

Marguerite E. O'Haire<sup>1</sup>Samantha J. McKenzie<sup>2</sup>Alan M. Beck<sup>1</sup>Virginia Slaughter<sup>3</sup>

<sup>1</sup>Center for the Human Animal Bond,  
Department of Comparative Pathobiology  
College of Veterinary Medicine  
Purdue University  
West Lafayette, IN, 47907 USA,  
E-mail: mohaire@purdue.edu

<sup>2</sup>School of Population Health  
The University of Queensland  
Herston, QLD, 4006 Australia

<sup>3</sup>School of Psychology  
The University of Queensland  
Brisbane, QLD, 4072 Australia

# Animals May Act as Social Buffers: Skin Conductance Arousal in Children With Autism Spectrum Disorder in a Social Context

**ABSTRACT:** Children with autism spectrum disorder (ASD) experience high rates of social stress and anxious arousal. Preliminary evidence suggests that companion animals can act as buffers against the adverse effects of social stress in adults. We measured continuous physiological arousal in children with ASD and typically developing (TD) children in a social context during four conditions: (a) a baseline of reading silently, (b) a scripted classroom activity involving reading aloud, (c) free play with peers and toys, and (d) free play with peers and animals (guinea pigs). Our results confirmed heightened arousal among children with ASD compared to TD children in all conditions, except when the animals were present. Children with ASD showed a 43% decrease in skin conductance responses during free play with peers in the presence of animals, compared to toys. Thus, animals may act as social buffers for children with ASD, conferring unique anxiolytic effects. © 2015 Wiley Periodicals, Inc. *Dev Psychobiol* 57:584–595, 2015.

**Keywords:** animal-assisted intervention; arousal; autism spectrum disorder; children; classroom; electrodermal activity; guinea pigs; human-animal interaction; skin conductance; social anxiety; social buffer; typical development

## INTRODUCTION

Children with autism spectrum disorder (ASD) experience significantly more social anxiety than their typically developing (TD) peers (e.g., Kuusikko et al., 2008). The developmental pathway to social anxiety for

children with ASD is posited to involve a cyclical relationship between heightened physiological arousal, social withdrawal, social skills deficits, and negative peer interactions. Heightened arousal during social situations may lead to social withdrawal, which limits opportunities to develop effective social skills, and may make children with ASD more sensitive to negative peer interactions such as those characterized by prejudice or rejection (Bellini, 2006). Indeed, children with ASD experience substantially higher rates of peer victimization and bullying than their TD classmates (e.g., Little, 2001). Heightened arousal in social contexts may also prevent children with ASD from acquiring social skills and benefiting from targeted interventions (e.g., Goodwin et al., 2006). One strategy to reduce arousal in social situations may be to include a companion animal.

Companion animals can act as buffers against the adverse effects of social exclusion and social anxiety.

Manuscript Received: 2 September 2014

Manuscript Accepted: 5 March 2015

Correspondence to: Marguerite E. O'Haire

Contract grant sponsor: WALTHAM<sup>®</sup> Centre for Pet Nutrition

Contract grant sponsor: Eunice Kennedy Shriver National

Institute of Child Health and Development

Contract grant number: R03HD070683

Contract grant sponsor: The Thomas Meloy Foundation

Contract grant sponsor: The American Australian Association

Contract grant sponsor: The Australia Awards Endeavour Program

Article first published online in Wiley Online Library  
(wileyonlinelibrary.com): 27 April 2015

DOI 10.1002/dev.21310 • © 2015 Wiley Periodicals, Inc.

Adults experiencing social exclusion report greater wellbeing if an animal is present (Aydin et al., 2012). When shown pictures of identical scenes both with and without an animal present, adults rate social scenes with animals as less tense, and the people in them as more friendly and less threatening (Lockwood, 1983). The mere presence of an animal appears to change people's perception of social contexts, making them appear less stressful and more positive.

Although a long line of evidence espouses the benefits of human social support, it appears that in some instances, the presence of an animal may be superior to humans in reducing arousal. For example, when performing a stressful cognitive task, adults show lower cardiovascular reactivity in the presence of an animal, compared to a friend, spouse, or being alone (Allen, Blascovich, & Mendes, 2002). In laboratory studies designed to induce social stress among strangers, undergraduate students show lower salivary cortisol and heart rate when an animal is present, compared to a friend, or being alone (Polheber & Matchock, 2013). Initial evidence suggests similar findings among children. A group of 47 male 7- to 11-year-old children with insecure attachment participated in the Trier Social Stress Test, which involves preparing and giving a short speech to unfamiliar adults. After the task, children showed the quickest recovery in salivary cortisol when an animal was present, compared to a friendly human or toy animal (Beetz, Julius, Turner, & Kotrschal, 2012). These findings may be due to the perceived non-judgmental nature of animals. Whereas human counterparts inherently pass social judgment, animals are often perceived as sources of unconditional, positive support. For example, animals do not engage in the emotionally hurtful behavioral manifestations of judgment such as teasing, bullying, or insulting people. Taken together, a growing body of evidence suggests that the presence of an animal may ameliorate the adverse physiological effects of social anxiety.

Despite the pervasiveness of social stress and exclusion among children with ASD, only one study to date has examined the physiological effect of animals for children with ASD. In this study, mean cortisol awakening response was evaluated as a daily indicator of stress in 42 children aged 3–14 years. Results revealed significantly lower cortisol awakening response during four weeks with a service dog in the home, compared to two weeks prior to the dogs' arrival and two weeks after the dogs' removal (Viau et al., 2010). These findings suggest that the presence of an animal can reduce physiological stress in children with ASD in the home environment; however, the results are limited and indirect. They do not evaluate whether the findings are unique for children with ASD compared to

TD children, nor whether the findings are unique to animals compared to other novel stimuli that could be introduced into the home.

The current study is the first to directly examine continuous physiological arousal in children with ASD and their TD peers in a social context in the presence of animals compared to other novel stimuli. Arousal was assessed via skin conductance, which is one of the most robust and well-studied physiological signals (Dawson, Schell, & Filion, 2000). It increases in response to social stress among both children with ASD and their TD peers (Levine et al., 2012). It has also been effectively used to distinguish the physiological response profiles of children with ASD and their TD peers with respect to some social stimuli, such as direct gaze. Compared to faces with averted gaze or closed eyes, the level of increased arousal to direct gaze was positively associated with social impairment in children with ASD, but not their TD peers (Kaartinen et al., 2012). We measured skin conductance for these reasons and because it is a relatively low-invasive method compared to taking saliva samples.

The current study is part of a larger project examining the relationship between human–animal interactions and the developmental pathways to social anxiety in ASD. A total of 192 age 5- to 12-year-old children participated in the study, including 64 children with ASD and 128 classroom-matched TD children. Guinea pigs were selected as the study animal due to their small size, to be closely comparable to a control condition of toys, as well as their suitability to research in the school classroom environment (American Society for the Prevention of Cruelty to Animals, 2008). Data were collected to reflect each element of the developmental pathways model for social anxiety in ASD, including social skills deficits, social withdrawal, negative peer interactions, and physiological arousal. Findings revealed that children with ASD showed global improvements in parent- and teacher-reported social skills after eight weeks with animals in the school classroom, compared to a waitlist control period (O'Haire, McKenzie, McCune, & Slaughter, 2014).

For a subsample of 99 participants (33 with ASD), naive behavioral observation and skin conductance data were collected. Children participated in groups of three, including one child with ASD and two classroom-matched TD peers. Four conditions were presented, each designed to mirror the social context of a traditional classroom setting, where school-age children spend the majority of their time. Conditions included: (a) a baseline of reading silently, (b) a scripted classroom activity involving reading aloud, (c) free play in the presence of toys, and (d) free play in the

presence of animals. Results of the behavioral data showed that children with ASD exhibited less social withdrawal and fewer negative peer interactions when the animals were involved, compared to the toys (O'Haire, McKenzie, Beck, & Slaughter, 2013). Taken together, these initial findings suggest that the presence of an animal ameliorates three of the four components of the developmental pathways model to social anxiety in ASD (i.e., social skills, social withdrawal, and negative peer interactions). It is therefore essential to evaluate the final component, physiological arousal, as a potential mechanism for observed behavioral changes.

Here, we explore the results of the skin conductance data for both children with ASD and their TD peers. We predicted that children with ASD would show higher physiological arousal in all conditions, compared to their TD peers, consistent with elevated rates of heightened social arousal in children with ASD. Our main hypothesis was that children with ASD would show reduced physiological arousal in the presence of the animals, compared to the other three conditions. We expected that children with ASD would show greater decreases in arousal than their TD peers, for whom an informal social setting would not trigger heightened arousal.

## METHODS

### Ethics Statement

All human-related and informed consent protocols were approved by The University of Queensland's Human Ethics Committee and all animal-related protocols were approved by The University of Queensland's Animal Ethics Committee. Approval to approach school principals was granted by the Queensland Department of Education, Training, and Employment for state schools and Brisbane Catholic Education for private schools. Upon written consent from the principal, teachers, and parents (including next of kin or guardians) were approached for written consent on behalf of child participants, who also gave verbal assent.

### Participants

**Inclusion Criteria.** Each participant group consisted of one target participant with ASD and two TD peers. Inclusion criteria for participants with ASD included: (a) age between 5 and 13 years; (b) enrolment in a grade K-7 mainstream classroom, (c) a parent- and teacher-reported diagnosis of ASD (details below) and (d) no prior parent-reported history of animal abuse. Given the limited amount of time available for testing within the school classroom, lengthy diagnostic instruments such as the Autism Diagnostic Observation Schedule (ADOS) were replaced with validated parent- and

teacher-report screening instruments. Inclusion criteria for data analysis were based on two ASD screening instruments, and included: (a) a score  $\geq 11$  on the Social Communication Questionnaire (SCQ), which is the optimal cut-off value for clinical use to indicate the presence of ASD (Norris & Lecavalier, 2010) and (b) a percentile rank  $\leq 25$  on the Social Skills Rating System (SSRS) Social Skills domain parent- or teacher-version to indicate low social skills characteristic of ASD (Macintosh & Dissanayake, 2006). Alternatively, in the absence of SCQ data ( $n=3$ ) or an SCQ score  $< 11$  ( $n=3$ ), the inclusion criterion was set to a more stringent percentile rank of  $\leq 5$  on SSRS Social Skills. Inclusion criteria for TD peers included: (a) age between 5 and 13 years, (b) enrollment in a classroom with a target participant with ASD, (c) no parent- and teacher-reported diagnosis of ASD, and (d) no prior parent-reported history of animal abuse.

**Sample Characteristics.** Thirty-eight groups of three children (114 children total) participated in the study. Each group consisted of one target participant with ASD and two TD peers. Following data collection, five groups were excluded from data analysis for the following reasons: (a) the child with ASD changed schools prior to completing data collection, (b) one of the TD children decided that they did not want to participate, and (c) three participants with ASD did not meet the screening criteria for ASD. The final sample included 33 groups comprised of 99 children from 15 classrooms in four schools throughout the greater Brisbane area in Australia.

Target participants with ASD included 33 children aged 5.2–12.1 years with a diagnosis of ASD, including Autism Spectrum Disorder ( $n=7$ ), Autistic Disorder ( $n=7$ ), Asperger's Disorder ( $n=14$ ), and Pervasive Developmental Disorder Not Otherwise Specified ( $n=5$ ). Diagnoses were made by independent pediatricians ( $n=30$ ), clinical psychiatrists ( $n=2$ ), and clinical psychologists ( $n=1$ ). On the SCQ, 18 participants qualified for ASD and 9 qualified for autism. The remaining six target participants (three scoring  $< 11$  and three missing SCQ data) all scored a percentile rank  $\leq 5$  on SSRS Social Skills. The sample of TD participants included 66 children aged 5.1–12.7 years with no prior diagnosis of ASD. No TD children met the criteria for ASD or autism on the SCQ (all scores  $\leq 10$ ). Mean participant demographic and ASD screening data are reported in Table 1.

### Procedure

All participants met individually with the researcher (MEO) prior to the experimental procedure. The initial meeting was intended to familiarize participants with the researcher and the study, and to prevent potential novelty effects of a new person. Children were thus accustomed to the experimenter, but not to the study materials, prior to the experiment. Children participated in experimental sessions in groups of three, including one child with ASD and two randomly selected TD children from the same classroom. Sessions took place during school hours in a quiet space outside of the child's regular classroom. Four experimental conditions were administered with each group by the researcher in the same

**Table 1. Demographics and Screening Measures for Children With Autism Spectrum Disorder (ASD) and Typically Developing (TD) Children**

	Demographics			ASD Screening Measures					
	Sex (male)	Pet owners	Age (years), M (SD)	SCQ Lifetime Parent, M (SD)	SSRS Social Skills Teacher, M (SD)	SSRS Social Skills Parent, M (SD)	SSRS Problem Behaviors Teacher, M (SD)	SSRS Problem Behaviors Parent, M (SD)	SSRS Academic Teacher, M (SD)
ASD	72.7 %	81.8 %	9.4 (2.3)	18.9 (6.6)	24.4 (24.9)	6.9 (12.2)	75.6 (23.0)	86.1 (19.8)	26.0 (27.8)
TD	42.4 %	72.9 %	9.0 (2.3)	3.7 (2.7)	72.9 (28.7)	53.3 (28.0)	38.1 (27.6)	45.5 (26.9)	50.9 (25.3)
<i>p</i>	.004	.214	.465	<.001	<.001	<.001	<.001	<.001	<.001

SCQ, Social Communication Questionnaire; SSRS, Social Skills Rating System; *p*, comparison between ASD and TD.

order with the same three participants. Physiological data were collected continuously throughout all conditions for both children with ASD and TD children.

**Baseline (Reading Silently).** A baseline period of reading silently allowed for participants to adjust to the experimental setting and to collect physiological data during a quiet activity among peers. The stimulus material for reading silently was a child-selected book from their classroom library. Participants were instructed to engage in reading silently or browsing for five minutes.

**Scripted Activity (Reading Aloud).** For participants in first grade (year one) and beyond, the stressor activity was reading aloud in front of peers and the experimenter. The stimulus materials for reading aloud were selected from the Dynamic Indicators of Basic Literacy Skills (DIBELS) Oral Reading Fluency, which offers approximately 20 standardized passages per grade level with high test-retest and alternate-form reliability (Good, Gruba, & Kaminski, 2002). The DIBELS Oral Reading Fluency procedure requires each child to read aloud for one minute. For each group, the selected passages and reading order were pre-determined through a computerized randomization procedure. The entire procedure took approximately 5 min for a group of three children.

For younger children without reading skills (<25% of sample) the stressor task consisted of an experimenter-directed coloring task in which children were instructed to use pre-determined colors in a regimented order to complete a drawing within a specified time frame.

**Toys.** The toy condition consisted of 10 min of free play with peers and toys. The toys included a standardized set of items, which the children had not previously seen. A variety of toys was selected for both genders and a range of ages. Examples include cars, dolls, colored clay, and spinning tops for use in a plastic battle arena. For a complete listing of the toys, see O'Haire et al., 2013.

**Animals.** The animal condition consisted of 10 min of free play with peers and animals. The animals included two guinea pigs, which the children had not previously seen.

Guinea pigs were selected as the study animal due to their small size, to be most comparable to toys. They were obtained at a young age to enable early socialization to human handling. Each same-sex pair of guinea pigs was housed in a large, two-level cage with soft, dry bedding, a hiding house refuge, and constant access to a fresh supply of food and water. To ensure that outcomes were not due to an individual guinea pig, a different pair of guinea pigs was randomly allocated to each classroom. Children were instructed prior to the session on how to properly hold guinea pigs.

## Measures

**Autism Screening.** Two standardized instruments were administered for ASD screening purposes. The Social Communication Questionnaire (SCQ), formerly known as the Autism Screening Questionnaire, is the most researched and well validated parent-report screening tool for ASD (Norris & Lecavalier, 2010; Rutter, Bailey, & Lord, 2003). It demonstrates good reliability and validity, and shows strong discrimination between ASD and non-ASD cases, irrespective of child IQ or parental education (Chandler et al., 2007). The Social Skills Rating System (SSRS) is a commonly used parent- and teacher-report tool to assess social functioning. It demonstrates adequate internal consistency and test-retest reliability (Gresham & Elliott, 1990). Given diagnostic deficits in social skills associated with ASD, the SSRS has been demonstrated as an effective tool to differentiate individuals with ASD from TD individuals (Norris & Lecavalier, 2010).

**Social Anxiety.** The Social Worries Questionnaire (SWQ) is a 10-item (parent version) and 8-item (teacher version) survey instrument designed to assess social anxiety in children (Spence, 1995). It can reliably screen for social anxiety disorder (Bailey, Chavira, Stein, & Stein, 2006), and has been used to demonstrate higher social anxiety among children with ASD compared to TD children (Gillott, Furniss, & Walter, 2001). On the SWQ, informants are prompted to rate how often a child avoids or worries about certain social situations. To provide greater variability of responses, we expanded the original 0–2 scale to a 0–3 scale (0 = never

true, 1 = rarely true, 2 = sometimes/partially true, 3 = usually/typically true). Higher total scores represent greater social anxiety. The current study yielded excellent internal reliability ( $\alpha = .93$ ), which is consistent with previous research reporting  $\alpha = .82$  (Sofronoff, Attwood, & Hinton, 2005).

**Character Description.** Parents and teachers were asked to rate how much they agreed with three character descriptions about participants. Statements included a social rating (i.e., "He/she is social"), confidence rating (i.e., "He/she is confident"), and calm rating (i.e., "He/she is calm"). Responses were rated on a 7-point Likert scale (0 = strongly disagree, 1 = disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = agree, 6 = strongly agree). Responses were re-coded from  $-3$  to  $3$  for ease of interpretation.

**Emotional Valence.** At the end of the study, children were asked to report how they felt during each condition on a 1-5 Likert scale with faces (1 = 😞, 2 = 😐, 3 = 😊, 4 = 😄, 5 = 😁). Questions began with, "How do you feel when you are..." and conditions included "reading quietly," "reading aloud," "with the toys," and "with the guinea pigs."

**Skin Conductance.** Physiological arousal was assessed via electrodermal, eccrine sweat gland activity, which indicates sympathetic nervous system arousal. Skin conductance data were collected using wireless, wristband sensors designed for continuous assessment in naturalistic settings (Q Sensor, Affectiva Inc., Waltham, MA). Skin conductance recordings from the central wrist are highly correlated with more traditional, laboratory-based measurements on the fingertips, mean  $r = .574$  (van Dooren, de Vries, & Janssen, 2012).

To reduce motion artifacts and electrical noise, raw skin conductance data were smoothed using a 5-second Hanning window and then filtered using a zero-phase first order Butterworth filter with a normalized cut-off frequency of 0.05 Hz (Bach, Friston, & Dolan, 2013). Next, continuous decomposition analysis was used to extract skin conductance components based on standard deconvolution (Benedek & Kaernbach, 2010). Extracted components included *non-specific skin conductance responses (SCRs)* and *skin conductance level (SCL)*. Each represents a unique indicator of autonomic arousal. Skin conductance responses (SCRs) are indicative of phasic activity; they show the "phases" or abrupt increases in skin conductance. Skin conductance level (SCL) is indicative of tonic activity; it shows the overall "tone" of the slow-changing, background skin conductance level. In both cases, higher levels represent greater physiological arousal.

The sensor sampling rate was set to 8 Hz and skin conductance measurements are provided in microSiemens ( $\mu\text{S}$ ). The minimum amplitude threshold for SCRs was set to  $0.01 \mu\text{S}$  (Boucsein et al., 2012). SCRs are reported as the number of significant (above threshold) non-specific skin conductance responses per minute. SCL is reported as the square-root-transformed mean of the decomposed tonic skin conductance component.

**Skin Temperature.** Skin temperature ( $^{\circ}\text{C}$ ) was assessed via the wristband electrode, which approximates the temperature underneath the sensor.

**Motor Movement.** A tri-axial accelerometer (g) within the wristband device was used to estimate movement during experimental sessions. Tri-axial accelerometers assess motion in the anteroposterior ( $x$ -axis), mediolateral ( $y$ -axis), and vertical ( $z$ -axis) planes. Motor movement was calculated as the sum of the absolute values of motion change in each direction.

## Data Analysis

Prior to examining the primary hypotheses, we checked for differences between ASD and TD participants on the two ASD screening measures (SCQ raw scores and SSRS percentile ranks) in order to provide additional validation of parent- and teacher-reported ASD diagnoses. We also checked for differences on potentially confounding demographic variables (age, gender, and pet ownership status) as well as social anxiety measures (SWQ raw scores and parent and teacher ratings). Independent samples  $t$  tests were conducted for continuous variables and  $\chi^2$  tests were used for categorical variables. We examined participants' self-reported emotional valence using a repeated measures analysis of variance (ANOVA) with the between-subjects variable of diagnosis (ASD, TD) and the within-subjects variable of condition (reading silently, reading aloud, toys, and animals).

To account for the nested study design (i.e., multiple conditions nested within individuals nested within classrooms with different guinea pigs), we used specialized hierarchical analyses (Raudenbush & Bryk, 2002). Hierarchical linear modeling (HLM) was used for the continuous variable of SCL and hierarchical generalized linear modeling (HGLM) was used for the count data variable of number of SCRs per minute. We conducted a series of three-level models, where the levels reflected repeated measurements (Level 1), individual effects (Level 2), and classroom or guinea pig effects (Level 3). Random effects in the model were identified as intercepts at the repeated measures effect of condition (to account for correlations between repeated observations of the same participant across conditions) as well as intercepts at the individual-level (to account for variance across individuals) and classroom-level (to account for correlation between individuals in the same classroom with the same guinea pigs).

We addressed our primary hypotheses, that in the animal condition, children with ASD would show reduced physiological arousal relative to the other conditions and relative to their TD peers, by including the fixed effects of experimental condition (reading silently, reading aloud, toys, and animals), diagnosis (ASD, TD), and the interaction between diagnosis and condition. To control for potential covariates and their interaction with condition, we included the additional fixed factors of age, pet ownership, parent- and teacher-reported social anxiety (SWQ scores), skin temperature, motor movement, and the interaction between each of these factors and experimental condition. Continuous variables were grand-mean centered prior to mixed model analyses.

Skin conductance data were processed using Ledalab Version 3.4.3 (see Benedek & Kaernbach, 2010) in MATLAB Version 7.13 (MathWorks, Natick, MA). Tests of statistical significance were conducted using SPSS Version 21 (IBM, Armonk, NY). All tests were two-tailed with a significance level of  $\alpha < .05$ . Post-hoc analyses were conducted using the Bonferroni correction (Tabachnick & Fidell, 2012). HLM results are reported as unstandardized betas with 95% confidence intervals to indicate differences in SCR and SCL across conditions and diagnosis. Effect sizes were calculated using the corrected formula for Cohen's  $d$  in hierarchical linear models, which divides the estimated mean difference by the pooled raw standard deviation (Feingold, 2009). Values greater than 0.20, 0.50, and 0.80 were interpreted as small, medium, and large, respectively (Cohen, 1988).

## RESULTS

### Social Anxiety

Results showed significant differences in social anxiety between participants with ASD and their TD peers (Table 2). Participants with ASD scored significantly higher on the SWQ on both the parent-version,  $t(94) = 9.49$ ,  $p < .001$ , and the teacher-version,  $t(97) = 4.34$ ,  $p < .001$ , indicating greater anxiety and worry about social situations. Participants with ASD also scored significantly lower on character descriptions as social (parent:  $t(94) = 6.26$ ,  $p < .001$ , teacher:  $t(97) = 7.57$ ,  $p < .001$ ), confident (parent:  $t(94) = 4.81$ ,  $p < .001$ , teacher:  $t(97) = 4.69$ ,  $p < .001$ ), and calm (parent:  $t(94) = 3.99$ ,  $p < .001$ , teacher:  $t(96) = 5.59$ ,  $p < .001$ ); thus, both parents and teachers perceived children with ASD to have greater social anxiety and to be less social, confident, and calm than their TD peers.

### Emotional Valence

Children's self-reported emotional valence during each condition was explored with a 2 (diagnosis: ASD, TD)  $\times$  4 (condition: reading silently, reading aloud, toys, and animals) repeated-measures ANOVA. Means and standard deviations are reported in Table 3. Results showed a main effect for condition,  $F(3, 291) = 39.52$ ,

$p < .001$ , but no main effect for diagnosis,  $F(1, 97) = 2.38$ ,  $p = .126$ . The interaction between diagnosis and condition was non-significant,  $F(3, 291) = 0.68$ ,  $p = .566$ ; thus, there were no differences in self-reported emotional valence between children with ASD and TD children in any condition. Bonferroni-adjusted post-hoc testing for condition revealed that children felt the best when with the animals, with large effects compared to toys ( $p < .001$ ,  $d = 0.91$ ), reading silently ( $p < .001$ ,  $d = 1.30$ ), and reading aloud ( $p < .001$ ,  $d = 1.50$ ). They also felt better when playing with toys, with small to medium effects compared to reading silently ( $p = .045$ ,  $d = 0.36$ ), and reading aloud ( $p < .001$ ,  $d = 0.65$ ). Taken together, children who participated in the study reported feeling the best when with the animals, followed by toys, reading silently, and reading aloud (Fig. 1).

### Skin Conductance

**Random Effects.** The three-level hierarchical models we conducted accounted for within-participant variance across repeated assessments (Level 1), between-participant variance across individuals (Level 2), and between-classroom variance (Level 3). Results showed that the random effect of classroom with different guinea pigs was not significant for either model (SCR:  $p = .087$ , SCL:  $p = .073$ ; Table 3). Thus, there was no significant variability in outcomes across classrooms or guinea pigs. However, results were significant for the random effects of between-participant variance and within-participant variance in both models (all  $p$ 's  $< .001$ ). These findings indicate that the use of hierarchical models was appropriate to account for heterogeneity across individual participants and repeated measurements across conditions (Table 4).

**Main Effect of Condition.** Across all participants, the presence of animals was related to decreased skin conductance. When children were with animals, the mean number of SCRs per minute was lower than when they were with toys ( $p < .001$ ,  $d = 0.28$ ), reading aloud ( $p < .001$ ,  $d = 0.22$ ), and reading silently

**Table 2. Social Anxiety Means (and Standard Deviations) by Diagnosis**

	SWQ Social Worries		Social Rating		Confidence Rating		Calm Rating	
	Teacher	Parent	Teacher	Parent	Teacher	Parent	Teacher	Parent
ASD	12.7 (6.2)	18.8 (5.8)	0.4 (1.7)	-0.2 (1.7)	0.1 (1.9)	-0.2 (1.9)	0.5 (1.7)	-0.2 (2.0)
TD	6.7 (6.6)	7.8 (5.1)	2.2 (0.8)	1.7 (1.2)	1.6 (1.3)	1.3 (1.2)	2.1 (1.1)	1.3 (1.5)
$p$	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001

SWQ, Social Worries Questionnaire; ASD, autism spectrum disorder; TD, typically developing;  $p$ , comparison between ASD and TD.

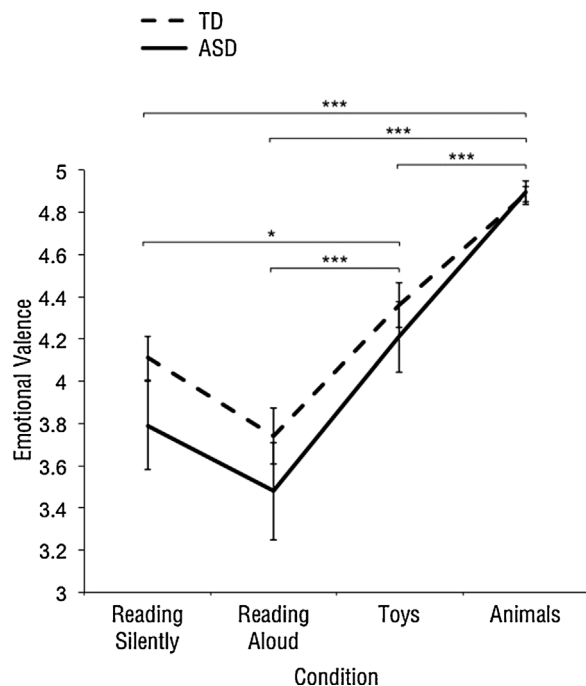
**Table 3. Emotional Valence Means (and Standard Deviations) by Experimental Condition and Diagnosis**

	Reading Silently	Reading Aloud	Toys	Animals
ASD	3.8 (1.2)	3.5 (1.3)	4.2 (1.0)	4.9 (0.3)
TD	4.1 (0.8)	3.7 (1.1)	4.4 (0.9)	4.9 (0.3)

ASD, autism spectrum disorder; TD, typically developing.

( $p < .001$ ,  $d = 0.21$ ). Children showed fewer abrupt increases in sympathetic activity during the animal condition, compared to all other conditions. This pattern of results was less pronounced in SCL, for which the animal condition was significantly lower than the toy condition only ( $p = .049$ ,  $d = 0.34$ ). The main effect of condition revealed that all children had a lower general state of arousal in the presence of animals compared to toys.

**Main Effect by Diagnosis.** For children with ASD, Bonferroni-adjusted post-hoc analyses revealed the same pattern of results with medium to large effects (Fig. 2). On average, children with ASD showed 43%



**FIGURE 1** Child-reported emotional valence by experimental condition. Higher values indicate a more positive emotional valence. Horizontal significance bars show differences between conditions, using the Bonferroni-adjusted  $p$ -values of  $*p < .05$  and  $***p < .001$ . There were no significant differences between children with autism spectrum disorder (ASD) and typically developing (TD) children for any condition. Error bars represent standard error of the mean.

fewer skin conductance responses (SCR) per minute in the presence of animals, compared to toys in a social context. SCRs were significantly lower during animal presence compared to toys ( $p = .007$ ,  $d = 0.96$ ), reading aloud ( $p = .015$ ,  $d = 0.58$ ), and reading silently ( $p = .017$ ,  $d = 0.58$ ), and SCL was significantly lower during animal presence compared to toys ( $p = .025$ ,  $d = 0.51$ ), but not reading aloud ( $p = .271$ ) or reading silently ( $p = .155$ ). Among TD children, Bonferroni-adjusted post-hoc analyses showed no significant differences across conditions for SCRs (all  $p$ 's  $> .237$ ) and an inverse pattern of results for SCL with small effects. With respect to general arousal, TD children showed greater SCL in the presence of animals, compared to all other conditions, including toys ( $p = .022$ ,  $d = 0.31$ ), reading aloud ( $p = .031$ ,  $d = 0.30$ ), and reading silently ( $p = .031$ ,  $d = 0.31$ ). Thus, the presence of animals reduced general arousal (SCL) and the number of arousal peaks (SCRs) for children with ASD, but increased general arousal (SCL) among TD children.

**Interaction Between Diagnosis and Condition.** Children with ASD showed greater physiological arousal than their TD peers in all conditions where the animal was not present, including toys (SCR:  $p < .001$ ,  $d = -0.26$ ; SCL:  $p < .001$ ,  $d = -0.89$ ), reading aloud (SCR:  $p = .005$ ,  $d = -0.21$ ; SCL:  $p = .008$ ,  $d = -0.67$ ), and reading silently, (SCR:  $p < .001$ ,  $d = -0.26$ ; SCL:  $p = .003$ ,  $d = -0.75$ ). However, this pattern reversed when the animal was present. Children with ASD showed lower arousal than their TD peers in the presence of animals (SCR:  $p = .007$ ,  $d = 0.19$ ; SCL:  $p = .049$ ,  $d = 0.46$ ). The interaction between diagnosis and condition demonstrated that the presence of animals reduced both the general level of arousal (SCL) and the number of arousal peaks (SCRs) in children with ASD compared to their TD peers.

## DISCUSSION

This study presents the first evaluation of physiological arousal in the presence of animals for children with ASD, compared to their TD peers. The results confirmed that children with ASD showed significantly higher skin conductance, indicative of physiological arousal, than TD children across the baseline, reading aloud and free play with toys conditions. This was consistent with parent- and teacher-reports indicating greater ongoing social anxiety in children with ASD compared to their TD peers. The results also supported our primary hypothesis that children with ASD would show reduced physiological arousal during peer interaction when animals were present, compared to toys,

**Table 4. Skin Conductance Outcomes by Experimental Condition and Diagnosis**

Effect (Reference Category)	Skin Conductance Responses (SCR)				Skin Conductance Level (SCL)			
	<i>b</i> (SE)	<i>t</i>	95% CI	<i>d</i>	<i>b</i> (SE)	<i>t</i>	95% CI	<i>d</i>
<b>Fixed Effects</b>								
Condition (Animal)								
Total Sample								
Reading Silently	1.10 (0.29)	3.89***	0.55, 1.66	0.21	0.19 (0.14)	1.38	-0.08, 0.47	0.23
Reading Aloud	1.12 (0.28)	3.96***	0.57, 1.67	0.22	0.16 (0.14)	1.14	-0.12, 0.44	0.20
Toys	1.45 (0.28)	5.09***	0.89, 2.00	0.28	0.28 (0.14)	1.98*	0.00, 0.56	0.34
ASD only <sup>a</sup>								
Reading Silently	2.95 (1.23)	2.40*	0.22, 5.67	0.58	0.28 (0.14)	1.95	-0.00, 0.56	0.36
Reading Aloud	2.97 (1.23)	2.42*	0.22, 5.71	0.58	0.24 (0.14)	1.69	-0.04, 0.53	0.32
Toys	4.97 (1.85)	2.68*	0.53, 9.40	0.96	0.39 (0.15)	2.65*	0.10, 0.67	0.51
TD only <sup>a</sup>								
Reading Silently	-1.25 (0.71)	-1.76	-2.96, 0.46	-0.24	-0.26 (0.09)	-2.87*	-0.45, -0.08	-0.31
Reading Aloud	0.05 (0.78)	0.06	-1.49, 1.59	0.01	-0.25 (0.09)	-2.75*	-0.43, -0.07	-0.30
Toys	0.22 (0.78)	0.29	-1.53, 1.97	0.04	-0.26 (0.09)	-2.92*	-0.44, -0.09	-0.31
Condition x Diagnosis (ASD)								
Reading Silently	-1.39 (0.37)	-3.74***	-2.12, -0.66	-0.26	-0.55 (0.18)	-2.95**	-0.91, -0.18	-0.75
Reading Aloud	-1.04 (0.37)	-2.80**	-1.76, -0.31	-0.21	-0.49 (0.19)	-2.66**	-0.86, -0.13	-0.67
Toys	-1.36 (0.36)	-3.75***	-2.07, -0.65	-0.26	-0.65 (0.18)	-3.53***	-1.01, -0.29	-0.89
Animals	0.97 (0.36)	2.71**	0.27, 1.67	0.19	0.39 (0.20)	1.99*	0.00, 0.77	0.46
	<i>b</i> (SE)	Wald Z	95% CI		<i>b</i> (SE)	Wald Z	95% CI	
<b>Random Effects</b>								
Classroom	0.28 (0.17)	1.71	0.09, 0.89		0.11 (0.06)	1.79	0.04, 0.33	
Individual	0.60 (0.13)	4.55***	0.39, 0.93		0.21 (0.04)	5.21***	0.15, 0.31	
Repeated Measures	0.63 (0.07)	9.59***	0.51, 0.77		0.18 (0.02)	11.55***	0.15, 0.21	

Both models controlled for age, pet ownership, parent- and teacher-reported social anxiety, skin temperature, and motor movement.

SCR, skin conductance responses per minute; SCL, skin conductance level in  $\mu\text{S}$ ; *b*, unstandardized coefficient; SE, standard error; CI, confidence interval; *d* = Cohen's *d*; ASD, autism spectrum disorder; TD, typically developing.

<sup>a</sup>Bonferroni-adjusted post-hoc analyses; \*  $p < .05$ ; \*\*  $p < .01$ ; \*\*\*  $p < .001$ .

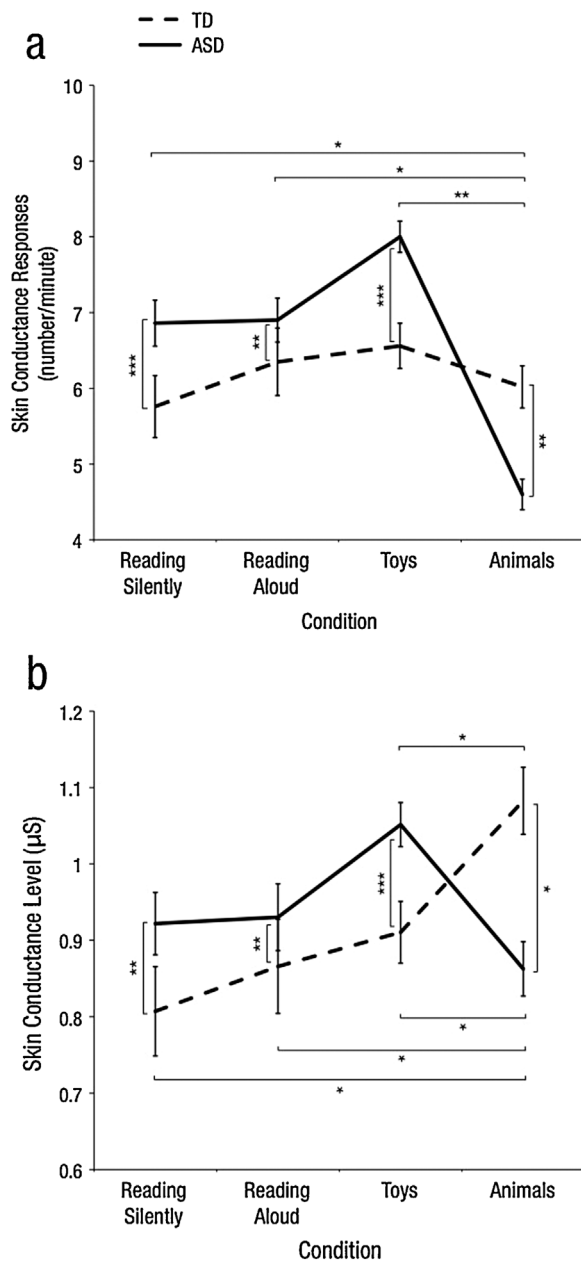
and compared to reading aloud and reading silently in a social context. Effect sizes were in the medium to large range for children with ASD. These outcomes were independent of differences across classrooms, guinea pigs, individuals, repeated assessments, age, pet ownership, parent- and teacher-reported social anxiety, skin temperature, and general motion. The findings suggest that the presence of an animal confers a unique anxiolytic effect for children with ASD.

Previous studies with this population and other children with ASD have demonstrated that the presence of an animal is related to increased social skills (e.g., Carlisle, 2014; O'Haire et al., 2014), less social withdrawal, and fewer negative social interactions (e.g., Berry, Borgi, Francia, Alleva, & Cirulli, 2012; Gabriels et al., 2012; O'Haire et al., 2013). These outcomes represent three components of the proposed developmental pathway to social anxiety in ASD. The present study evaluated the final component of the model—physiological arousal. Results showed reduced arousal related to animal presence in a social context. Reduc-

tions in heightened arousal may provide a feasible mechanism for observed increases in social behavior in children with ASD. With lower arousal levels, children with ASD may feel more at ease and amenable to positive peer interaction.

Reduced arousal during animal presence in social settings may be due to the perceived non-judgmental nature of animals, which are often reported as comforting and supportive sources for children (McNicholas & Collis, 2001). Children with ASD may be in particular need of additional support given that they may be bullied and isolated from their TD peers (e.g., Rowley et al., 2012). The positive nature of the animals' presence in the current study is evidenced by children's self-reported emotional valence. Both children with ASD and TD children reported feeling the best when they were with the animals, with large effect sizes compared to toys, reading aloud, and reading silently. Interestingly, the elation experienced by both groups of children differentially influenced their physiological response. Children with ASD showed reduced





**FIGURE 2** Skin conductance by experimental condition. Panels represent (a) skin conductance responses (SCR) in number per minute and (b) skin conductance level (SCL) in  $\mu\text{S}$ . Vertical significance bars show differences between children with autism spectrum disorder (ASD) and typically-developing (TD) children at each time point, where  $*p < .05$ ,  $**p < .01$ , and  $***p < .001$ . Horizontal significance bars show differences between conditions for participants with ASD (above lines) and TD participants (below lines) using Bonferroni-adjusted  $p$ -values. Error bars represent standard error of the mean.

arousal in the animals' presence, while TD children showed increased arousal in the animals' presence. Differential physiological responding to positive emotions has also been demonstrated in previous research. For example, one study evaluated participants with high and low social speech anxiety. All participants in the study reported feeling most positive when viewing an image of a person with a joyful expression. However, positive feelings manifested differentially in physiological outcomes across groups. Individuals with high social anxiety showed decreased SCL in response to the positive stimuli while individuals with low social anxiety showed increased SCL in response to the positive stimuli (Vrana & Gross, 2004).

These differences mirror findings in the current study. Children with ASD had high social anxiety, and the presence of a positive stimulus (animals) resulted in lower SCL. In contrast, TD children had low social anxiety, and the presence of a positive stimulus resulted in higher SCL. For children with ASD, the stressful nature of social interaction may have been ameliorated by animal presence, resulting in relatively lower skin conductance. For TD children, the neutral setting may have been enhanced by the excitement of a novel animal, resulting in relatively higher skin conductance.

It is noteworthy that increased arousal for TD children was not seen in skin conductance responses (SCR), but only in skin conductance level (SCL). Recent data have elucidated different neural mechanisms for SCRs and SCL (Nagai, Critchley, Featherstone, Trimble, & Dolan, 2004). SCRs are related to activation in the amygdala, and increase with activities involving emotional processing and mental burden (Patterson II, Ungerleider, & Bandettini, 2002; Williams et al., 2001). In the current study, children with ASD showed more SCRs than their TD peers during all conditions *without* animals. Navigating and engaging in a social context may be a more emotionally complex and mentally burdensome task for children with ASD compared to their TD peers. However, when the animals were present, children with ASD showed fewer SCRs compared to other conditions, indicating that they may have felt less burdened when they were with the animals. In contrast, TD children showed no differences in SCRs across conditions. Thus, it is likely that they experienced no differences in emotional processing and mental burden across conditions. However, TD children did show increased SCL when the animals were present. Increases in SCL are related to decreased activity in the ventromedial prefrontal cortex, which occurs when individuals are orienting to external cues or engaging in an attention-demanding task (Nagai et al., 2004). Indeed, the presence of a novel animal

may have offered a captivating external stimulus for TD children, for whom the social environment was less emotionally and mentally challenging.

The issue of novelty in the current study may be considered a limitation. The children were exposed to a new animal, compared to a new set of toys. It is likely that over time, physiological responses to the novel stimuli would habituate, possibly at different rates. Existing data suggest that roughly half of teachers have had an animal in their classroom at some stage (Daly & Suggs, 2010; Rud & Beck, 2003). We suspect that nearly all teachers have had toys in their classroom. Given that animals may be less common, the arousal patterns that we observed in the presence of animals, in particular, could change over repeated assessments. Further studies should include longitudinal data on physiological responses to animals in order to evaluate potential novelty effects of the presence of a new animal, and to assess whether the presence of a familiar animal also has anxiolytic effects for children with ASD in social settings. It will also be informative in future studies to directly connect physiological data to specific behaviors to determine whether certain behavioral patterns and activities characterize interactions in the presence of animals, and how these behaviors may be related to physiological arousal.

In conclusion, the current study demonstrates that the presence of animals in a social context reduces autonomic arousal among children with ASD. This arousal-reducing effect of animals appears to be unique for children with ASD, compared to their TD peers, possibly because social situations are inherently more arousal-inducing for children with ASD. Furthermore, the animals induced positive emotions among children with ASD. The combination of reduced arousal and increased positive emotion may create an effective environment for targeted social skills interventions. Further investigation will be necessary to evaluate the application of these findings to targeted therapeutic protocols. The present findings suggest that this is a worthwhile avenue for ongoing study and they contribute to a growing body of literature suggesting that animals may function as effective social buffers for individuals with ASD (O'Haire, 2013).

## NOTES

The content is solely the responsibility of the authors and does not necessarily represent the official views of the Eunice Kennedy Shriver National Institute of Child Health and Human Development or the National Institutes of Health. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. We thank the RSPCA Queensland, the Queensland Government Department of

Education, Training, and Employment, and Brisbane Catholic Education for their assistance with school recruitment. We are also grateful to the dutiful research assistants and volunteers who assisted in data collection and coding, especially Fatima Issa, Jinny Hong, Laura Fitzalan, and Sharlene Teo.

## REFERENCES

- Allen, K., Blascovich, J., & Mendes, W. B. (2002). Cardiovascular reactivity and the presence of pets, friends, and spouses: The truth about cats and dogs. *Psychosomatic Medicine*, 64(5), 727–739. doi: 10.1097/01.psy.0000024236.11538.41
- Pets in the Classroom: Considerations ASPCA Resource guide for teachers (pp. 13–14). New York, NY.
- Aydin, N., Krueger, J. I., Fischer, J., Hahn, D., Kastenmüller, A., Frey, D., & Fischer, P. (2012). “Man’s best friend:” How the presence of a dog reduces mental distress after social exclusion. *Journal of Experimental Social Psychology*, 48(1), 446–449. doi: 10.1016/j.jesp.2011.09.011
- Bach, D. R., Friston, K. J., & Dolan, R. J. (2013). An improved algorithm for model-based analysis of evoked skin conductance responses. *Biological Psychology*, 94(3), 490–497. doi: 10.1016/j.biopsycho.2013.09.010
- Bailey, K. A., Chavira, D. A., Stein, M. T., & Stein, M. B. (2006). Brief measures to screen for social phobia in primary care pediatrics. *Journal of Pediatric Psychology*, 31(5), 512–521. doi: 10.1093/jpepsy/ksj044
- Beetz, A., Julius, H., Turner, D., & Kotrschal, K. (2012). Effects of social support by a dog on stress modulation in male children with insecure attachment. *Frontiers in psychology*, 3, 352. doi: 10.3389/fpsyg.2012.00352
- Bellini, S. (2006). The development of social anxiety in adolescents with autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities*, 21(3), 138–145. doi: 10.1177/10883576060210030201
- Benedek, M., & Kaernbach, C. (2010). A continuous measure of phasic electrodermal activity. *Journal of Neuroscience Methods*, 190(1), 80–91. doi: 10.1016/j.jneumeth.2010.04.028
- Berry, A., Borgi, M., Francia, N., Alleva, E., & Cirulli, F. (2012). Use of assistance and therapy dogs for children with autism spectrum disorders: A critical review of the current evidence. *The Journal of Alternative and Complementary Medicine*, 19(2), 73–80.
- Boucsein, W., Fowles, D. C., Grimnes, S., Ben-Shakhar, G., Roth, W. T., Dawson, M. E., & Filion, D. L. (2012). Publication recommendations for electrodermal measurements. *Psychophysiology*, 49(8), 1017–1034. doi: 10.1111/j.1469-8986.2012.01384.x
- Carlisle, G. (2014). The social skills and attachment to dogs of children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 1–9. doi: 10.1007/s10803-014-2267-7
- Chandler, S., Charman, T., Baird, G., Simonoff, E., Loucas, T., Meldrum, D., ... Pickles, A. (2007). Validation of the social communication questionnaire in a population cohort of children with autism spectrum disorders. *Journal of the American Academy of Child and Adolescent Psychiatry*, 46(10), 1324–1332. doi: 10.1097/chi.0b013e31812f7d8d

- Cohen J.(1988). *Statistical power analysis for the behavioral sciences*. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum.
- Daly, B., & Suggs, S. (2010). Teachers' experiences with humane education and animals in the elementary classroom: implications for empathy development. *Journal of Moral Education*, 39(1), 101–112. doi: 10.1080/03057240903528733
- M. E. Dawson, A. M. Schell, & D. L. Filion (2000). The electrodermal system. In J. T. Cacioppo, L. G. Tassinary & G. C. Berntson (Eds.), *Handbook of psychophysiology* (2nd ed., pp. 200–223): Cambridge University Press.
- Feingold, A.(2009). Effect sizes for growth-modeling analysis for controlled clinical trials in the same metric as for classical analysis. *Psychological Methods*, 14(1), 43–53. doi: 10.1037/a0014699
- Gabriels, R. L., Agnew, J. A., Holt, K. D., Shoffner, A., Zhaoxing, P., Ruzzano, S., ... Mesibov, G. (2012). Pilot study measuring the effects of therapeutic horseback riding on school-age children and adolescents with autism spectrum disorders. *Research in Autism Spectrum Disorders*, 6(2), 578–588. doi: 10.1016/j.rasd.2011.09.007
- Gillott, A., Furniss, F., & Walter, A. (2001). Anxiety in High-Functioning Children with Autism. *Autism*, 5(3), 277–286. doi: 10.1177/1362361301005003005
- Good, R. H., Gruba, J., & Kaminski, R. A. (2002). Best practices in using Dynamic Indicators of Basic Early Literacy Skills (DIBELS) in an outcomes-driven model. *Best practices in school psychology IV*, 1, 699–720.
- Goodwin, M. S., Groden, J., Velicer, W. F., Lipsitt, L. P., Baron, M. G., Hofmann, S. G., & Groden, G. (2006). Cardiovascular arousal in individuals with autism. *Focus on Autism and Other Developmental Disabilities*, 21(2), 100–123. doi: 10.1177/10883576060210020101
- Gresham F. M., & Elliott S. N. (1990). *Social skills rating system*. Circle Pines, MN: American Guidance Service.
- Kaartinen, M., Puura, K., Mäkelä, T., Rannisto, M., Lemponen, R., Helminen, M., ... Hietanen, J. K. (2012). Autonomic arousal to direct gaze correlates with social impairments among children with ASD. *Journal of Autism and Developmental Disorders*, 42(9), 1917–1927. doi: 10.1007/s10803-011-1435-2
- Kuusikko, S., Pollock-Wurman, R., Jussila, K., Carter, A. S., Mattila, M.-L., Ebeling, H., ... Moilanen, I (2008). Social anxiety in high-functioning children and adolescents with autism and asperger syndrome. *Journal of Autism and Developmental Disorders*, 38(9), 1697–1709. doi: 10.1007/s10803-008-0555-9
- Levine, T. P., Sheinkopf, S. J., Pescosolido, M., Rodino, A., Elia, G., & Lester, B. (2012). Physiologic arousal to social stress in children with autism spectrum disorders: A pilot study. *Research in Autism Spectrum Disorders*, 6(1), 177–183. doi: http://dx.doi.org/10.1016/j.rasd.2011.04.003
- Little, L.(2001). Peer vicimization of children with asperger spectrum disorders. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(9), 995–996. http://dx.doi.org/10.1097/00004583-200109000-00007.
- R. Lockwood (1983). The influence of animals on social perception. In A. H. Katcher C & A. M. Beck (Eds.), *New perspectives on our lives with companion animals* (pp. 64–72). Philadelphia: University of Pennsylvania Press.
- Macintosh, K., & Dissanayake, C. (2006). Social skills and problem behaviours in school aged children with high-functioning autism and asperger's disorder. *Journal of Autism and Developmental Disorders*, 36(8), 1065–1076. doi: 10.1007/s10803-006-0139-5
- McNicholas, J., & Collis, G. M. (2001). Children's representations of pets in their social networks. *Child: Care, Health and Development*, 27(3), 279–294. doi: 10.1046/j.1365-2214.2001.00202.x
- Nagai, Y., Critchley, H. D., Featherstone, E., Trimble, M. R., & Dolan, R. J. (2004). Activity in ventromedial prefrontal cortex covaries with sympathetic skin conductance level: a physiological account of a “default mode“ of brain function. *Neuroimage*, 22(1), 243–251. doi: 10.1016/j.neuroimage.2004.01.019
- Norris, M., & Lecavalier, L. (2010). Screening accuracy of level 2 autism spectrum disorder rating scales: A review of selected instruments. *Autism: The International Journal of Research and Practice*, 14(4), 263–284. doi: 10.1177/1362361309348071
- O'Haire, M. E.(2013). Animal-assisted intervention for autism spectrum disorder: A systematic literature review. *Journal of Autism and Developmental Disorders*, 43(7), 1606–1622. doi: 10.1007/s10803-012-1707-5
- O'Haire, M. E., McKenzie, S. J., Beck, A. M., & Slaughter, V. (2013). Social behaviors increase in children with autism in the presence of animals compared to toys. *PLoS ONE*, 8(2), e57010. doi: 10.1371/journal.pone.0057010
- O'Haire, M. E., McKenzie, S. J., McCune, S., & Slaughter, V. (2014). Effects of classroom animal-assisted activities on social functioning in children with autism spectrum disorder. *Journal of Alternative and Complementary Medicine*, 20(3), 162–168. doi: 10.1089/acm.2013.0165
- Patterson II, J.C, Ungerleider, L. G., & Bandettini, P. A. (2002). Task-independent functional brain activity correlation with skin conductance changes: An fMRI study. *Neuroimage*, 17(4), 1797–1797. doi: 10.1006/nimg.2002.1306
- Polheber, J., & Matchock, R. (2013). The presence of a dog attenuates cortisol and heart rate in the Trier Social Stress Test compared to human friends. *Journal of Behavioral Medicine*, 1–8. doi: 10.1007/s10865-013-9546-1
- Raudenbush S. W., & Bryk A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. Thousand Oaks, CA: Sage Publications.
- Rowley, E., Chandler, S., Baird, G., Simonoff, E., Pickles, A., Loucas, T., & Charman, T. (2012). The experience of friendship, victimization and bullying in children with an autism spectrum disorder: Associations with child characteristics and school placement. *Research in Autism Spectrum Disorders*, 6(3), 1126–1134. doi: 10.1016/j.rasd.2012.03.004
- Rud, A. G., & Beck, A. M. (2003). Companion animals in Indiana elementary schools. *Anthrozoos*, 16(3), 241–251.

- Rutter M. L., Bailey A., & Lord C. (2003). Social communication questionnaire. Los Angeles, CA: Western Psychological Services.
- Sofronoff, K., Attwood, T., & Hinton, S. (2005). A randomised controlled trial of a CBT intervention for anxiety in children with Asperger syndrome. *Journal of Child Psychology and Psychiatry*, 46(11), 1152–1160. doi: 10.1111/j.1469-7610.2005.00411.x
- S. H. Spence (1995). The social worries questionnaire. In S. H. Spence (Ed.), *Social skills training: Enhancing social competence with children and adolescents*. Windsor, Berkshire, England: NFER-NELSON.
- Tabachnick B. G., & Fidell L. S. (2012). 5th ed. Boston, MA: Allyn and Bacon.
- van Dooren, M., de Vries, J.J. G. G.-J., & Janssen, J. H. (2012). Emotional sweating across the body: comparing 16 different skin conductance measurement locations. *Physiology & behavior*, 106(2), 298–304. doi: 10.1016/j.physbeh.2012.01.020
- Viau, R., Arsénault-Lapierre, G., Fecteau, S., Champagne, N., Walker, C.-D., & Lupien, S. (2010). Effect of service dogs on salivary cortisol secretion in autistic children. *Psychoneuroendocrinology*, 35(8), 1187–1193. doi: 10.1016/j.psyneuen.2010.02.004
- Vrana, S. R., & Gross, D. (2004). Reactions to facial expressions: Effects of social context and speech anxiety on responses to neutral, anger, and joy expressions. *Biological Psychology*, 66(1), 63–78. doi: 10.1016/j.biopsycho.2003.07.004
- Williams, L. M., Peduto, A., Gordon, E., Phillips, M. L., Brammer, M. J., Skerrett, D., ... David, A. S. (2001). Arousal dissociates amygdala and hippocampal fear responses: Evidence from simultaneous fMRI and skin conductance recording. *Neuroimage*, 14(5), 1070–1079. doi: 10.1006/nimg.2001.0904