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Dog training intervention improves adaptive social communication skills in young children with autism spectrum disorder: A controlled crossover study

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Abstract

Controlled studies examining canine therapy in autism spectrum disorder are scarce. This study examined the effectiveness of a "Dog Training Intervention" on adaptive skills, autism severity, and anxiety using a controlled crossover design. Seventy-three participants diagnosed with autism spectrum disorder (M_{age} = 4:10 ± 1:0) were divided into two groups that received the dog training intervention during half of the school year in addition to standard-of-care interventions. The dog training intervention, in which the children were taught how to interact with and train dogs, was given twice weekly for 4 months within autism spectrum disorder–specific special education school. Those receiving the dog training intervention first showed significantly increased adaptive social and communication skills compared to the controls, and the gains were maintained after the dog training intervention. Belonging to the first dog training intervention group, higher pre-intervention adaptive skills, higher baseline cognitive ability, and less severe autism severity predicted better adaptive social and communication skills. The controls improved in adaptive skills only during their receipt of dog training intervention after crossover. The positive impact on social communication skills suggests that dog training may serve as an effective model for establishing social interaction. Dog training intervention appears to be an effective adjunct treatment to interventions provided in special education schools for children with autism spectrum disorder.

Lay abstract

There is some evidence that using therapy dogs for children with autism spectrum disorder generally results in improved social communication skills and reduced behavioral problems. However, well-controlled studies that examine its effectiveness are scarce. This study examined the effectiveness of a "Dog Training Intervention." The study included 73 participants diagnosed with autism spectrum disorder (61 males, 12 females) with age range of 2:10–7:6 years (M = 4:10 ± 1:0) who attend autism spectrum disorder–specific special education schools. The study population was divided into two groups. Each group received the dog training intervention during one part of the school year (first half or second half) in addition to the standard interventions provided by the special education school settings. The dog training intervention was given twice weekly for 4 months within the school setting. The group that received the dog training intervention first showed a significant increase in adaptive social and communication skills in comparison to the second group that did not receive the intervention in this period. This improvement was maintained after the dog training intervention. The second group, which received intervention at the second half of the year, showed improvement in communication and socialization adaptive skills only during the period in which they received the dog training intervention. The positive impact on social communication adaptive skills of the dog training intervention among young children with autism spectrum disorder suggests that dogs may serve as an effective model for establishing social interaction. Dog training intervention appears to be an effective adjunct treatment to the interventions provided in special education schools for young children with autism spectrum disorder.

Keywords

adaptive skills, anxiety, autism severity, autism spectrum disorder, dog training intervention

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Autism spectrum disorder (ASD) is characterized by deficits in social communication and restricted, repetitive behaviors and is considered a lifelong disability (American Psychiatric Association [APA], 2013). It is now well accepted that ASD should be diagnosed as early as possible and that early intervention is crucial for achieving the most optimal outcomes (Magiati et al., 2012; Zwaigenbaum et al., 2015). Early intensive behavioral intervention in ASD has resulted in reported gains in cognitive and adaptive functioning, as well as decreased ASD symptom severity (Ben-Itzchak et al., 2014; Ben-Itzchak & Zachor, 2011; Dawson et al., 2010). In addition to established intervention methods, clinicians have also sought effective adjunct treatments, but not all have demonstrated efficacy in empirical research (Davis et al., 2013).

One alternative practice that has been proposed to treat a range of medical problems and developmental disabilities is animal-assisted intervention (AAI) (Silva et al., 2011). The theory behind this intervention is that positive interaction between humans and animals results in enhanced physical and emotional outcomes (Esposito et al., 2011). Physiologic and psychological benefits have been reported in the presence of animals, such as reduced blood pressure and heart rate (Bass et al., 2009); similarly, mitigated social needs and improved general well-being (Jau & Hodgson, 2017) have been reported. AAI includes animal-assisted therapy (AAT) and animal-assisted activities (AAA). AAT refers to interventions in which an animal is helpful in teaching a specific skill and is conducted by trained personnel; AAA refers to interventions in which an animal is involved for general positive effect but there are no specific goals (Palley et al., 2010). AAI has become a popular intervention for individuals with developmental disabilities, using a variety of animals from dogs and horses to dolphins and other species (Bass et al., 2009).

Using dogs as part of an intervention plan has been postulated as an effective strategy to improve social skills of children with ASD by targeting core ASD symptoms. It has been associated with increased social interaction, with the animal postulated to act as a social facilitator (Sams et al., 2006). Researchers suggested that the rationale for its effectiveness is the simple and predictable social actions required for a child's engagement, such as walking the dog on a leash or giving a hand command (Redefer & Goodman, 1989). Studies of dog therapy for children with ASD have reported subsequently decreased negative behavioral patterns (aggression and obsessive behavior) and improvements in a variety of areas including verbal and non-verbal social behaviors (Redefer & Goodman, 1989), the amount of language used and social interaction taking place within a school-based occupational therapy program (Sams et al., 2006), social engagement, smiles, eye contact, affectionate behaviors (Silva et al., 2011), and calmness (Martin & Farnum, 2002; Silva et al., 2018). In addition, the dog provides strong multisensory stimuli, thereby improving sensory avoidant behaviors in ASD (Redefer & Goodman, 1989).

Notwithstanding this body of evidence, only a few studies have included larger cohorts, control groups, or standard assessment instruments. One study used a randomly assigned group comparison design: dog play therapy versus baby doll play therapy. The study included 10 children, aged 7–10 years, who met the diagnostic criteria for ASD, along with a matched comparison group (Fung & Leung, 2014). The study found that the dog intervention produced small but statistically significant increases in verbal social behavior of the children with autism, whereas the comparison intervention did not. Two more comprehensive studies were recently published. The first examined 49 psychiatrically hospitalized youth with ASD, aged 6–8 years, utilizing a crossover design in which participants served as their own comparator by engaging in two 10-min-long interventions: an experimental dog and handler interaction, and a novel toy and handler control interaction. The dog-assisted activities were found to promote social communication behaviors (better positive facial expressions, gestures, talking, and eye contact) (Germone et al., 2019). The second study examined 19 children with a confirmed or probable ASD diagnosis (mean age of 46.2 months) who received a dog intervention in nine sessions of 20 min each and were assessed by measures of direct observation. Significant improvements were found in most items that evaluated the frequency of child–dog social interactions and child–therapist interactions. The researchers concluded that the dog-assisted intervention for children is feasible and seems to improve communication and social interaction skills (Ávila-Álvarez et al., 2020). In addition, O'Haire (2017) reviewed the literature between 2012 and 2016 and concluded that replication of high-quality studies is crucial to move AAI from an enrichment activity to an evidence-based practice for ASD.

In sum, there is preliminary evidence in the literature that dogs may serve as an effective model for establishing social interaction among children with ASD. However, more rigorous testing methodology is necessary. This study is a pioneering effort to be the first to examine the effect of a "Dog Training Intervention" (DTI) in a relatively large cohort of young children with ASD using a controlled crossover study design and utilizing standardized measures.

In this controlled crossover study, we examined the effectiveness of DTI using a structured protocol for children diagnosed with ASD who were enrolled in special education schools designated for children with ASD. The study had two main aims: (1) to assess the effectiveness of a DTI among children with ASD on adaptive skills, autism severity, and anxiety levels and (2) to identify predictors of outcomes in adaptive socialization and communication post-DTI. Variables under investigation included pre-intervention cognitive ability, adaptive skills, autism severity, and the receipt of the DTI.

We hypothesized that the DTI would be superior to the comparison intervention (the standard of care interventions

provided by the special education schools), resulting in improved adaptive skills, decreased autism severity, and reduced anxiety symptoms. We hypothesized that better pre-intervention adaptive skills, less severe autism symptoms, and the use of DTI would predict more adaptive post-intervention socialization and communication skills.

Methods

Participants

The study included 73 participants, 61 boys and 12 girls, with an age range of 2:10–7:6 years (M = 4:10, SD = 1:0). All participants were White. Although specific information about socioeconomic variables was not collected, participants lived in an area characterized by middle-high socioeconomic status. All the participants were previously diagnosed with ASD based on medical and psychological evaluations and had met *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; DSM-IV-TR) or *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-V; APA, 2000, 2013) criteria for ASD at the time of diagnosis. The participants were recruited from 10 ASD-specific special education schools within the same municipality, and 7–8 participants were recruited from each. All participants had been recognized as having ASD by the Israeli National Insurance Institute, which is a prerequisite for eligibility to attend these schools.

Measures

Social Responsiveness Scale–second edition. The Social Responsiveness Scale–second edition (SRS-2) is a 65-item rater report of autistic traits on a 4-point Likert-type scale (0–3 points) (Constantino & Gruber, 2012). SRS-2 scoring is aligned with DSM-5 criteria for diagnosis of ASD. The SRS-2 yields a total score and two higher order indices that correspond to the two symptom domains of ASD: Social Communication and Interaction (SCI) and Restricted Interests and Repetitive Behavior (RIRB). The SRS-2 mean score is 50 with an SD of 10; higher scores indicate more autistic traits. The SRS-2 scores of 60T–65T correspond to the mild severity range, 66T–75T is the moderate severity range, and scores of 76T or higher correspond to the severe range. T-scores $\geqslant$65 (i.e. 1.5 SDs $\geqslant$ the population mean of 50) suggest clinically significant autistic traits.

Vineland Adaptive Behavior Scales. The Vineland Adaptive Behavior Scales (VABS) is a standardized caregiver interview designed to assess adaptive behaviors in children from birth through age 18 (Sparrow et al., 2005). The VABS is organized into four sub-domains: communication, daily living skills (DLS), socialization, and motor skills, each of which yields a standard score (mean of 100, SD of 15). In addition, the measure yields a total score, the Adaptive Behavior Composite (mean of 100, SD of 15). In the VABS, higher scores reflect better functioning.

Spence Children's Anxiety Scale. The Spence Children's Anxiety Scale (SCAS) is used to measure child-rated anxiety symptoms. It consists of 44 items (e.g. "I am afraid when I have to sleep alone," "I worry about things") on a 4-point scale, ranging from "never" (0) to "always" (3) (Spence et al., 2001). The instrument consists of six subscales corresponding to descriptions of different types of anxiety in the DSM-IV: panic/agora phobia, separation anxiety, social phobia, generalized anxiety, obsessive compulsive anxiety, and anxiety about physical injury. The SCAS has good psychometric properties (SCAS norms: for age 4 years, M = 18.81, SD = 10.90; for age 5 years, M = 18.27, SD = 12.23) (Spence et al., 2003) (Cronbach's alpha 0.86–0.94).

DTI ("Dog Time")

The DTI program "Dog Time" was designed by, and performed in cooperation with, the non-profit organization "Dogs for People." This organization selects gentle, neglected dogs from dog shelters and runs dog therapy programs in which these mixed breed dogs are trained to work with children and adults with special needs and at-risk populations. Their therapeutic interventions are provided by certified dog therapists who completed a dog therapy course at an accredited academic institution, Achva Academic College. The course requires 250 classroom hours and 240 h of field practicum. The course content includes dog training, psychology, behavioral approaches, and characteristics of populations with special needs such as those with ASD. Upon completion of the course requirements, the therapists receive an official certificate from the college. Each program cycle lasted 4 months and included two weekly treatment sessions with a 1:1 therapist to child ratio, whether an individual session or in pairs of children with two therapists. In the first and last months, the sessions lasted 45 min and included the entire DTI group from each school (eight children). In the first month, the purpose was to facilitate the adjustment of the children to the dog, and in the last month, the purpose was to practice and generalize the activities with the dog from an individual to a group setting. In the two middle months, the training was conducted in pairs (two children and two trainers) and lasted 20 min. Six dogs participated in the program: one Australian shepherd, one small Jack Russell terrier, four large breed dogs, and one small mixed breed dog. All dogs had been vetted beforehand and exhibited calm responses, even when treated unpleasantly (e.g. petted too hard, pulled on), or were exposed to extreme human behavior (e.g. angry outbursts, yelling). The dogs were chosen based on their basic characteristics and,

depending on the stage of the training program, the calmer and more obedient dogs were chosen for the first stages, while the more energetic and less obedient ones were utilized for the later stages.

The program had several stages:

1. Adjustment to the dogs—the dog walked among the children, around the school and the yard, without any requirement on the part of the children to do something. This stage lasted about 2 weeks.
2. First physical contact with the dogs—touching or petting the dog, starting from the tail and working up toward the head.
3. Feeding the dogs with a spoon without touching them.
4. Walking the dogs with a leash. Over time, the length of the leash was shortened and the length of time walking was extended. In the beginning, the trainer held the leash with the child and then gradually the trainer let go of the leash and the child began to walk the dog alone.
5. Learning to communicate with the dog. This stage involved teaching how to give the dog commands using gestures or words and proper intonation and observe how the integration of various communication components results in better dog responsivity to commands. In this stage, the children also learned to give positive reinforcement (a treat or a good word) to the dog for obeying a command.
6. Two children walking one dog with two leashes. This activity required the children to coordinate and communicate with one another.
7. Learning to give commands that combine a simultaneously coordinated word and gesture combined with the child's movement (commanding "jump" while the child is running). In this stage, the transition was made to more energetic dogs, and devices such as springboards and cones were used.
8. Learning to give commands composed of two or more parts.
9. Independent initiation on the part of the children with the dogs in the context of group work.

The intervention was delivered by three skilled therapists who had received training in a special program of dog training operated by the "Dogs for People" organization. Two therapists participated in each session.

Procedure

The research was approved by the Ethical Committee of the Governmental Department of Education as required. Parents of all the child participants provided written informed consent on behalf of their children, allowing both the participation of their children in the research and the use of their data in accordance with ethical committee requirements.

Table 1. Children's characteristics according to intervention group.

	Group 1	Group 2	F	μ^2
Age	5:4 (0:10)	4:4 (0:11)	25.46***	0.26
DQ/IQ scores	71.54 (19.71)	76.81 (18.08)	2.25	0.04
SRS-2 total scores	73.24 (11.67)	68.06 (9.97)	4.01	0.05
VABS total scores	75.49 (16.37)	79.03 (12.06)	1.04	0.01

SRS: Social Responsiveness Scale; VABS: Vineland Adaptive Behavior Scale.
***$p < 0.001$.

The study was conducted via a controlled crossover design. The cohort was divided into two groups of five schools, matched based on the teachers' impression of the average level of functioning of each group of children in the school. The group to receive the experimental intervention first (group 1) participated in the DTI in the beginning of the school year for 4 months. The second group (group 2) served as a control group during that time period and then received the experimental intervention during the second phase.

Group 1 included 37 participants (29 boys and 8 girls) and group 2 included 36 participants (32 boys and 4 girls). The male-to-female ratio did not significantly differ ($\chi^2(1) = 1.47$, $p = 0.23$) between the groups. As presented in Table 1, the groups did not significantly differ in their DQ/IQ scores or baseline VABS total scores. However, group 1 was older than group 2.

All 10 special education schools used the same educational protocols based on behavioral and developmental principles. The individual learning program focused on language, communication, social skills, DLS, cognitive skills, and gross and fine motor skills. All the children received individual and group therapies provided by a multidisciplinary team including speech pathologists, psychologists, occupational therapists, and applied behavioral analysts and were supported by the Ministry of Health. The schools operated 50 h a week over 6 days.

Information on the study cohort's ages and sexes was obtained from the participants' files at each school. Cognitive assessments were administered by the school psychologists during the first "semester" of the school year. The teachers completed the SRS-2 and SCAS anxiety questionnaires and were interviewed by the study coordinator using the VABS to assess each participant. This information was obtained during the first 2 months of the year (T1). Then, group 1 received the DTI for the next 4 months, while group 2 received the multidisciplinary standard-of-care interventions provided by the schools as described above. At the end of the DTI (T2), the teachers completed again the SRS-2, VABS, and SCAS on all the participants. Subsequently, group 2 started receiving the

DTI and group 1 received the multidisciplinary standard-of-care interventions provided by the schools. After four additional months (T3), the teachers completed the two questionnaires and the VABS interview again regarding all the participants.

Statistical analysis

At baseline, the two groups were compared for age, cognitive ability, autism severity (SRS-2 total scores), and adaptive skills using one-way analyses of variance (ANOVAs). In addition, the two groups were compared for male-to-female ratio using the chi-square test. For evaluating pre-post VABS subdomain standard scores and SRS-2 two subdomain scores, two 2 × 3 multivariate analyses of variance (MANOVAs) (2 Groups × 3 Times) with repeated measures for Time were performed. To evaluate the effect of the intervention on anxiety, 2 × 3 ANOVAs (2 Groups × 3 Times) with repeated measures for Time for the SCAS total score were performed. When Time × Group interactions were significant, simple main effect tests were used. When a Time effect was found, paired comparisons were used to determine when the change occurred.

Community involvement statement: The school team was involved in implementation of the evaluation at all time points. Teachers were interviewed for the VABS, Speech and Language Pathologists provided the language assessments, and educational psychologists provided the cognitive assessments. Teacher assistants helped in treatment implementation.

Results

Adaptive skills

The 2 × 3 MANOVA (2 Groups × 3 Times) with repeated measures for Time for the VABS scores yielded a significant Time × Group effect ($F(8, 56) = 5.89$, $p < 0.001$, $\mu^2 = 0.47$). Separate ANOVAs for each subdomain yielded significant Time × Group interactions for communication ($F(2, 126) = 7.72$, $p = 0.001$, $\mu^2 = 0.11$) (Figure 1(a)), socialization ($F(2, 126) = 7.26$, $p = 0.001$, $\mu^2 = 0.10$) (Figure 1(b)), and motor subdomain scores ($F(2, 126) = 2.98$, $p = 0.05$, $\mu^2 = 0.04$) (Figure 1(c)). We then examined each group separately. For the first group, the MANOVA with repeated measures for Time yielded a significant Time effect ($F(8, 25) = 10.00$, $p < 0.001$, $\mu^2 = 0.76$). Separate ANOVAS with repeated measures for Time for each subdomain yielded significant Time effects. For the communication subdomain ($F(2, 64) = 31.45$, $p < 0.001$, $\mu^2 = 0.50$), a significant increase was noted from T1 to T2 but no significant change from T2 to T3. For the socialization subdomain, a significant Time effect was noted ($F(2, 64) = 8.14$, $p = 0.001$, $\mu^2 = 0.20$) with a significant increase from T1 to T2 but no significant change from T2 to T3. For the motor subdomain, a significant Time effect was found ($F(2, 64) = 10.20$, $p < 0.001$, $\mu^2 = 0.20$) with a significant increase from T1 to T2 and a significant decrease from T2 to T3. For the second group, the MANOVA with repeated measures for Time yielded a significant Time effect ($F(8, 25) = 5.82$, $p < 0.001$, $\mu^2 = 0.65$). Separated ANOVAs with repeated measures for Time for each subdomain yielded significant Time effects. For the communication subdomain ($F(2, 64) = 6.53$, $p = 0.003$, $\mu^2 = 0.17$), no significant change was noted from T1 to T2, but a significant increase was seen from T2 to T3. For the socialization subdomain, a significant Time effect was noted ($F(2, 64) = 7.83$, $p = 0.001$, $\mu^2 = 0.20$) with no significant change from T1 to T2 but with a significant increase from T2 to T3. For the motor subdomain, a significant Time effect was found ($F(2, 64) = 3.26$, $p = 0.04$, $\mu^2 = 0.09$) with no significant change from T1 to T2 or from T2 to T3, but a significant increase from T1 to T3 was noted.

For the DLS subdomain, no significant Time × Group interaction was found ($F(2, 126) = 0.82$, $p =$ NS). A trend for statistical significance was found for a Time effect ($F(2, 68) = 2.82$, $p = 0.06$, $\mu^2 = 0.04$) as a small but significant increase was noted from T1 ($M = 84.17$, $SD = 16.84$) to T3 ($M = 86.43$, $SD = 15.56$; $p = 0.05$). No age effect was found for the VABS MANOVA ($F(4, 60) = 1.35$, $p =$ NS).

Anxiety symptoms

Baseline anxiety scores for the two study groups were within the medium-low normal range, not indicating clinical anxiety. The 2 × 3 ANOVA (2 Groups × 3 Times) with repeated measures for Time yielded a significant Time × Group interaction ($F(2, 65) = 8.01$, $p = 0.001$, $\mu^2 = 0.20$) (Figure 2). Separate ANOVAs for each group revealed (for group 1) a trend toward statistical significance ($F(2, 35) = 2.62$, $p = 0.09$, $\mu^2 = 0.13$); paired comparison tests revealed a significant increase from T1 to T2 ($p = 0.03$) with no significant change from T2 to T3. Group 2 showed a significant Time effect as well ($F(2, 30) = 14.29$, $p < 0.001$, $\mu^2 = 0.49$); however, paired comparison tests revealed an opposite direction—a significant decrease was found from T1 to T2 ($p < 0.001$) and from T2 to T3 ($p = 0.001$). It should be noted that all mean scores for the two groups were within the norms of the SCAS at all time points. No significant age effect was found in an ANOVA for the SCAS total scores ($F(2, 60) = 1.17$, $p =$ NS).

Autism severity

The 2 × 3 MANOVA (2 Groups × 3 Times) for the SCI and RIRB subdomains of the SRS-2 yielded a significant Time effect ($F(4, 64) = 3.08$, $p = 0.02$, $\mu^2 = 0.16$). Separate ANOVAs for each subdomain revealed a

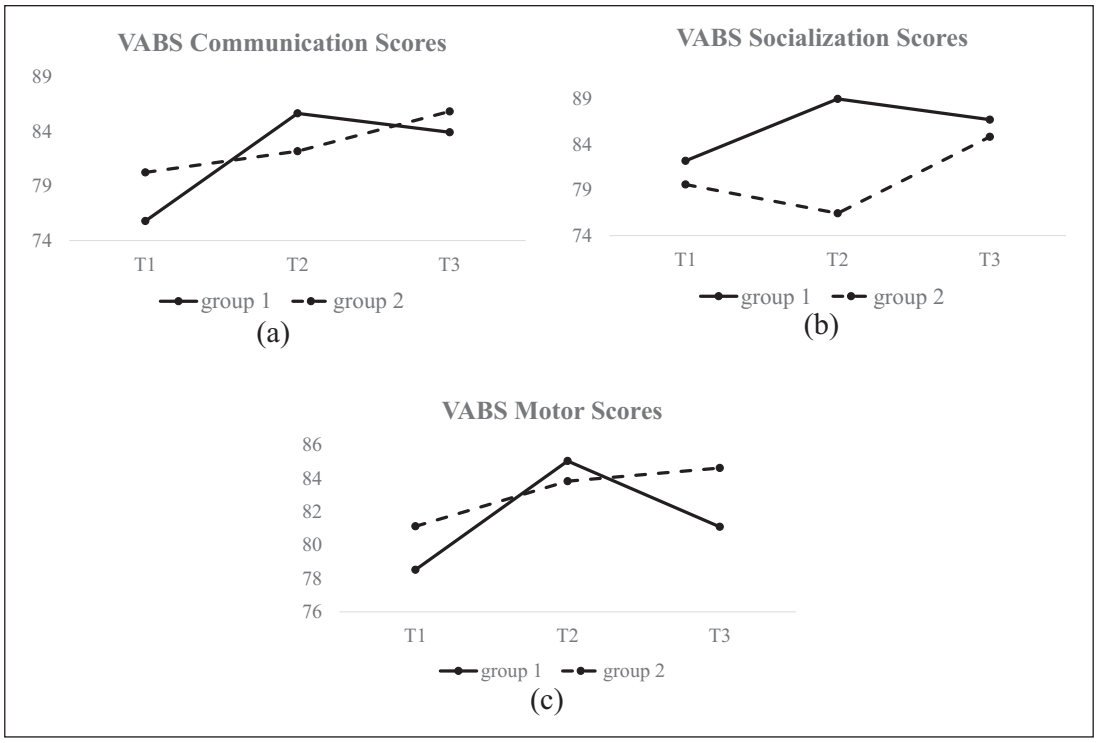

Figure 1. (a) VABS communication scores for the two study groups at three time points, (b) VABS socialization scores for the two study groups at three time points, and (c) VABS motor skills scores for the two study groups at three time points.

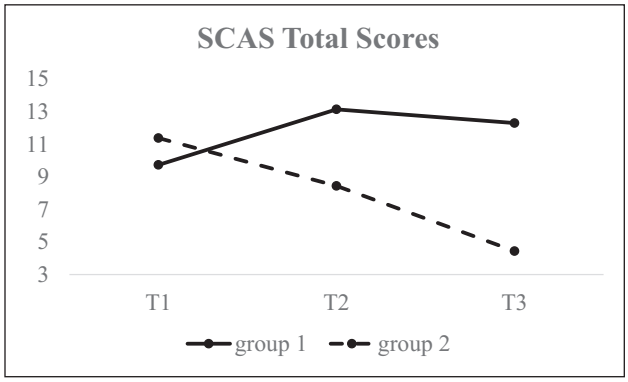

Figure 2. SCAS total scores for the two study groups at three time points.

significant Time effect only for the RIRB subdomain scores but not for the SCI subdomain scores (Table 2). Paired comparison tests revealed a significant increase for the RIRBs from T1 to T2 ($p = 0.001$) and significance decrease from T2 to T3 ($p = 0.002$). Only a trend toward statistical significance was found for a Time × Group interaction ($F(4, 64) = 2.20$, $p = 0.08$, $\mu^2 = 0.12$). However, separate ANOVAs for each of the SRS-2 subdomains did not yield a significant Time × Group interaction: neither for the SCI subdomain ($F(2, 134) = 2.28$, $p =$ NS) nor for the RIRB subdomain ($F(2, 134) = 0.89$, $p =$ NS). Of note, all measurements for both subdomains were above the cut-off point (60) for ASD at all three time points.

Interestingly, the 2 × 3 MANOVA for SRS-2 scores yielded an Age effect ($F(2, 67) = 31.79$, $p < 0.001$, $\mu^2 = 0.49$), which was then investigated. First, we divided the study population into two groups, above and below the median age (59 months). The younger group included 33 participants and the older group included 37 participants. A 2 × 3 MANOVA (2 Age Groups × 3 Times) yielded a significant Age Group × Time interaction ($F(4, 65) = 3.01$, $p = 0.02$, $\mu^2 = 0.16$). Separate ANOVAs for each SRS-2 subdomain yielded significant Age Group × Time interactions for the SCI subdomain ($F(2, 136) = 5.88$, $p = 0.004$, $\mu^2 = 0.08$) (Figure 3(a)) and RIRB subdomains ($F(2, 136) = 3.08$, $p = 0.05$, $\mu^2 = 0.04$) (Figure 3(b)). We then examined each age group separately. For the younger age group, a MANOVA with repeated measures for Time for SRS-2 subdomains yielded a significant Time effect ($F(4, 29) = 9.97$, $p < 0.001$, $\mu^2 = 0.58$). Separate ANOVAs for each SRS-2 subdomain yielded a significant Time effect for the SCI ($F(2, 64) = 14.80$, $p < 0.001$, $\mu^2 = 0.32$) and the RIRB ($F(2, 64) = 6.49$, $p = 0.003$, $\mu^2 = 0.14$) subdomains. Paired comparison analyses revealed a significant decrease in SRS-2 SCI scores from T1 to T2 and from T2 to T3. For the RIRB, a significant decrease was found from T2 to T3 and from T1 to T3, but not from T1 to T2.

For the older age group, the MANOVA with repeated measures for Time for the SRS-2 subdomain scores did not

Table 2. SRS-2 scores at three time points.

	T1	T2	T3	*F*	μ^2	Paired comparisons
SRS-2 SCI	70.00 (10.09)	68.91 (11.73)	66.57 (13.55)	1.57	0.02	
SRS-2 RIRB	69.43 (15.17)	72.71 (15.18)	68.44 (10.03)	4.40**	0.06	T1 < T2; T2 > T3

SRS-2: Social Responsiveness Scale–second edition; SCI: social communication interaction; RIRB: Restricted Interests and Repetitive Behavior.
**$p < .01$.

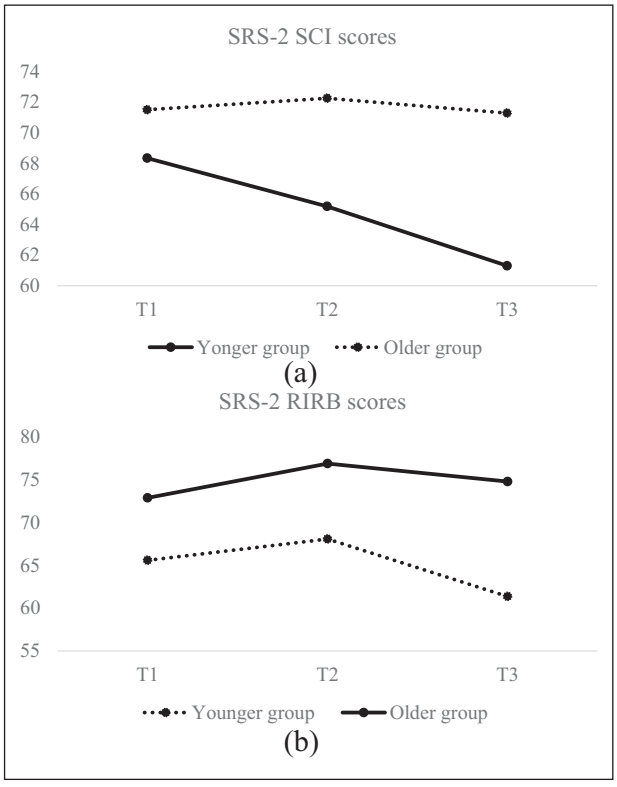

Figure 3. (a) SRS-2 Social Communication and Interaction Scores for younger and older age groups at three time points and (b) SRS-2 Restrictive Interests and Repetitive Behaviors scores for younger and older age groups at three time points.

yield a significant Time effect ($F(4, 33) = 1.82$, p = NS). To summarize, younger, but not older, children showed a decrease in autism severity over time, which was unrelated to the intervention group.

Regarding the second aim (i.e. to identify predictors of outcomes in adaptive socialization and communication post-DTI), we examined which variables predicted T2 VABS socialization and communication scores after the first cycle of DTI (Table 3). For the first stage of analysis, we looked for variables that correlated significantly with T2 VABS socialization. Of the examined variables, T2 VABS socialization correlated significantly and positively with T1 VABS socialization ($r = 0.72$, $p < 0.001$) and IQ scores ($r = 0.55$, $p < 0.001$) and negatively with SRS-2 SC ($r = -0.27$, $p = 0.01$) and RIRB ($r = -0.22$, $p < 0.05$) scores. For the second stage of analysis, we conducted a stepwise linear regression analysis in which the T2 VABS socialization score served as a dependent variable. Independent variables included age and sex in the first step, T1 VABS socialization score in the second step, Group in the third step, DQ/IQ scores in the fourth step, and SRS-2 SCI and RIRB subdomain scores in the fifth step. Interactions of Group with age, sex, IQ, and SRS-2 scores were entered in the sixth step in a stepwise method.

The total model explained 74% of the T2 socialization scores. T1 VABS socialization scores in the second step correlated positively and significantly with T2 VABS socialization scores and added 53% to the explained variance. In the third step, the intervention group correlated negatively and significantly with T2 VABS socialization scores and added 8% to the explained variance. Being in the group that received the DTI intervention (coded as 1) was associated with better scores and added 5% to the explained variance. In the fourth step, IQ scores correlated positively and significantly with T2 VABS socialization scores and added 5% to the explained variance. Having better IQ scores was associated with better T2 VABS socialization scores. In the fifth step, autism severity SRS-2 subdomain scores added 9% to the explained variance. However, only T1 SRS-2 RIRB scores correlated significantly and negatively with T2 VABS socialization scores, as having higher scores at T1 in the SRS-2 RIRB was associated with lower T2 VABS socialization scores. None of the interactions entered in the sixth step yielded a significant effect.

In addition, we searched for variables that significantly predicted VABS communication scores at the end of the first time period (Table 4). Of the examined variables, T2 VABS communication scores correlated significantly and positively with T1 VABS communication ($r = 0.89$, $p < 0.001$) and IQ scores ($r = 0.74$, $p < 0.001$) and negatively with SRS-2 SCI scores ($r = -0.20$, $p = 0.04$).

The total model explained 86% of the T2 communication scores. T1 VABS communication scores in the second step correlated positively and significantly with T2 VABS communication scores and added 76% to the explained variance. In the third step, the intervention group correlated negatively and significantly with T2 VABS communication scores and added significantly 4% to the explained variance. Being in the group that received the DTI intervention (coded as "1") was associated with better T2

Table 3. Regression model for VABS socialization scores at T2.

	B	*SD* Error	β	R^2	ΔR^2
Step 1					
Age	0.01	0.18	0.00	0.00	0.00
Sex	1.05	5.58	0.02		
Step 2				0.53	0.53***
Age	0.159	0.126	0.108		
Sex	4.173	3.861	0.091		
T1 VABS soc.	0.808	0.093	0.741***		
Step 3				0.61	0.08***
Age	−0.085	0.134	−0.057		
Sex	2.601	3.582	0.057		
T1 VABS soc.	0.783	0.086	0.718***		
Group	−11.182	3.120	−0.325***		
Step 4				0.66	0.05**
Age	−0.066	0.127	−0.045		
Sex	2.555	3.386	0.056		
T1 VABS soc.	0.609	0.100	0.558***		
Group	−12.385	2.978	−0.360***		
IQ	0.247	0.084	0.273**		
Step 5				0.74	0.09***
Age	0.057	0.115	0.039		
Sex	4.202	3.152	0.092		
T1 VABS soc.	0.518	0.103	0.475***		
Group	−14.501	2.666	−0.421***		
IQ	0.193	0.076	0.214**		
T1 SRS-2 RIRB	−0.420	0.115	−0.368***		
T1 SRS-2 SCI	0.032	0.212	0.019		

SD: standard deviation; VABS: Vineland Adaptive Behavior Scale; SRS: Social Responsiveness Scale; RIRB: Restricted Interests and Repetitive Behavior; SCI: Social Communication and Interaction.
T1 VABS soc. = VABS socialization score at Time Point 1.
**$p < 0.01$, ***$p < 0.001$.

Table 4. Regression model for VABS communication scores at T2.

	B	*SD* Error	β	R^2	ΔR^2
Step 1					
Age	−0.24	0.19	0.15	0.03	0.03
Sex	−4.25	5.93	0.09		
Step 2					
Age	0.04	0.09	0.02	0.79***	0.76***
Sex	1.20	2.82	0.02		
T1 VABS com.	0.94	0.06	0.89***		
Step 3					
Age	−0.14	0.10	0.09	0.83***	0.04***
Sex	0.14	2.58	0.00		
T1 VABS com.	0.96	0.06	0.91***		
Group	−8.75	2.24	−0.24***		
Step 4					
Age	−0.13	0.09	−0.08	0.84***	0.01*
Sex	−0.11	2.50	−0.00		
T1 VABS com.	0.82	0.08	0.78***		
Group	−8.81	2.17	−0.24***		
IQ	0.17	0.07	0.17**		
Step 5					
Age	−0.06	0.09	−0.04	0.86***	0.02**
Sex	1.54	2.50	0.03		
T1 VABS com.	0.72	0.08	0.68***		
Group	−9.32	2.09	−0.25***		
IQ	0.15	0.07	0.16*		
T1 SRS-2 RIRB	−0.21	0.16	−0.11		
T1 SRS-2 SCI	−0.12	0.09	−0.10		

SD: standard deviation; VABS: Vineland Adaptive Behavior Scale; SRS: Social Responsiveness Scale; RIRB: Restricted Interests and Repetitive Behavior; SCI: Social Communication and Interaction.
T1 VABS com. = VABS communication scores at Time Point 1.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

VABS communication scores. In the fourth step, IQ scores correlated positively and significantly with T2 VABS communication scores and added significantly 1% to the explained variance. Having better IQ scores was associated with better T2 VABS communication scores. Autism severity SRS-2 subdomain scores in the fifth step, and the interaction entered in the sixth step, did not correlate significantly with T2 VABS scores.

Discussion

This study examined the effectiveness of a "DTI" among young children with ASD enrolled in special schools designated for children with ASD. Improvement in adaptive skills was the most prominent outcome of participating in the DTI. After completing 4 months of the dog intervention, the children who initially received this intervention showed an increase in adaptive social and communication skills in comparison to the control group. The same became true for the control group, which showed improvement in adaptive skills, only during the crossover phase in which they received the DTI. Importantly, it was noted that children who received the DTI in the first study phase maintained the acquired improvement in socialization and adaptive communication skills during the second study phase. Moreover, it was found that belonging to the group that received the dog intervention predicted better social and communication adaptive skills at the end of the first phase—beyond the predictive value of pre-intervention adaptive social and communication skills.

These findings support the rationale for choosing a dog-based intervention, which appears to be an effective model for teaching social communication skills. It is well known that one of the main challenges for individuals with ASD is difficulty with social initiation and responding. The same behavior that may be considered adequate in one situation or with a specific person may be totally inadequate in different circumstances. In contrast to humans, however, dogs' responses are more predictable, and a prescribed instruction for dog handling usually results in the same

behavior. In this study's dog intervention, the child only had to learn specific techniques to influence the dog without the need to understand the context, its emotional state, or other varying circumstances.

These findings also add stronger validity to previous findings on the effectiveness of animal-based interventions. In this study, the children's social communication skills were assessed by their teachers, who are excellent observers of the children's interactions with their peers and with the school's special education teams. In addition, adaptive skills were assessed by a commonly used standardized questionnaire that examines behavior in the natural environment. Therefore, the positive findings that were unearthed by these evaluations add more credibility to the notion that some social communication skills learned and experienced with dogs may generalize to more complex human interactions.

In regard to motor skills, the group who received the DTI in the first phase showed an increase in motor skills post-DTI, but this effect extinguished by the end of the second phase without the dog intervention. The control group, on the contrary, who received DTI in the second study phase, showed a gradual improvement in motor skills during both study phases (the whole school year) without correlation to the intervention. One possible reason for this may be the timing of the agility aspect of the DTI. As the DTI includes physical exercise (agility) with the dog mainly during the last stages (7–8) of the program, it may be that the intervention *did* impact motor skills but there was insufficient time to practice the newly acquired skills before the end of the study phase, resulting in extinction of the improvement in motor skills shortly after ceasing the intervention. For the control group who received DTI in the second phase, the effect of the dog intervention on motor skills was not significant.

Other studies also reported improvement in social interaction using dog interventions for children with ASD. However, most of these studies were limited in important ways. For instance, most of the studies examined the impact of dog interventions on child-to-dog and child-to-therapist social relationships (Ávila-Álvarez et al., 2020; Germone et al., 2019), rather than of social interactions in the natural environment. Furthermore, while improvement in communication skills (verbal and non-verbal), social engagement, and language have also been reported, those findings were based on observations during the dog intervention and/or the researcher's own coding system (Fung & Leung, 2014; Redefer & Goodman, 1989; Sams et al., 2006; Silva et al., 2011), rather than via standardized measures of autism severity and adaptive skills. In addition, no other studies utilized a crossover design to explore the effect of timing on the intervention, particularly whether any gains in outcome measures would be maintained over time. In sum, although the improvements reported in previous studies of dog interventions appear to align with the current findings, this study offers more robust, reliable evidence.

Regarding anxiety symptom severity, both groups possessed baseline scores within the normal (subclinical) range. Surprisingly, the group that received the DTI in the first part of the year showed a trend toward significantly increased anxiety symptoms at the time of intervention, while the control group who was receiving the non-interventional standard of care at that time showed a decrease in anxiety symptom severity during that period. When the control group subsequently crossed over and received the DTI, a further decrease in anxiety symptoms was then observed. In attempting to interpret this finding, we suggest the possibility that, at the beginning of a school year, the addition of the dog intervention on top of all of the other new changes presented to the children (e.g. new school experience, new teacher, new special education team) may have caused a rise in the level of anxiety. This finding may indicate it is less stressful for children with ASD to start a dog intervention after they are adjusted to a new routine. This seems to be further supported by the further decreased anxiety observed when the DTI was introduced to the control group in the second half of the school year. However, it is not clear whether this improvement was related to the implementation of the DTI or to the better adjustment to the school of this group all throughout the year. Finally, differences between schools (e.g. teaching style, kind and amount of experience of the special education teams) may account for the variance in anxiety scores between the groups. Future research would do well to explore these factors.

Previous research had suggested that dog therapy may have a calming effect on children with ASD. Indeed, Silva et al. (2018) examined the effectiveness of dog therapy among 10 children with severe ASD and serious compliance difficulties. This research compared the impact of interaction with a live dog and a robotic dog before being exposed to a demanding task. The live dog condition appeared to have a calming effect that manifested in being able to wait quietly, tension release behaviors, lower heart rates, and more compliance. However, no other studies assessed anxiety levels by observation or standardized questionnaires. Therefore, comparison to previous findings was not possible.

Changes in autism severity during the course of the school year did not appear related to the introduction of the DTI. In this study, the level of autism severity in the social communication domain did not change significantly among either group during the year. Interestingly, the level of autism severity in the restricted and repetitive behavior domain increased significantly during the first school semester and then decreased significantly during the second semester regardless of when the DTI was administered. As with the trajectory seen with anxiety levels, it is possible that the stress of the beginning of the school year

in adjusting to the new environment and its demands led to increased severity of RIRB.

Also of interest is the finding that, regardless of the order of receiving the DTI, changes in autism severity over time were related to age. The younger subpopulation within both groups did show a significant decrease in autism severity in the social communication domain in both study phases. In addition, a significant decrease in RIRB was also noted for this younger group, but most of the improvement occurred during the second half of the school year. In contrast, autism severity remained stable over time for the older population of children in both groups. This finding seems to emphasize the importance of intervention for children with ASD at younger ages, when brain plasticity enables changes in central nervous system circuits. This notion is aligned with previous studies that found that initiating interventions at a very young age leads to better outcomes (Ben-Itzchak & Zachor, 2011; Harris & Handleman, 2000; Luiselli et al., 2000; Turner & Stone, 2007; Zwaigenbaum et al., 2015).

An additional predictor for improved adaptive social and communication functioning following DTI was better baseline cognitive ability. In addition, less severe baseline RIRB symptoms predicted improved social adaptive skills too. These findings are in accordance with previous studies that identified cognitive ability (Ben-Itzchak & Zachor, 2011; Eldevik et al., 2012; Klintwall et al., 2015) and autism severity (Ben-Itzchak & Zachor, 2009; Eldevik et al., 2012; Fernell et al., 2011; Szatmari et al., 2003; Zachor, Ben-Itzchak, 2010) as predictors of outcomes in adaptive skills. Interestingly, in the regression models conducted, the interactions of Group and other child characteristics (e.g. age, sex, IQ, autism severity) were not significant. This may point to the effect of DTI on a variety of children with ASD and not on a specific subgroup.

The study has several important potential clinical implications. First, the study's findings points to the positive impact of a DTI on adaptive social communication skills for young children with ASD. Therefore, implementation of DTI in treatment protocols for such children is worthy of consideration, particularly if the study findings are replicated in future research. It should be emphasized, however, that similar to the treatment protocol used in this study, we propose that the DTI be an adjunct therapy to the comprehensive intervention programs commonly utilized in schools for children with ASD. The increase in anxiety symptoms seen among the children who received DTI in the first study period and the decrease in anxiety symptoms seem among those who received it in the second study period may suggest that it is better to implement such a program after a period of adjustment to the school environment, rather than at the beginning of the school year. The partial improvement in motor skills and anxiety symptoms, and the absence of change in autism severity, that were found to be associated with the DTI may also suggest the need to lengthen the program duration to at least 1 year to maximize its effect. Finally, the study results emphasize that younger children with ASD tended to demonstrate better intervention outcomes than older children with ASD, and therefore, early diagnosis and intervention remain crucial.

Study strengths

This is the first controlled crossover study that investigates the effectiveness of a DTI in the context of special education schools for children with ASD. The number of participants for this type of study was large in comparison to previous studies on this topic, which were generally singular case reports and small series; there is a paucity of studies that have included more than 50 participants. Third, in this study, a therapist-child-dog ratio of 1:1:1 was utilized, as were small group intervention sessions of a couple of children, therapists, and dogs, and larger group intervention sessions, in order to practice different types of social engagement. Fourth, this study used standardized measures of adaptive skills, autism severity, and anxiety; most of the previous studies did not use standardized outcome measures but rather coded observed behaviors directed toward the dog or the therapist during or post-intervention. By using standardized measures in this study, a more general impression of the children's functioning *across different domains* was possible, instead of focusing only on the interaction with the dog or the therapist.

Study limitations

Among the study limitations was the lack of racial diversity, the lack of socio-demographic controls, and the fact that the school teachers were not blinded to the intervention; however, the teachers were also not involved in the therapy sessions, so their ratings of the children may not have been subject to as much bias as if they were directly involved in the intervention. Furthermore, the intervention lasted for 4 months, which is the most frequently used intervention duration in previous studies. However, it is possible that providing a longer course of intervention would result in better gains.

Some may consider the absence of parental evaluation to be a limitation; however, we preferred to use the teachers' reports about the children's adaptive skills and anxiety symptoms, rather than those of the parents, because the teachers observe peer interactions more frequently in the school setting and therefore may be better informants.

To summarize, this study demonstrated that a DTI is an effective adjunct treatment to the standard of care interventions provided by various professionals in special education schools dedicated to children with ASD. This interactive and enjoyable intervention resulted in improved socialization and communication skills in the school setting.

Future studies should explore how the dog intervention can be best tailored to children's needs in conjunction with the other interventions offered by multidisciplinary therapeutic teams, as well as to explore predictors of good outcomes to identify the best responders to this intervention. In addition, future research should assess whether progress achieved with the dog training protocol correlates with positive changes in outcome measures. Finally, comparison of this dog therapy to other programs using simple models with predictable responses, such as other kinds of animal therapy, computer-based programs, and robot-assisted therapies (i.e. Bharatharaj et al., 2017), would allow clarification of the uniqueness of this intervention.

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