can stimulate the vagus nerve.

Aquatic Interventions for Individuals with ASD

The purpose of the review of previous interventions is to canvas the literature for insights that could aid in developing an effective aquatic and social skills intervention for individuals with ASD. The first conclusion is that swim and water safety skills are necessary for the survival of individuals with ASD. Second, aquatic interventions offer several physical and socioemotional benefits to individuals with ASD. Thus, it would be beneficial to include aquatics in treatment for individuals with ASD. Teaching youth with ASD to swim not only keeps these individuals safe in and around bodies of water, but also offers a form of social skills therapy that alleviates overstimulation.

Swim and Water Safety Skills

Given the increased risk of drowning that children with ASD face, the first step in the aquatic intervention was to foster swim and water safety skills. Previous aquatic interventions were successful in teaching swimming and water safety skills to children with ASD (Pan, 2006; Vonder Hulls, Walker & Powell, 2006). The present study modeled similar skills such as floating, gliding, kicking and independent arm movements. In addition, there was also an emphasis on slow controlled breathing in the water.

Social Skills

The second goal of the present intervention was to provide a social skills intervention for children with ASD. Although unintended, several aquatic interventions have displayed increases in appropriate social skills in children with ASD. Increases in desired social behaviors such as interest in engaging with others and playing with other children have been seen (Pan, 2010). Most notable were reductions in antisocial behaviors such as stimming as well as irritable and hostile behaviors. In addition, children with ASD began to initiate and maintain eye contact during aquatic interventions (Vonder Hulls, Walker & Powell, 2006). Participants were encouraged to interact with the instructor both in and out of the water. The instructor provided verbal praise for appropriate behaviors during all portions of the study.

Immersion

The immersion component of aquatic therapy yields meditative and sensory deprivation benefits (Becker, 2007; Fragala-Pinkham, Haley, & O'Neil, 2008; Getz, Hutzler, & Vermeer, 2006). For this reason, it is important to include immersion in an aquatic intervention. When implementing any type of intervention with children with ASD, variations and accommodations need to be made for children across the spectrum. Immersion was incorporated into aquatic sessions of all levels. For example, in early phases children engaged in immersion when they are learning to blow bubbles in the water, while in advanced levels, immersion occurred during lap swimming and diving.

Location

The intervention took place at a private outdoor pool. The pool was surrounded by plant life and provided a small waterfall to mimic a natural setting. The private location also provided a reduced-stimuli setting.

Water Temperature

The present intervention took place in comfortable water temperatures between 75-80ºF. Previous research has shown that both cool and warm water have therapeutic benefits. However, the temperatures that have been used were polar extremes and would not create a comfortable setting for children with ASD. Temperatures as high as 77ºF have been seen to increase vagal tone activation, while temperatures as high as 104ºF have shown increases in muscle mobility (Makinen et al., 2013; Becker & Cole, 2004). When creating an aquatic intervention, a comfortable temperature that will still yield benefits to the participant should be used. The water temperature recommended for swim lessons is 83ºF, but lower temperatures may be more appropriate for higher intensity programs (AEA, 2008). While using a moderate water temperature may make participants more comfortable, there is little research on its potential benefits. Additional research can assess the benefits of comfortable water temperatures on children with ASD.

The present study sought to explain the increase in social skills that individuals with ASD experience during aquatic interventions. The present study utilized a quasi-experimental block design with a control group or group of typically developing participants to allow for the comparison between the two groups. The author hypothesized that during aquatic interventions individuals with ASD will experience vagal tone activation. It was hypothesized that this increase in vagal tone will be associated with increases in socially appropriate behaviors and correct interpretation of socioemotional cues following swimming interventions. Additionally, associations between cognitive flexibility and vagal tone have been noted (Hammel et al., 2010; Mygind et al., 2018). An association between cognitive functioning and vagal tone activation was anticipated in the ASD group following the aquatic intervention. It was hypothesized that the control group would display an increase in vagus nerve activation but would not experience similar increases in social skills since they did not display an initial deficit in this area like the ASD group. Given, the diverse sample and minimal resources required to conduct the intervention, it is anticipated that the intervention could easily be replicated with children and young adults with ASD and produce similar results.

CHAPTER 2

Methodology

Design

A quasi-experimental block design was utilized in this study. A quasi-experimental design lacks the element of random assignment to treatment or control groups (Campbell & Riecken, 1968). In this study, randomization was not used because individuals with ASD acted as the treatment group while typically developing individuals acted as the control group. This study implemented a block design. In a block design, there is only one primary factor under consideration in the experiment. Similar test subjects are grouped into blocks. Each block is tested against all treatment levels of the primary factor (Lewis, Bryman & Liao, 2004). The participants in this study were blocked into ASD and typically developing categories. Each group participated in the aquatic treatment.

Participants

A power analysis with power of .8 and significance level of .05 indicated that a sample size of 64 participants was needed to detect an effect of size .50. Half of the participants were typically developing, and the other half were individuals with a diagnosis of ASD. Both groups consisted of children and young adults. Data were collected and analyzed for 64 participants, 32 participants with autism spectrum disorder (73% male, M_{age}=9.74, SD=5.44) and 32 typically developing participants (76% male, M_{age}=9.22, SD=6.12) each of whom participated in the aquatic intervention. The ASD group consisted of 42% Caucasian, 47% Hispanic, 1% African American, 5% Asian American participants and 5% identifying as other. The typically developing group varied by race including 49% Caucasian, 52% Hispanic, 1% African American, 3% Asian American participants and 5% identifying as other. The participants were recruited through Facebook advertisements. The participants were assessed with the Childhood Autism Spectrum Test (CAST) to reinforce previous outside diagnoses from medical providers and education systems. The CAST assessment has proven to be a valid and reliable screening measure for autism spectrum disorder in mainstream populations (Scott, Baron-Cohen, Bolton & Brayne, 2002; Williams et al., 2006). Childhood autism screening tests have shown to be effective screening tools for ASD in adolescent and young adult samples due to few changes in characteristics of ASD with age (Ashwood et al., 2016; Mesibov et al., 1998). Participants with ASD scored within the mild to moderate rages of ASD (M_{CAST}=18.2, *SD*=5.4). Typically Developing participants scored within the non-ASD range (M_{CAST}=1.8, *SD*=3.02). Total CAST scores can range from 0 to 31. Scores below 15 are considered to be within the non-ASD range. Scores between 16-23 indicate mild to moderate ASD while scores from 2431 indicate severe ASD (Williams et al., 2006).

Materials

Vagal Tone Monitor

A Rhythm+ heart rate monitor was utilized during this study to measure vagal tone (Scosche Rhythm+™). The vagal tone monitor is a small arm band that collects information about the participants' heart rate. The monitor was worn during cognitive and socioemotional tasks before and after the aquatic session.

Reading the Mind in the Eyes

The Reading the Mind in the Eyes assessment is widely used to assess individual differences in social cognition and emotion regulation across different groups and cultures (Tragash & Wohl, 2018). The exam includes multiple trials in which the participant is presented with images of human expressions specifically of the eyes and four words that describe emotions. The participant is then asked to match the emotion with the expression. Each participant completed two sets of the assessment, 14 trials before, and 14 trials after the aquatic session. See Appendix A for a sample trial. The test-retest reliability for total score on the Reading the Mind in the Eyes exam is .63 ($p<.01$) (Fernández-Abascal et al., 2013).

Social Skills Checklist

A social skills checklist was utilized during play probes and the aquatic session to assess the participants' social skills in and out of the water. The checklist included 11 items such as the occurrence and frequency of eye contact, verbalizations, and appropriate play (see Appendix B). The checklist behaviors were based on items in the Social Responsiveness Questionnaire (Costantino, 2004), Social Communication Questionnaire (Berument, Rutter, Lord, Pickles & Baily, 1999) and the Autism Spectrum Screening Questionnaire (Ehlers, Gillberg & Wing, 1999).

Procedure

Pre-Intervention

Prior to the aquatic intervention, the participant engaged in several cognitive and socio-emotional tasks outside of the water at the aquatic center.

Resting Phase. A resting baseline phase was conducted prior to the aquatic session. During this phase, the participant was asked to sit still and quietly for two minutes while wearing the vagal tone monitor in order to collect a baseline measure. Many children with ASD engage in applied behavioral analysis therapy in which there is an emphasis on calming techniques and adaptive skills such as sitting quietly and calmly in classroom settings (Page, 2016). Given the short amount of time, the participants did not have difficulty with this task.

Counting Task. Next, the participant was asked to count from one to five verbally and on their fingers. The researcher also counted along with them. This task allowed the researcher to assess the participants' cognitive processes as well as speech (Logie & Baddeley, 1987).

Reading The Mind in The Eyes assessment. The participant was asked to complete the Reading the Mind in The Eyes assessment. During this task, the participant was asked to view pictures of people's eyes. Each picture had four words around it. The researcher asked the participant to look carefully at the picture and then choose the word that best described what the person in the picture was thinking or feeling.

Play Probe. Finally, the participant engaged in a five-minute play probe. During the play probe the researcher announced that it was time to play and presented a toy bin to the participant. The participant was encouraged to select one or more toys out of the bin.

Aquatic Intervention

The aquatic intervention took approximately 20 minutes and was tailored to the participant's aquatic skill level during one-on-one instruction. The participant practiced swimming skills such as blowing bubbles, kicking and arm stroke technique. The intervention focused on submersion which was implemented across skill levels. For those who were beginners, submersion was implemented when first learning how to blow bubbles. For more advanced swimmers, submersion included tasks such as front crawl lap swimming and diving underwater to retrieve diving toys. Participants of all levels spent an average of 6 minutes of the 20-minute session submerged underwater.

Post Intervention

Following the aquatic intervention, the participant repeated the cognitive and socio-emotional tasks from the pretreatment phase.

Resting Phase. Following the aquatic session, a resting phase was conducted. During this phase, the participant was asked to sit still and quietly for two minutes while wearing the vagal tone monitor.

Counting task. Next, the participant was asked to count from one to five verbally and on their fingers. The researcher counted along with them.

Reading The Mind in the Eyes Assessment. The participant was asked to repeat the Reading the Mind in The Eyes assessment. The second portion of the assessment included new trials which the participants were not exposed to prior to the intervention. During this task, the participant was asked to view pictures of people's eyes. Each picture had four words around it. The researcher asked the participant to look carefully at the picture and then choose the word that best described what the person in the picture was thinking or feeling.

Play Probe. Lastly, the participant repeated the five-minute play probe. During the play probe, the researcher announced that it was time to play again and presented a toy bin to the participant. The participant was encouraged to select one or more toys out of the bin. If participants did not engage in the play activity within two minutes, the researcher prompted the participant a second time to select an item from the bin. If the participant was still unable to physically engage in play after the second prompt, social engagements such as eye contact and verbalizations continued to be assessed throughout the session.

Setting

This study took place in two locations. The first day of the study took place in a quiet lab space. In this location, the study was explained verbally and through text to the participants and their guardians. Next, the parents completed the CAST assessment (see Appendix C). The parents also completed several surveys about their background as well as their child's background (see Appendix C) and swim experience (see Appendix D). The second day the study took place at an aquatic center. Participants engaged in cognitive and socioemotional tasks at a table on the deck of the aquatic center. Then they entered the pool for the aquatic portion of the study and returned to the table on the deck for the post-intervention tasks.

Dependent Measures

Social behaviors were measured for each participant across pre-intervention, intervention and post-intervention conditions. Social behaviors included eye contact with the researcher, verbalizations, and appropriate play.

Eye Contact

The operational definition of eye contact is mutual gaze and a signal of interest and intention toward the perceiver (Gibson & Pick, 1963). In the present study, the perceiver was the researcher.

Verbalizations

Verbalizations are classified as any form of verbal communication or attempted communication (Dawson & Adams, 1984). Verbalizations were recorded as words and phrases. Words were operationalized as a single word stated such as “swim” or “bubble” whereas phrases were operationalized as strings of two or more words such as “blow bubbles” or “let’s go swimming.”

Non-verbal Engagement

Non-language forms of social engagement included laughter and smiling. Laughter has been considered a side effect of vagus nerve simulation and the two often occur together (Dolgoff-Kaspar et al., 2012). In addition, laughter and smiling allow non-speaking individuals to engage with others and socially communicate (Hudenko & Magenheimer, 2012).

Appropriate Play

Appropriate play included behaviors such as cooperative play with others, imaginative play or role playing and the appropriate use of toys. Appropriate play also included initiating and accepting play bids to play with the researcher (Stahmer & Schreibman, 1992; Stone et al.,1990).

Measurement

A partial interval scoring procedure was used to determine the occurrence of eye contact, verbalizations (words, phrases, laughter), and appropriate play (imaginative play, cooperative play, bids for joint play) during 10-second intervals within a five-minute session. Coders including the author and trained research assistants indicated whether the behaviors occurred or did not occur during each 10-second interval for every recorded session. The number of intervals during which the behaviors occurred was divided by the total number of possible intervals (i.e., 30) to yield the percentage of occurrence for the five-minute session.

Cardiac and vagal tone activity were collected using a Rhythm+ heart rate monitor and recorded with Immersion Neuroscience software (Zak & Barraza, 2018). To measure vagal tone activity, participants were fitted with the Rhythm+ armband on their forearm. Before the placement of the monitor, participants dried off completely.

Following data collection, the data was inspected using Immersion Neuroscience, a storage and data conversion platform. Cardiac waveforms were visually inspected for brief periods of signal loss, and data drop offs shorter than one second in length were replaced with the averages from adjacent parts of the waveform. Additionally, waveform noise due to experimenter-observer movement was smoothed using mean-value replacement from adjacent parts of the waveform (Norris, Larsen, & Cacioppo, 2007). Next, a 10-Hz low pass filter was applied to the waveform to remove high-frequency noise (Norris, Larsen, & Cacioppo, 2007). After transformations, the researcher extracted the average vagal tone from the pre-intervention session and from the post-intervention session (Barraza, Alexander, Beavin, Terris & Zak, 2015). These values were used to calculate the changes in vagal tone activity from pre to post intervention.

Reliability

The observer was trained by the author, and coded 33% of all sessions or approximately 1/3 of each phase for each participant, by measuring eye contact, verbalizations and appropriate play behaviors using the same scoring procedure. This method is standard practice in behavior analytic literature to determine reliability (Cooper, Heron & Howard, 2007; Poling, Methot & LeSage, 1995). Inter-observer agreement (IOA) was calculated by dividing the total number of agreements by the total number of disagreements plus agreements, and then multiplying this number by 100 (Cooper, Heron & Howard, 2007). Inter-observer reliability across participants was 96% for pre-treatment, treatment and post-treatment conditions.

Analysis

Changes in vagal tone were analyzed in each group using paired-samples *t*-tests, contrasting measures prior to and following the aquatic intervention. Paired-samples t-tests were used to test differences in pre-treatment and post-treatment social, emotional, cognitive and swim skills measures. A 2-way repeated-measures ANOVA was also used to test differences in pre-treatment and post-treatment social skills. Bivariate correlations will be used to assess the correlation between vagal tone and social, emotional, cognitive and swim skills.

Chapter 3

Results

Inspiration for the Present Study

The author of this study is an avid swimmer and a clinician experienced in working with children with ASD. In this role the author discovered a need for aquatic programs tailored for children with ASD as they were not frequently available in the community. Drawing on her two areas of expertise, the author developed an aquatic program for children with ASD. While the intention was only to teach swimming skills, the author noticed improvements in speech and social skills during the aquatic sessions. Surprisingly, nonverbal clients began speaking during the sessions. Multiple families were thrilled with the results of the program both intended and non-intended. Many of those families continued the program years after their child learned to swim because they were pleased with the social skills improvements seen in the water and following participation in the program. From there the author began to design a study to formally test this hypothesis.

Case Study

While the quantitative results of this study are compelling, case narratives provide insight on the study and the impact the intervention had on participants and their family members. Patrick is a 15-year-old Caucasian and Hispanic American male with ASD who participated in the present study. He had been previously diagnosed by outside therapists and schools. According to the CAST, Patrick had severe autism with a score of 23. In terms of communication, Patrick did not produce spontaneous words. According to his mother and therapists, Patrick has been non-verbal his entire life.

Prior to intervention Patrick did not speak. He engaged in vocal stereotypy but did not engage in communication. Patrick made eye contact less than one percent of the session. He did not engage in imaginative or cooperative play.

During the aquatic intervention, Patrick said his first word and phrase. He stated, "Take the squid!" while working with the instructor. During the aquatic intervention Patrick also displayed an increase in eye contact, imaginative play and cooperative play.

Following the aquatic intervention, Patrick continued to make verbalizations totaling in seven words and 20 phrases. In addition, he displayed a significant increase in eye contact, imaginative play and cooperative play. His mother was overjoyed by the outcome of his participation in the study. The data below speak to this experience and the experience of many other participants.

Vagal Tone

Participants with ASD displayed a significant increase in vagal tone following the swimming intervention (M_{pre}= 8.08, SD= 6.56; M_{post}=9.57, SD=1.07; t=6.63 (31), p<.001). Conversely, typically developing participants displayed a significant decrease in vagal tone following the swimming intervention (M_{pre}= 7.00, SD= 4.52, M_{post}=6.43, SD=4.49; t=6.78 (31), p <.001). Finally, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was not significant, F (1, 55)=1.97, p=0.08.

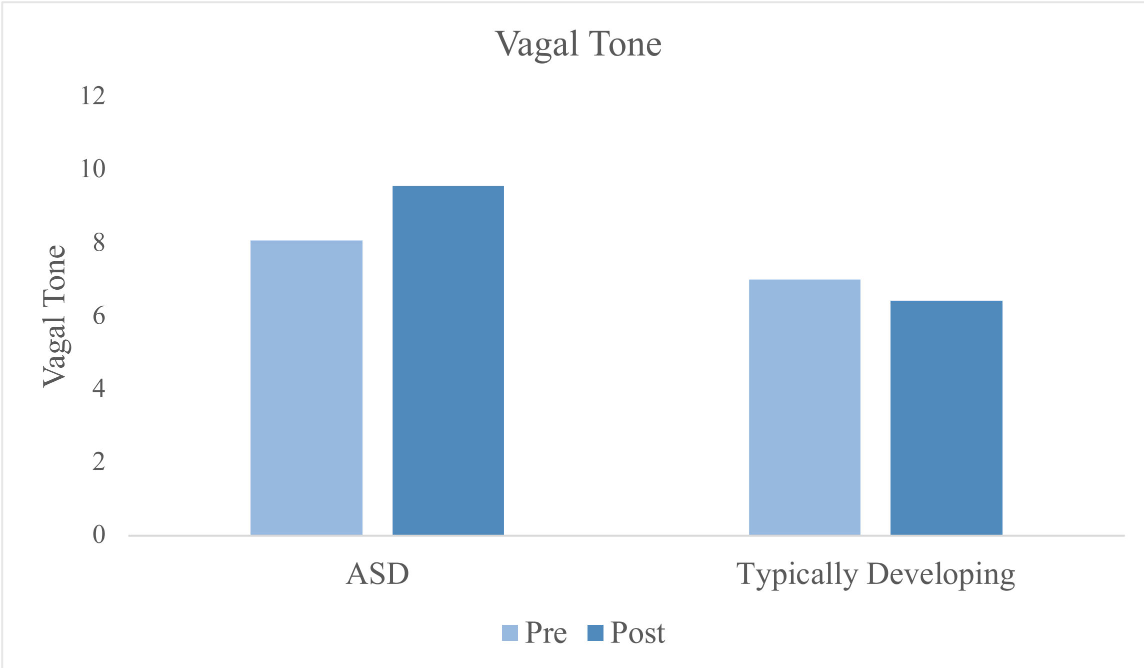

Figure 1. Vagal Tone measurements pre-treatment and post-treatment

Swim Skills

Significant increases in swimming and water safety skills occurred in both participant groups. Participants with ASD displayed a significant increase in swim and water safety skills following the swimming intervention (M_{pre}= 3.58, *SD*= 1.81; M_{post}=4.11, *SD*=3.59; *t*=11.55, *p* <.001). Typically developing participants also displayed a significant increase in swim and water safety skills following the swimming intervention (M_{pre}= 5.19, *SD*= 2.66; M_{post}=5.90, *SD*=2.02; *t*=11.55, *p* <.001). Finally, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was not significant, F (1, 61)=33.96, p=.139.

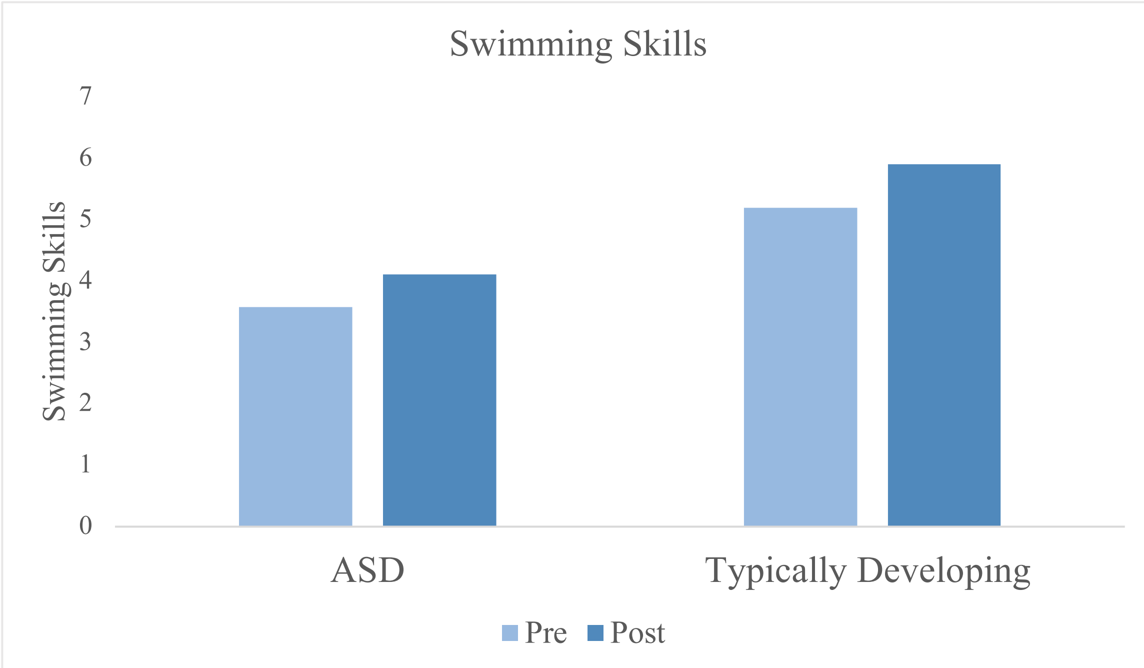

Figure 2. Swimming skills pre-treatment and post-treatment

Social Skills

Significant increases in social skills measures were seen in both participants with ASD and typically developing participants during free play probes.

Verbal Communication

This first social skills measure to be discussed is verbal communication, a common deficit in individuals with ASD. Both groups displayed significant increases in verbalizations following the swimming intervention. Participants with ASD displayed a significant increase in the number of words stated following the aquatic intervention (M_{pre}= 3.05, *SD*= 3.11; M_{post} =8.56, *SD*=6.86; *t*=5.73 (31), *p*<.001). Similarly, significant increases in words said were also present in the typically developing group. The control group demonstrated a significant increase in the number of words stated following the aquatic intervention (M_{pre}= 4.08, *SD*= 2.68; M_{post}=7.85, *SD*=5.15; *t*=6.91 (31), *p*<.001). Finally, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was not significant, F (1, 61)=.175, p=.68.

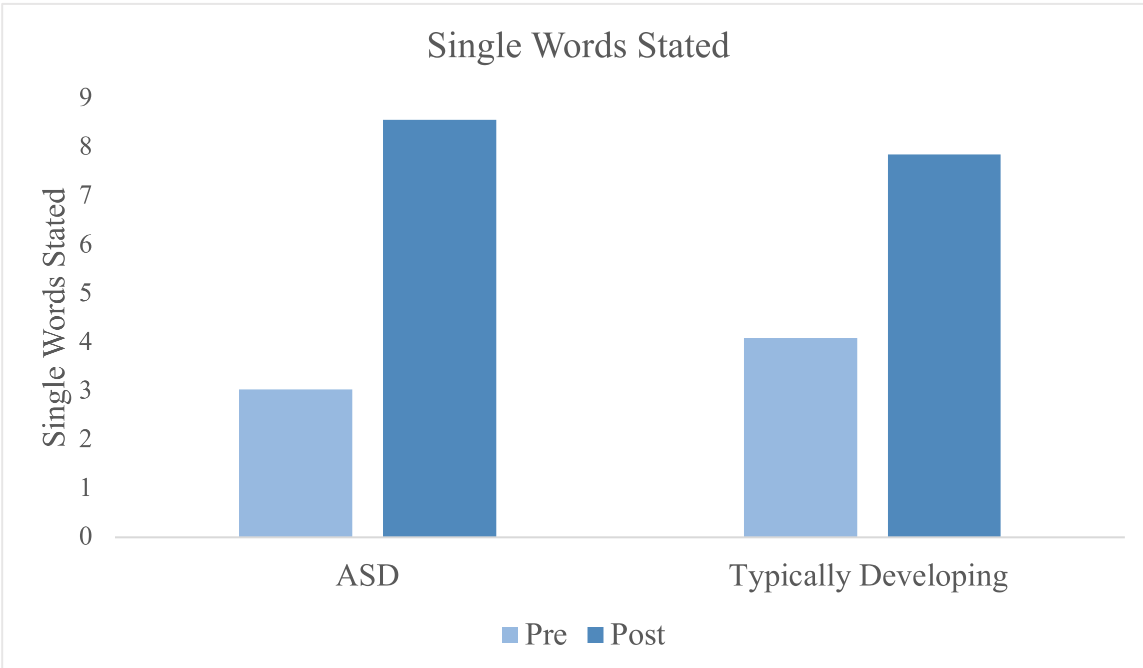

Figure 3. Single words stated pre-treatment and post-treatment

Children with ASD also had a significant increase in the number of phrases stated following the aquatic intervention (M_{pre}= 6.29, *SD*= 9.10; M_{post}=13.47, *SD*=9.84; *t*=4.03 (31), *p*<.001. Typically developing participants also demonstrated a significant increase in the number of phrases stated following the aquatic intervention (M_{pre}= 10.18, *SD*= 8.16; M_{post}=18.43, *SD*=10.31; *t*=5.77 (31), *p*<.001). Lastly, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was significant, F (1, 61)=46.42, p= <.001.

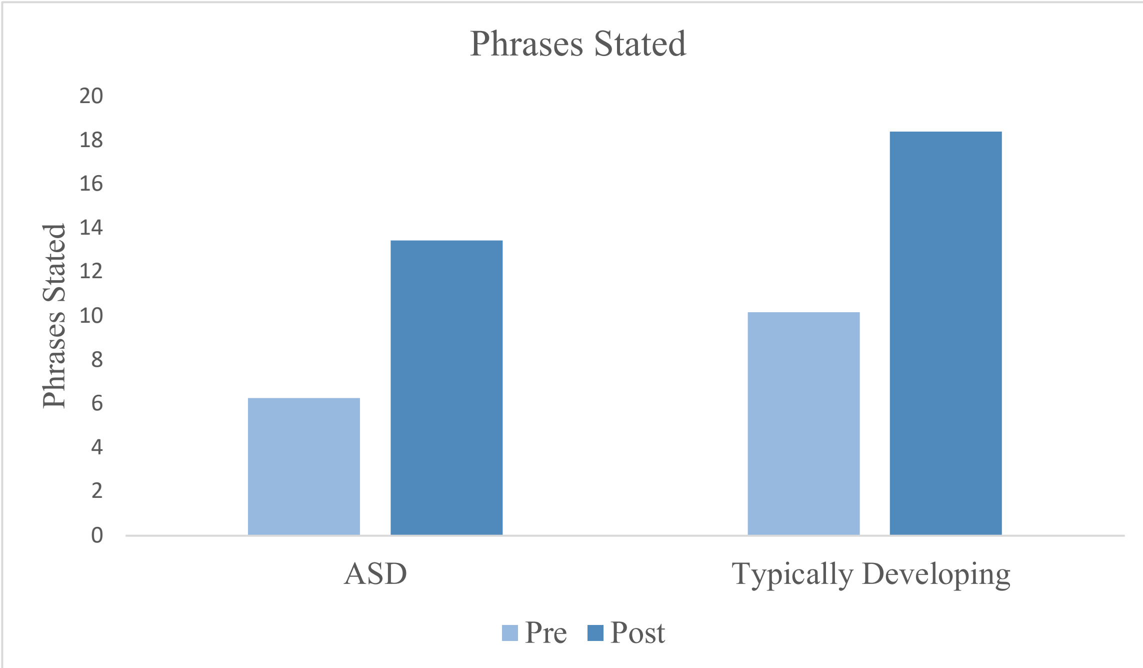

Figure 4. Phrases stated pre-treatment and post-treatment

Eye Contact

Engaging in eye contact is a common deficit in individuals with ASD. Participants with ASD demonstrated a significant increase in the number of times eye contact was made following intervention (M_{pre}= 1.20, *SD*= 1.95; M_{post}=6.35, *SD*=4.87; *t*=2.60 (31), *p*<.00). The control group also demonstrated a significant increase in the amount of eye contact made following treatment (M_{pre}= 4.08, *SD*= 2.68; M_{post}=6.35, *SD*=9.14; *t*=4.85 (31), *p*<.001). Finally, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was significant, F (1, 61)=141.38, p<.001.

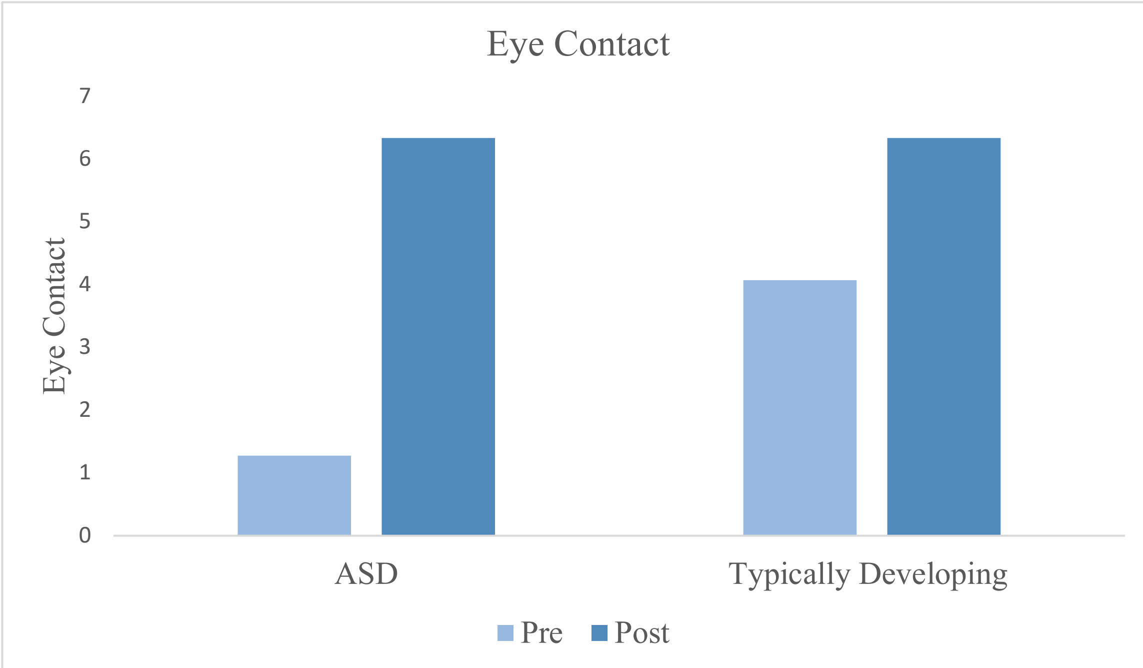

Figure 5. Eye contact made pre-treatment and post-treatment

Laughter

The frequency of the participants' laughing was assessed prior to and following the aquatic intervention. The participants with ASD demonstrated a significant increase in the number of times they laughed following treatment (M_{pre}= 4.08, *SD*= 2.68; M_{post}=9.14, *SD*=6.00 *t*=4.85 (31), *p*<.001). Typically developing children also displayed a significant increase in the number of times they laughed following the aquatic intervention treatment (M_{pre}= 2.14, *SD*= 2.69; M_{post}=4.57, *SD*=2.20; *t*=9.50 (31), *p*<.001). Lastly, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was significant, F (1, 61)=80.40, p<.001.

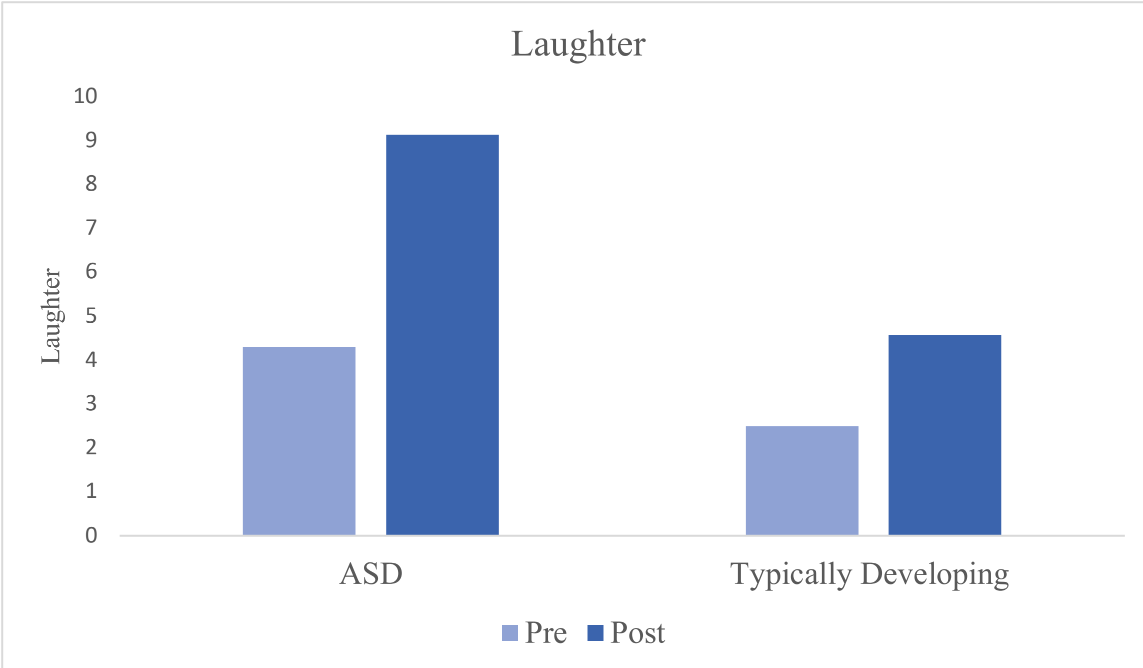

Figure 6. Laughter made pre-treatment and post-treatment

Imaginative Play

Imaginative play is an activity including role play and acting out scenarios. Children with ASD do not typically engage in imaginative play. The frequency of imaginative play was assessed prior to and following the aquatic intervention. Participants with ASD demonstrated a significant increase in the number of times they engaged in imaginative play following the aquatic intervention (M_{pre}=0.26, *SD*= 0.79; M_{post}=1.56, *SD*=1.48; *t*=6.40 (31), *p*<.001).Typically developing participants also displayed a significant increase in the number of times they engaged in imaginative play following treatment (M_{pre}= 1.66, *SD*= 2.03; M_{post}=3.09, *SD*=1.79; *t*=7.94 (31), *p*<.001). Finally, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was not significant, F (1, 61)=.174, p=.678.

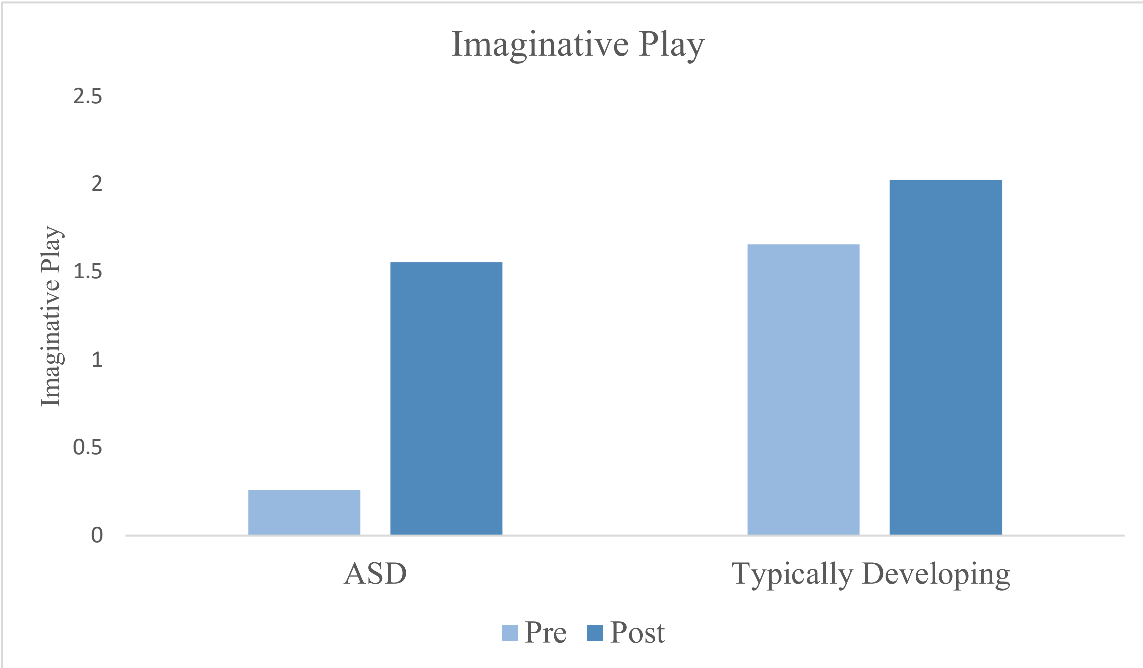

Figure 7. Imaginative play pre-treatment and post-treatment

Cooperative Play

Cooperative play is characterized by play involving working together to achieve a common goal. Given their social skills deficit, individuals with ASD have difficulty engaging in cooperative play. Participants with ASD displayed a significant increase in the number of times they engaged in cooperative play following treatment (M_{pre}= 0.82, *SD*= 0.75; M_{post}=2.68, *SD*=1.71; *t*=6.33 (31), *p*<.001). Typically developing participants also demonstrated a significant increase in the number of times they engaged in cooperative play following treatment (M_{pre}= 1.76, *SD*= 1.37; M_{post}=3.09, *SD*=1.79; *t*=5.87 (31), *p*<.001). Laslty, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was significant, F (1, 61)=5.14, p=.027.

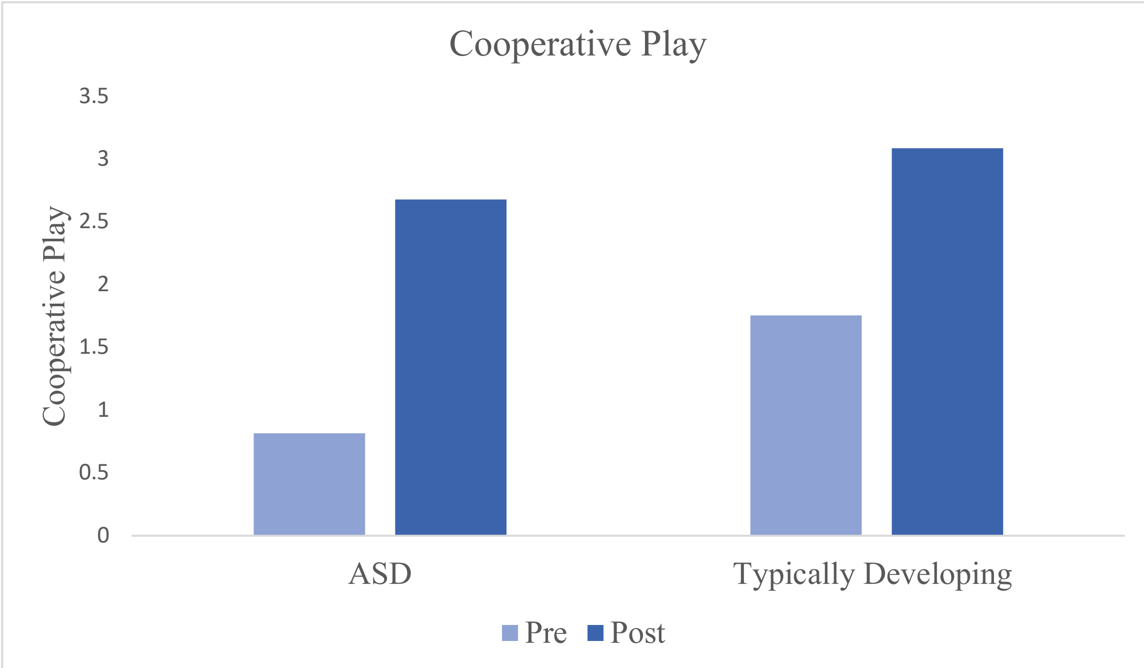

Figure 8. Engagement in cooperative play pre-treatment and post-treatment

Initiate Joint Play

Individuals with ASD do not frequently initiate social interactions with others. However, both groups in the study displayed a significant increase in initiating bids for play. Participants with ASD displayed a significant increase in the number of times they initiated an opportunity to engage in joint play following treatment (M_{pre}= 0.91, *SD*= 1.46; M_{post}=1.55, *SD*=1.24; *t*=3.61 (31), *p*<.001). Typically developing children displayed a smaller but also significant increase in initiation of play bids. The control group demonstrated a significant increase in the number of times they initiated opportunities to engage in joint play following treatment (M_{pre}= 1.62, *SD*= 1.50; M_{post}=1.67, *SD*=1.43; *t*=5.87 (31), *p*=.009). Finally, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was significant, F (1, 61)=7.26, p=.009.

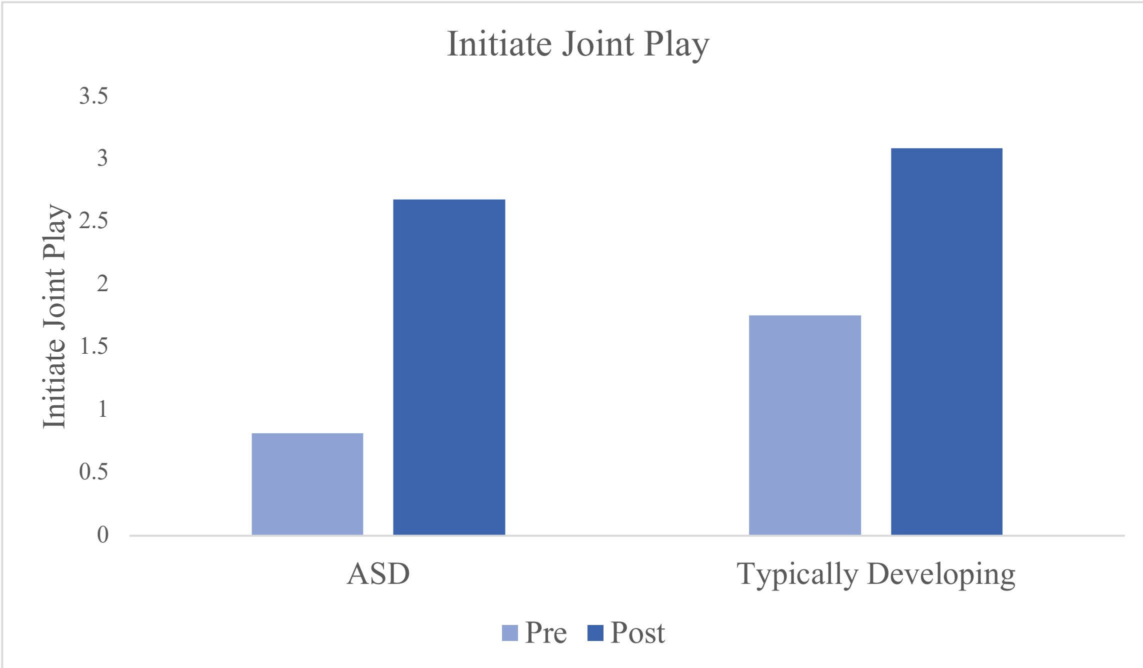

Figure 9. Initiated opportunity to engage in joint play pre-treatment and post-treatment

Smile

Participants with ASD and typically developing participants both displayed a significant increase in the number of times they smiled following the aquatic intervention. The participants with ASD demonstrated a significant increase in the number of times they smiled following treatment (M_{pre}= 2.50, *SD*= 2.93; M_{post}=6.68, *SD*=5.25 *t*=4.85 (31), *p*<.001). The control group also displayed a significant increase in the number of times they smiled following the aquatic intervention treatment (M_{pre}= 3.95, *SD*= 3.11; M_{post}=8.00, *SD*=3.77; *t*=95.82 (31), *p*<.001). Finally, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was significant, F (1, 61)=179.95, p<.001.

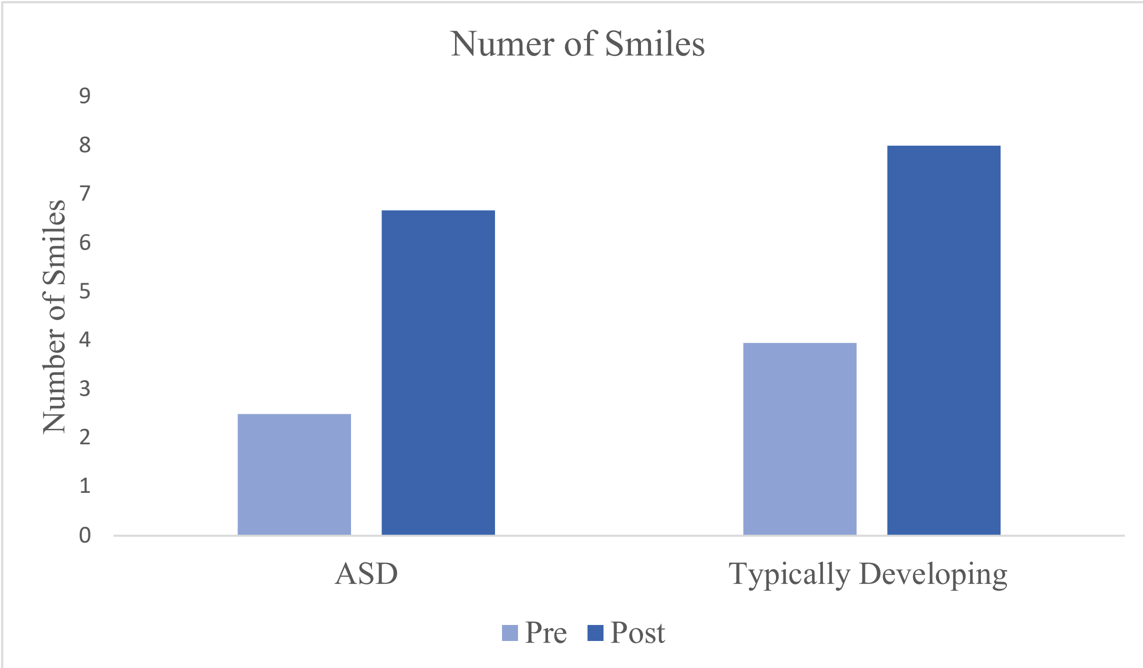

Figure 10. Smiles made pre-treatment and post-treatment

Socioemotional Skills

Reading the Mind in the Eyes (RME)

This tool is used to describe the socioemotional states of individuals with and without ASD. Previous studies have shown that those with ASD have impairments in theory of mind (Baron-Cohen, Wheelwright & Hill, 2001). In the current study, participants were given the Reading the Mind in the Eyes assessment prior to and following the aquatic intervention. Both participant groups displayed a significant increase in the number of correct responses to the Reading the Mind in the Eyes assessment following the aquatic intervention. The participants with ASD demonstrated a significant increase in the number of correct RME trials following treatment (M_{pre}= 3.47, SD= 3.36; M_{post}=5.67, SD=4.47 t=6.02 (31), p<.001). Typically developing participants also displayed a significant increase in the number of correct RME trials following treatment (M_{pre}= 6.48, SD= 3.36; M_{post}=8.71, SD=3.13 t=8.80 (31), p<.001). Lastly, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was not significant, F (1, 61)=31.79, p=.748.

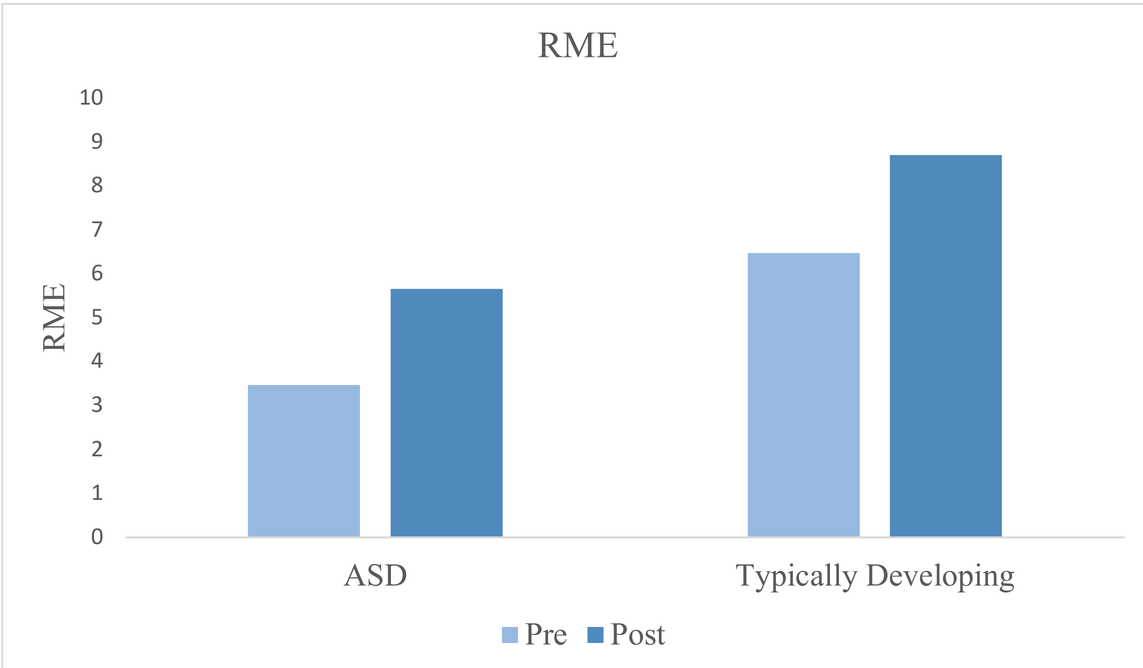

Figure 11. Correct RME trials pre-treatment and post-treatment

Cognitive Abilities

Counting

Participants' ability to count out loud and on their fingers was assessed prior to and following the aquatic intervention. Participants were awarded one point for each of the following; counting out-loud, counting on their fingers, and counting fully to the number of five, earning a total of three points. Significant increases in counting abilities were seen in both participant groups. Participants with ASD demonstrated a significant increase in their score on the counting task following treatment (M_{pre}= 2.59, SD= 0.81; M_{post}=2.65, SD=0.74 t=19.06 (31), p<.001). Typically developing participants also displayed a significant increase in their score on the counting task following treatment (M_{pre}= 2.67, *SD*= 0.80; M_{post}=2.86, *SD*=0.65 *t*=15.36 (31), *p*<.001). Finally, in a repeated measures ANOVA, the interaction between group (ASD vs. TD) and time (pre vs. post) was not significant, F (1, 61)=2.41, p=.126.

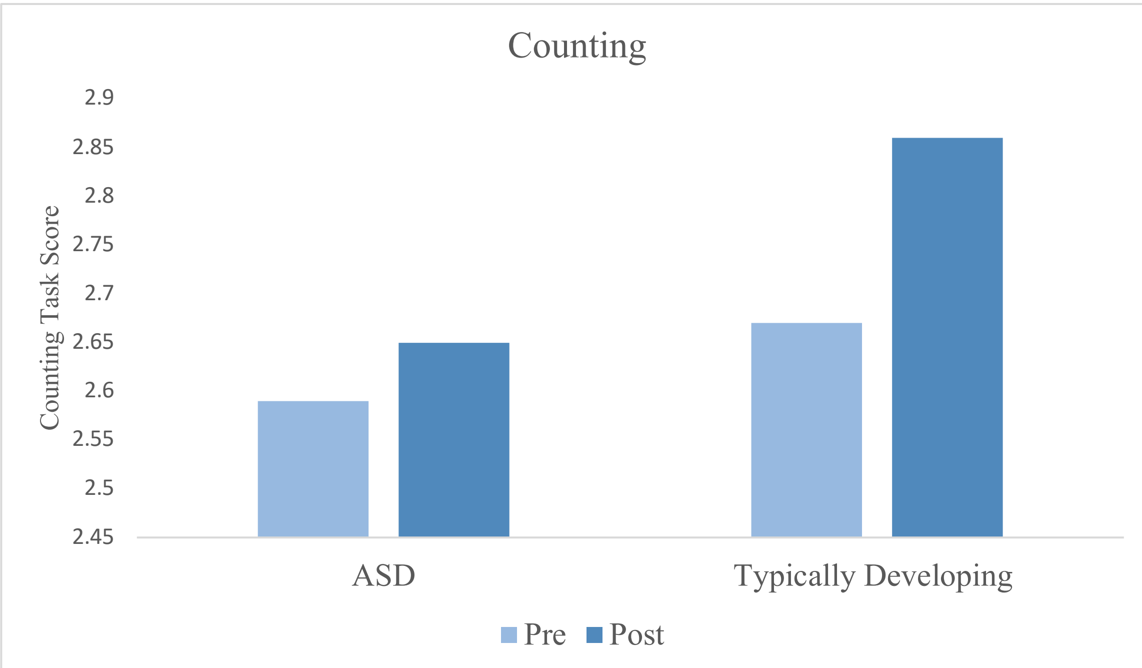

Figure 12. Score on counting task pre-treatment and post-treatment

Vagal Tone and Symptoms of ASD

Children with ASD are more likely to have dysregulated vagal tone levels. As anticipated, the severity of individual's ASD symptoms were correlated with vagal tone activation. A moderate negative correlation was found between pre-intervention vagal tone and CAST scores (*r*=-.40, *p*=.017). That is, participants with high CAST scores or more severe symptoms of ASD tended to have lower vagal tone activation. However, following the aquatic treatment, participants with ASD displayed a significant increase in their vagal tone measures. As noted earlier, a significant difference between pre vagal tone (*M*= 8.08, *SD*= 6.56) and post vagal tone (*M*=9.57, *SD*=1.07) conditions t=6.63 (31), p<.001, was found in participants with ASD. As anticipated, a correlation was not found between pre-intervention vagal tone and CAST scores in the typically developing group (r=.013, p=.47).

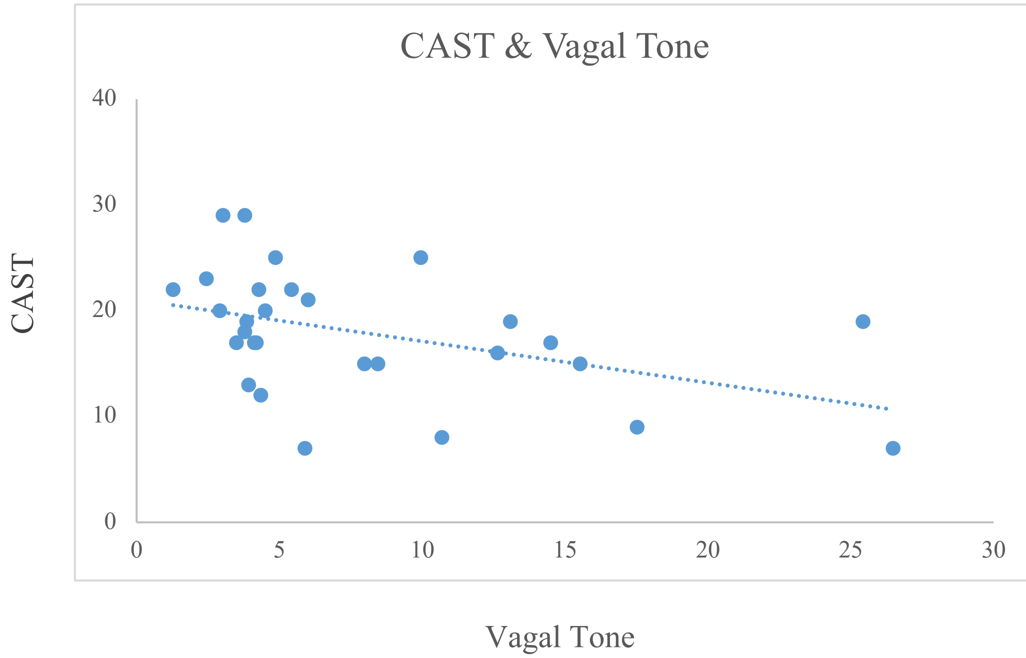

Figure 13. Negative correlation between CAST score and pre-intervention vagal tone in participants with ASD

Social Behaviors and Vagal Tone

Following the aquatic intervention participants experienced significant increases in each of the social measures. It was anticipated that engaging in more intimate social behaviors such as making eye contact would have positive correlations with post-intervention vagal tone levels in the ASD group. It was also expected that there would be a positive correlation between laughter and vagal tone, since previous research has found laughter to be an effective method in increasing vagus nerve activation (Dolgoff-Kaspar et al., 2012). No correlations were expected in the typically developing group, since it was not anticipated for the control group to experience significant differences in their vagus nerve activation.

Several positive correlations were noted between post-intervention vagal tone levels and post-intervention social behaviors. A moderate positive correlation between eye contact and vagal tone was present in participants with ASD (r=.55, p=.002). As participants' vagal tone levels increased, their amount of eye contact made also increased. A lack of eye contact is a common deficit in individuals with ASD. Typically, lack of eye contact is addressed in intense applied behavioral analysis therapy across numerous sessions (Cooper et al., 2007). A similar correlation was not found for the typically developing group (r=-.016, p=.466).

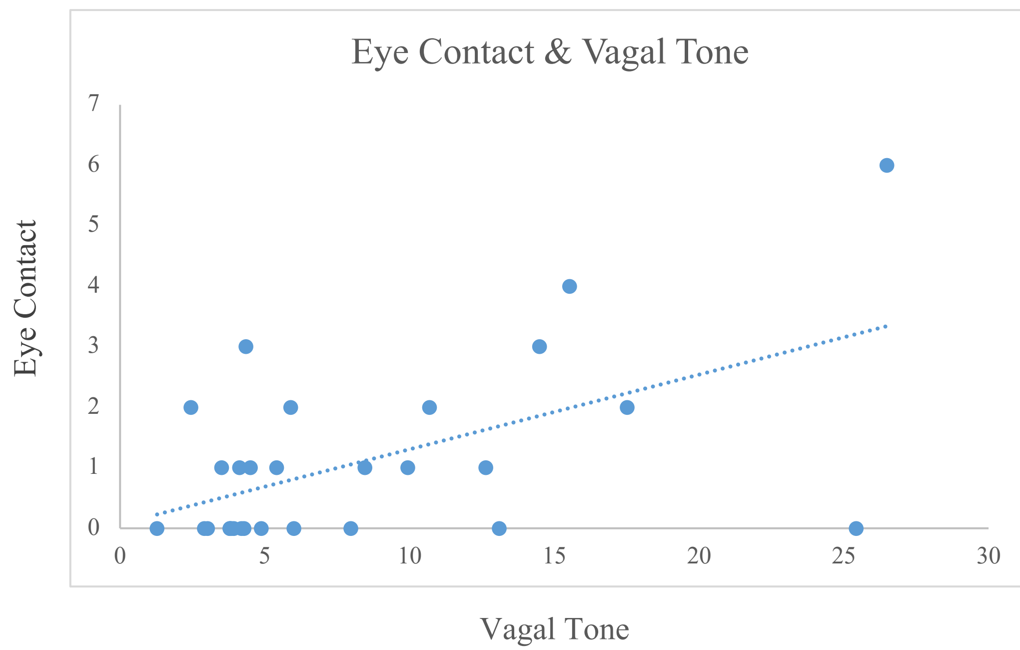

Figure 14. Positive correlation between eye contact and vagal tone in participants with ASD

A moderate positive correlation between vagal tone and Laughing was noted in participants with ASD (r=.47, p=.005). As participants' vagal tone levels increased, their amount of laughter also increased. Similar to eye contact, laughter is an indicator of social engagement. In addition, laughter is a form of social communication. Laughter allows non-speaking individuals with ASD to engage with others and communicate in a verbal manner (Hudenko & Magenheimer, 2012). A similar correlation was not found for the typically developing group (*r*=-.074, p=.357).

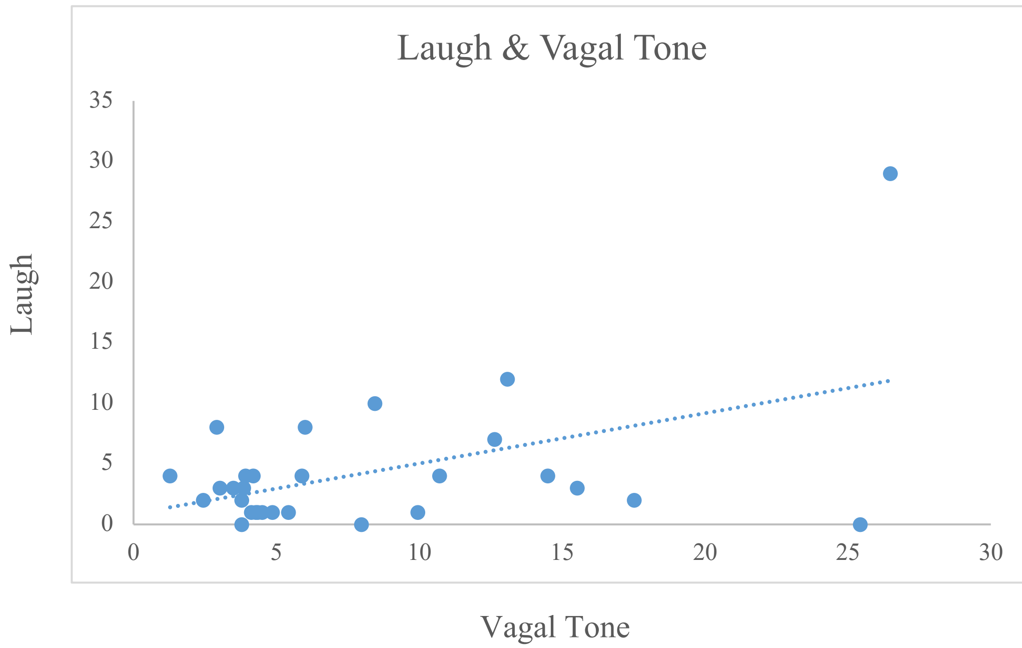

Figure 15. Positive correlation between laugh and vagal tone in participants with ASD

Positive correlations for the remaining social measures were not found in either the ASD or the control group (see Appendix E).

CHAPTER 4

Discussion

The results of the present study indicated that the aquatic intervention successfully increased vagal tone and promoted social skills and swimming skills in participants with ASD. In addition, the aquatic intervention also yielded significant increases in social and swimming skills in typically developing participants. However, many of the gains were greater for the participants with ASD. This present study identifies vagal tone as a mechanism through which aquatic therapy increases social, emotional and cognitive abilities in individuals with ASD.

The present study demonstrated similarities to previous research such as increases in swimming and social skills in participants with ASD (Hettig & Darden-Melton, 2004; Pan, 2010). Previous aquatic interventions also presented a decrease in maladaptive social behaviors such as hand flapping and echolalia in participants with ASD (Hettig & Darden-Melton, 2004; Pan, 2010). Given the positive context of the present study negative behaviors were not assessed. It is anticipated that the present intervention would have produced a similar decrease in maladaptive behaviors since the participants showed an increase in social engagement. Despite the social skills advancements demonstrated in previous research, the interventions were unable to determine the mechanism behind the positive changes in social behavior in children with ASD. The present study has identified vagal tone as the contributing factor to increases in social skills as well as emotional and cognitive abilities in individuals with ASD.

Previous research displayed similar social and swimming skill advances following multiple aquatic treatment sessions. The present study did not take place over the course of several weeks like previous research (Pan, 2006; Vonder Hulls et al., 2006). Instead, participants engaged in a single aquatic lesson, as previous studies found improvements in social and swimming skills within the first session of their programs (Pan, 2006; Vonder Hulls, Walker & Powell 2006). This allowed the researcher to assess the skills acquired in one session. It was also time efficient for the researcher given the large sample size.

Although the present study did not assess longitudinal effects of the intervention, it is hypothesized that with ongoing aquatic treatment results would be maintained. Previous research has shown that participants maintained the increase in social skills for up to 10 weeks following treatment (Pan, 2010). Since this treatment is based on a preferred activity of children with ASD, a multiple session program can be feasible and even desired by participants. A long-term aquatic program is likely to produce maintenance of social skills in individuals with ASD.

The Mechanisms Behind the Change

The aquatic intervention may have led to rapid demonstration of social skills in children with ASD for a number of reasons. The increase in vagus nerve activation during the treatment can account for increases in social skills. It is known that individuals with ASD display lower basal vagal tone level than typically developing individuals (Bal et al., 2010; Kushki et al., 2013; Ming et al., 2005; Porges et al., 2013) and that vagal tone is associated with a variety of social behaviors (Kok & Fredrickson, 2010; Porges, 2005). Increasing vagal tone levels were associated with the increase in social skills following the aquatic intervention. The present study found positive correlations between post-intervention eye contact and post-intervention vagal tone levels ($r=.55$, $p=.002$) as well as laughing and vagal tone levels ($r=.47$, $p=.005$). As anticipated, more intimate social behaviors were correlated with an increase in vagus nerve activation. Previous research has shown that laughter and vagus nerve activation are positively correlated (Dolgoff-Kaspar et al., 2012). Other social behaviors such as speech and play displayed a significant increase following the aquatic intervention. However, those measures were not positively correlated with vagal tone. This suggests that increases in the remaining social measures were due to other properties of the aquatic intervention. The increase in social measures such as types of speech and play may be because swimming is often a preferred activity in those with ASD. Individuals with ASD are more likely to initiate social interactions and engage in joint and cooperative play when the interactions are centered around their preferred interests (Koegel, Koegel, & Schwartzman, 2013; Kuhl et al., 2005; Watkins et al., 2019). In addition, individuals with ASD are also more likely to speak when engaging with others about their preferred interests (Kuhl et al., 2005; Vismara & Lyons, 2007).

Second, the aquatic intervention provides a reduced stimulus setting. Individuals with ASD often present or report symptoms pertaining to overstimulation in their environments. The aquatic intervention provided a setting in which the participants could easy reduce auditory stimuli by submerging under water. In addition to allowing participants relief from auditory stimuli, aquatic environments provide hydrostatic pressure. Hydrostatic pressure provides equal and comfortable resistance to all submerged portions of the body (Fragala-Pinkham, Haley, & O'Neil, 2008; Getz, Hutzler, & Vermeer, 2006). This process is thought to have an alleviating and calming effect on individuals with ASD (Nicholas, 2014). The reduced stimuli and relaxing setting may have provided an optimal context for an individual with ASD to interact with other.

Lastly, aquatic activities tend to be a preferred activity among individuals with ASD. Of the participants with ASD in this study, 98% of their parents reported that their child was highly attracted to water. Previous research also found that children with ASD are deeply drawn to water (Huettig & Darden- Melton 2004; Yilmaz, et al., 2004). Participating in a preferred activity may provide motivation for individual with ASD to engage in social behaviors and verbalizations more frequently than in a non-preferred activity.

Vagal Tone Differences Between Groups

Following the aquatic intervention both the ASD and typically developing groups displayed an increase in swimming, social and cognitive abilities. It was anticipated that each group would also experience an increase in vagus nerve activation. However, the typically developing group demonstrated a decrease in vagal tone. Regulation of the vagus nerve may explain the difference in vagal tone between the groups. Vagal tone is highly associated with heart rate and heart rate variability (HRV); that is when HRV increases, vagal tone also increases (Olshansky et al., 2008; Wang et al., 2010). With a physical activity such as swimming, HRV and vagal tone are likely to increase and when the physical activity is completed, HRV and vagal tone will decrease. The participants had several minutes between the swimming intervention and the phase in which their vagal tone was measured to allow for drying and reapplication of the monitor. In this time, the typically developing participants may have experienced a decrease in HRV and vagal tone. Such a decrease would be less likely in participants with ASD because swimming is a special interest for many individuals with ASD. Emotional excitement is likely to elicit elevated heart rate (Piira et al., 2013). A participant with ASD may have maintained HRV and vagal tone due to their excitement over the preferred activity of swimming even after the completion of the treatment session. Typically developing participants did not report a high attraction to water and would be less likely to share this excitement and therefore elevated HRV after the completion of the session. Ideally, vagus nerve data would be collected while the participants are swimming as well as when they exit the pool. However, such devices were not available at the time of data collection.

Replication

Aquatic intervention addresses several needs of individuals with ASD including deficits in social skills as well as water safety and swimming skills. Since the intervention provides treatment in two crucial areas of development in individuals with ASD, it is important that the treatment can be replicated. A limitation of this program is access to an aquatic facility. However, such facilities are often found in local community centers, high schools and physical therapy or occupational therapy centers. Since autism is a spectrum disorder, it is recommended that during replication the treatments are tailored specifically to the participants' individual skill level and goals. Programs aimed at specific age groups may be better able to meet the needs of participants and find less variability in the participants' vagal tone and social, cognitive and swimming skills measures. Future research can utilize an experimental design with only participants with ASD within a treatment group, a group exposed to water but not swimming and lastly a control group that is not involved in any treatment.

Future Directions

The present intervention displayed increases in swimming skills in a controlled aquatic facility. It is often reported that individuals with ASD are unable to generalize swimming skills in novel settings (Rimland,1964). It would be beneficial for future studies to determine if the skills learned in a controlled aquatic intervention are maintained in novel settings such as a lake or ocean. The present intervention displayed increases in social and swimming skills in individuals with ASD within one aquatic session. Previous research found that these skills could be maintained for up to 10 weeks (Pan, 2010). Future research could assess the longitudinal social and physical benefits of aquatic interventions for individuals with ASD.

The current aquatic intervention proved successful in increasing vagal tone measures and social skills in participants with ASD. It is possible that a similar intervention could benefit those with other disorders. Aquatic therapy and surfing therapy have been implemented to treat those with PTSD. Participants reported a reduction in stress and anxiety as well as a decrease in pain and use of pain medication (Herold et al., 2004; Caddick, Smith & Phoenix, 2015). Similar effects were seen in groups with depression. Those participating in aquatic interventions reported decreases in depression and increases in quality of life (Khanjari & Garooei, 2015; Matos et al., 2017). Such programs have also been successful in treating substance abuse and addiction (Harris, 2015). Although these programs were successful in treating a number of disorders, aquatic therapy is underused in the public sector. Aquatic therapy can be used as a supplement to traditional medical treatments and therapy.

The present study shows that aquatic therapy has proven to be a beneficial social skills treatment for children and young adults with ASD. With the potential to be replicated, this treatment can be accessible to many with ASD. In addition, aquatic therapy has potential to treat those suffering from disorders such PTSD, depression and addiction.

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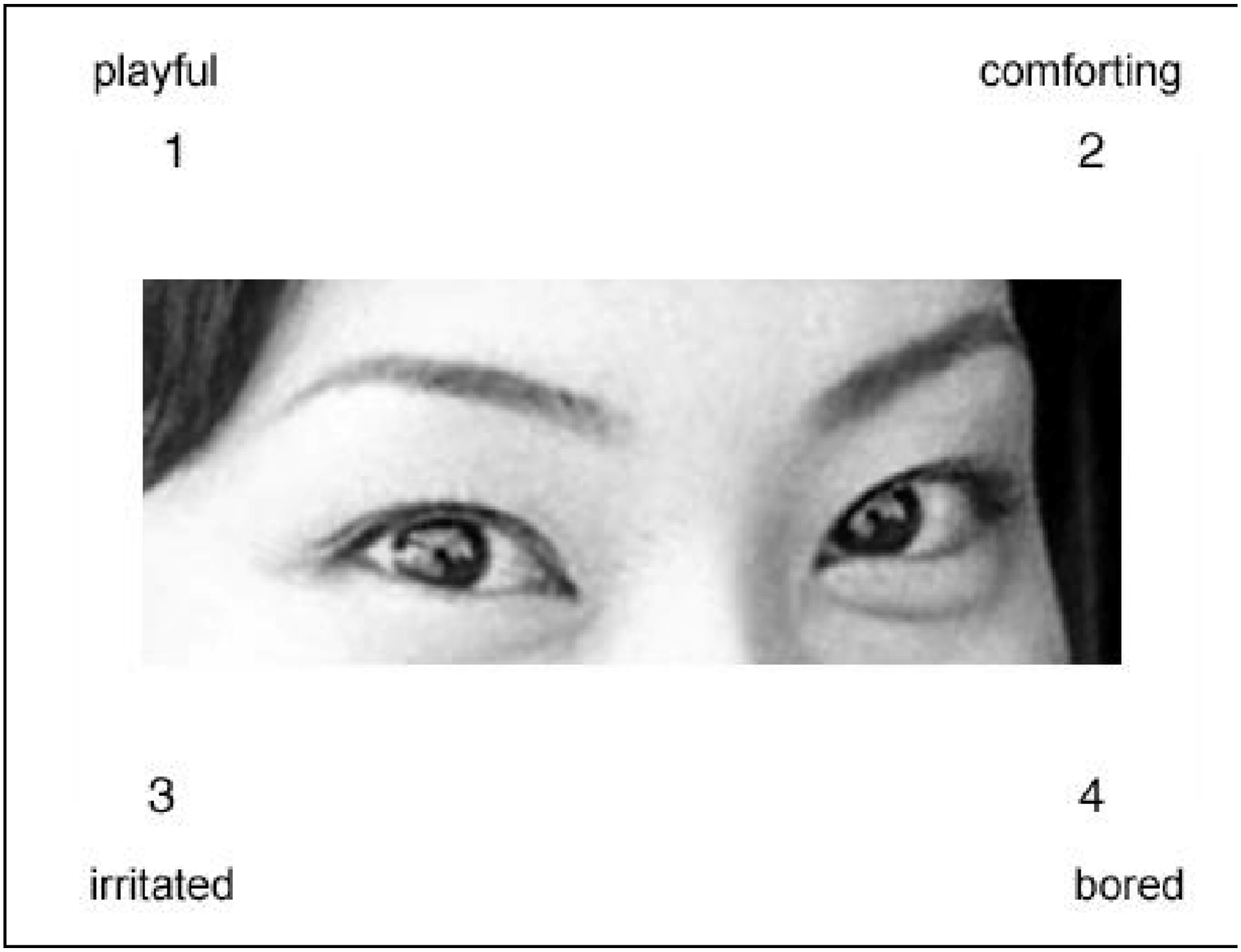
Appendix A

Reading the Mind in the Eyes Trial Example



Appendix B

Social Skills Checklist

Pre

Counting

RME

Words

Phrases

Eye Contact

IM Play

CP Play

Initiation

Smile

Laugh

Praise

Parent Praise

Parent Instruction

Intervention

Words

Phrases

Eye Contact

IM Play

CP Play

Initiation

Appendix C

Background Questionnaire and Social Skills Profile

Social Skills Profile

Child's Name: ____
First Middle Last

Birthdate: _______________ Age: ______ Today's Date: _____________

Mo. Day Yr. Mo. Day Yr.

Grade: __________ Sex: Male / Female Ethnicity: _______________

Parent/Guardian: ____
First Middle Last

Relationship to Child: Mother Father Guardian Other ___________

Please read the following questions carefully and circle the appropriate answer. All responses are confidential.

1. Does s/he join in playing games with other children easily? Yes No

2. Does s/he come up to you spontaneously for a chat? Yes No

3. Was s/he speaking by 2 years old? Yes No

4. Does s/he enjoy sports? Yes No

5. Is it important to him/her to fit in with the peer group? Yes No

6. Does s/he appear to notice unusual details that others miss? Yes No

7. Does s/he tend to take things literally? Yes No

8. When s/he was 3 years old, did s/he spend a lot of time pretending (e.g., play-acting being a superhero, or holding teddy's tea parties)? Yes No

9. Does s/he like to do things over and over again,

in the same way all the time?	Yes	No
10. Does s/he find it easy to interact with other children?	Yes	No
11. Can s/he keep a two-way conversation going?	Yes	No
12. Can s/he read appropriately for his/her age?	Yes	No
13. Does s/he mostly have the same interests as his/her peers?	Yes	No
14. Does s/he have an interest which takes up so much time that s/he does little else?	Yes	No
15. Does s/he have friends, rather than just acquaintances?	Yes	No
16. Does s/he often bring you things s/he is interested in to show you?	Yes	No
17. Does s/he enjoy joking around?	Yes	No
18. Does s/he have difficulty understanding the rules for polite behavior?	Yes	No
19. Does s/he appear to have an unusual memory for details?	Yes	No
20. Is his/her voice unusual (e.g., overly adult, flat, or very monotonous)?	Yes	No
21. Are people important to him/her?	Yes	No
22. Can s/he dress him/herself?	Yes	No
23. Is s/he good at turn-taking in conversation?	Yes	No
24. Does s/he play imaginatively with other children, and engage in role-play?	Yes	No
25. Does s/he often do or say things that are tactless or socially inappropriate?	Yes	No
26. Can s/he count to 50 without leaving out any numbers?	Yes	No
27. Does s/he make normal eye-contact?	Yes	No
28. Does s/he have any unusual and repetitive		

movements? Yes No

29. Is his/her social behavior very one-sided and always on his/her own terms? Yes No

30. Does s/he sometimes say “you” or “s/he” when s/he means “I”? Yes No

31. Does s/he prefer imaginative activities such as play-acting or story-telling, rather than numbers or lists of facts? Yes No

32. Does s/he sometimes lose the listener because of not explaining what s/he is talking about? Yes No

33. Can s/he ride a bicycle (even if with stabilizers)? Yes No

34. Does s/he try to impose routines on him/herself, or on others, in such a way that it causes problems? Yes No

35. Does s/he care how s/he is perceived by the rest of the group? Yes No

36. Does s/he often turn conversations to his/her favorite subject rather than following what the other person wants to talk about? Yes No

37. Does s/he have odd or unusual phrases? Yes No

SPECIAL NEEDS SECTION
Please complete as appropriate

38. Have teachers/health visitors ever expressed any concerns about his/her development? Yes No

If Yes, please specify____

39. Has s/he ever been diagnosed with any of the following?

Language delay Yes No

Hyperactivity/Attention Deficit Disorder (ADHD) Yes No

Hearing or visual difficulties Yes No

Autism Spectrum Disorder, incl. Asperger’s Syndrome Yes No

A physical disability	Yes	No
Other (please specify)	Yes	No

If Yes, please specify____

Appendix D

Swim Experience Survey

Swim Experience Survey

Participant Name: _______________________

For questions 1-2 please circle the number that represents your level of agreement to the statement.

1. My child is attracted to water.

Strongly Agree	Somewhat Agree	Neural	Somewhat disagree	Strongly disagree
1	2	3	4	5

2. My child enjoys being in water.

Strongly Agree	Somewhat Agree	Neural	Somewhat disagree	Strongly disagree
1	2	3	4	5

For Question 3-5 please select the response that best represents your experience.

3. Has your child had a near drowning or negative experience in water?
   a. Yes
   b. No

   If yes, please describe the experience below:

4. Has your child had swim lessons?
   a. Yes
   b. No

   If yes, how many swim lessons has your child had?
   c. 1-4
   d. 5-8
   e. 9+

5. What level swimmer is your child?
   a. Water Discovery: Child can respond to verbal cues and jump on land

b. Water Exploration: Child is comfortable working with an instructor without a parent in the water
c. Water Accumulation: Child will go under water voluntarily
d. Water Movement: Child can do a front or back float on their own
e. Water Stamina: Child can swim 10-15 yards on their front or back
f. Stroke Introduction: Child can swim 15 yards, front or back crawl
g. Stroke Development: Child can swim across the pool front crawl, back crawl and breaststroke
h. Stroke Mechanics: Child can swim across the pool and back front crawl, back crawl and breaststroke

Appendix E

Post-Intervention Social Skills Measures without correlation with Vagus Nerve Activation by Group

	Words	Phrases	Imaginative Play	Cooperative Play	Initiate Play	Smile	RME
ASD *n*=32	*r*=.229 p=.112	*r*=.097 p=.301	*r*=.078 p=.341	*r*=-.057 p=.382	*r*=.067 p=.362	*r*=-.070 p=.301	*r*=.040 p=.417
Typically Developing *n*=32	*r*=.013 p=.475	*r*=.058 p=.386	*r*=.040 p=.421	*r*=-.038 p=.425	*r*=-.268 p=0.08	*r*=-0.161 p=.212	*r*=.008 p=.484