Animal-Assisted Interventions for school-aged children with Autism Spectrum Disorder: a meta-analysis

Mirena Dimolareva[1] & Thomas J. Dunn[1]

1. Psychology Division, Bishop Grosseteste University, Lincoln.

Abstract

Research has indicated beneficial effects of Animal-Assisted Interventions (AAIs) for children with Autism. However, there is a dearth of meta-analyses and the findings are often contradictory. The current meta-analysis assesses the effectiveness of AAIs on social interaction, communication and global Autism symptoms. A total of 1447 studies were returned, of which 16 (n = 489) met the inclusion criteria. The meta-analyses indicated small effect sizes related to improvements in social interaction and communication and reduction in ASD symptoms. Additionally, there was little evidence for a relationship between dosage and effect size. In conclusion, AAIs appear to offer small improvements in social interaction and communication for children with Autism, which may be comparable to activities used in active control conditions.

Key Words: Animal-Assisted Interventions, Autism, Children, School-Age

Recently there has been an upsurge in research concerning the therapeutic benefits of Animal-Assisted Interventions (AAIs). AAIs are sessions with therapeutic, health and/or wellbeing goals which involve the presence of an animal (SCAS, 2013). There are different types of AAIs such as Animal-Assisted Therapy (e.g. Animal-Assisted Play Therapy), Animal-Assisted Activities (e.g. therapy animal visits to nursing homes), Animal-Assisted Education (i.e. completing tasks with therapy animals to improve educational outcomes). AAIs can vary in duration and length, for example, from weekly, 1-hour sessions for 6- months (Kern et al., 2011), to weekly 1-hour sessions for 10 weeks (Gabriels et al., 2012) or twice weekly, 20-minute sessions for 8 weeks (O'Haire, McKenzie, McCune & Slaughter, 2014). AAI sessions can include structured (e.g. how to lead and care for a horse) as well as unstructured components (e.g., free play time with the animals) (e.g. Gabriels et al., 2012; O'Haire et al., 2014). AAI research also differs in terms of design, where some studies use a randomised and/or controlled design (e.g. Becker, Rogers & Burrows, 2017; Gabriels et al., 2012) compared to others who employ pre-post designs with no control group (e.g. Anderson & Meints, 2016).

In general, the literature points to positive effects of interacting and engaging with animals, across a range of disorders (e.g., Schuck, Emmerson, Fine & Lakes, 2015; Friedmann, Katcher, Thomas, Lynch & Massent, 1983; Stefanini, Martino, Bacci & Tani, 2016). However, assessing AAIs' 'true' impact for children with Autism Spectrum Disorder (ASD) has somewhat lagged behind the volume of single-study publications. The evidence from systematic literature reviews focusing on single case studies is promising (O'Haire, 2013; O'Haire, 2017; Brelsford, Meints, Gee & Pfeffer, 2017; Mapes & Rosén, 2016) and highlight beneficial effects of AAIs for school-aged children with ASD (Brelsford et al., 2017; Davis et al., 2015; O'Haire, 2013; O'Haire, 2017; Mapes & Rosén, 2016). More specifically, children who participate in AAIs show a reduction in global ASD behavioural symptoms and maladaptive behaviours as well as improvement in empathetic behaviours, classroom participation, self-regulation, and social interaction with others (Anderson & Meints, 2016; Anderson & Olson, 2006; Kern et al., 2011; O'Haire, 2013; O'Haire, 2017; Ajzenman, Standeven & Shurtleff, 2013; Mapes & Rosén, 2016). Research shows that autistic children seek interaction with animals more often than with humans and inanimate objects (Prothmann, Ettrich & Prothmann, 2009), thus it is proposed that interacting with animals may act as a facilitator for human interaction (McNicholas & Collis, 2000). Furthermore, some researchers argue animals communicate their intentions non-verbally through body language, which might be easier to understand by individuals with ASD (Prothmann et al., 2009). In line with this, research demonstrates that after participating in an AAI, children with ASD produce more meaningful

utterances (Stevenson, Jarred, Hinchcliffe & Roberts, 2015) and show improvements in motor action such as posture and non-verbal communication (Ajzenman et al., 2013; Borgi et al., 2016**;** Gabriels et al., 2015). Although findings are generally consistent and point to a benefit of AAIs for children with ASD, some studies have only found non-significant trends towards improvement in children's behaviour, language ability and communication (Gabriels et al., 2012; Anderson & Meints, 2016; Jenkins & DiGennaro, 2013) and rely on reporting anecdotal parent perception of AAI benefits (Jenkins & DiGennaro, 2013).

To the current authors' knowledge, there are only two meta-analyses related to the effects of AAIs, both of which were published over twelve years ago. Taken together, these two meta-analyses indicate that AAIs may offer small to moderate beneficial effects for depression as well as general well-being, medical and behavioral indicators (Souter & Miller, 2007; Nimer & Lundahl, 2007). One meta-analysis showed positive effects of Animal-Assisted Therapy (AAT) for children with ASD ($d = 0.72$, $k = 4$) (Nimer & Lundahl, 2007), however this was limited to four studies and excluded research involving general Animal-Assisted Activities (i.e., studies where animal interaction was goal-directed but not accompanied by some other form of therapy such as Animal-Assisted Education) (Fine, 2015). Given the practical implications of providing a therapeutic intervention to an increasing population of children with special educational needs (Department of Education, 2018), and more specifically school-age children with ASD, it is important to include instances where the isolated impact of AAI on ASD is assessed (Mapes & Rosén, 2016) Additionally, previous research (including one meta-analysis) have failed to account for the impact of dosage (e.g., time engaged in AAI) on outcome. Although intervention dose is an essential condition of drug development, it is somewhat neglected in behavioral interventions. Retrospective data analyses (such as meta-analysis) are one way of examining the dose-response relationship (i.e., intervention efficacy).

AAIs are becoming increasingly popular in schools, despite the lack of clarity relating to the effectiveness of the evidence (Brelsford et al., 2017). Given the growth in AAI research over the last decade, it is crucial to gauge the current state of knowledge relating to the impact of AAIs for children with ASD. Therefore, the objective of the current meta-analysis is to specifically investigate the effect of any Animal-Assisted Interventions on children's ASD symptoms and most common deficits, namely social interaction and communication (Redefer & Goodman, 1989). This meta-analysis extends previous publications in four ways: 1) it employs a broad and comprehensive range of search terms and databases (see supplementary material); 2) it seeks to capture all Animal-

Assisted Interventions regardless of animal type; 3) it utilises meta-regression techniques and subgroup analysis to account for possible sources of heterogeneity and compare effect sizes across study design; 4) it undertakes a comprehensive Risk of Bias Assessment.

The current meta-analysis aims to:

i. Conduct an up-to-date meta-analysis of studies examining the effect of AAI on children with ASD.
ii. Estimate the effect of AAI on two core components of ASD (social interaction & communication) as well as global ASD scores.
iii. Provide an assessment as to the quality of AAI studies in the field.
iv. Explore the role of dosage in AAI's effect on ASD symptoms.

Methods

Eligibility criteria

Studies investigating the effect of AAIs on social, communication and diagnostic symptoms of school-aged children with ASD were selected for this meta-analysis. PRISMA Guidelines were followed (Liberati et al., 2009). The following criteria was set for inclusion: (1) article must be written in English (2) participating children had a formal diagnosis of ASD (3) participants were of school-age (4) research included a measure of social interaction and/or communication and/or ASD symptoms (5) only published, peer-reviewed studies were included to maintain a set quality of research. In reference to point (3), articles including only children of school age were included as Animal-Assisted Interventions are becoming increasingly popular in schools and the effectiveness of these interventions should be quantitatively assessed to establish their suitability for school-aged children and shape decisions around organising and implementing AAIs. Articles were excluded from the analysis if: (1) the interventions were not with children of school-age (4-18 years) (2) there were no measures of ASD global score, communication and/or social interaction as an outcome variable (3) the article status was 'unpublished' (4) the article was not peer-reviewed as part of the publication process.

Databases

Seven databases were searched from their start date until present. The searches were completed on 01.03.2020. The databases searched were: Academic Search Complete, Anthrozoöes, Autism Data, PsychArticles, PsychInfo, Science Direct, Web of Science.

Search

The search terms were pre-determined. The following terms were used to ensure all aspects of AAI were included in the search as Animal-Assisted Interventions in this case was used as an umbrella term to include more specific interventions: “Animal-Assisted Intervention”, “Animal-Assisted Activities”, “Animal-Assisted Therapy”, “Canine-Assisted Intervention”, “Canine-Assisted Activities”, “Canine-Assisted Therapy”, “Dog-Assisted Intervention”, “Dog-Assisted Activities”, “Dog-Assisted Therapy”, “Equine-Assisted Intervention”, “Equine-Assisted Activities”, “Equine-Assisted Therapy” were paired with “special needs”, “learning difficulties”, “developmental delay”, “special educational needs”, “Autism Spectrum Disorder”, "Attention Deficit Hyperactivity Disorder", “language delay”, “language disorder”. These search terms were chosen to widen the search and ensure inclusivity of research articles as ASD is often diagnosed with other comorbid conditions.

Selection process

All searches were conducted by the first author. Selection of articles was completed by both authors, ensuring participants had a formal diagnosis of ASD and had appropriate measures for social interaction and/or communication and/or ASD symptoms. The second author contacted researchers when data clarifications were required.

Data items

The meta-analysis was set out by outcome measure and design type. The following data were extracted from each study: (1) Participant Information (diagnosis, N, age etc.); (2) Measures (communication, social interaction, ASD symptoms); (3) Design (pre-post, control group, single group, active control, follow-up, case-study); (4) Statistics (*Mean*, *SD*, *Effect size*).

Data collection process

A spreadsheet was developed by the second author who also extracted the data required for the meta-analysis calculations. The participant information and design data were extracted by both authors separately to reduce likelihood of bias.

Risk of bias within individual studies

A risk of bias summary was constructed based on the Cochrane collaboration tool for assessing risk of bias (Higgens & Green, 2014). This evaluates potential areas of bias including selection bias, performance bias, attrition bias, detection bias, and reporting bias. To supplement this,

additional AAI-specific risk of bias criteria were included (ASD diagnostic tool, ASD diagnostician, intervention instructor, outcome measure, rater consistency).

For Cochrane derived risk of bias items, the review protocol was that as set out in the Cochrane handbook (Higgens & Green, 2014). The coding protocol for AAI-specific items was as follows: ASD diagnostic tool (validated/reliable diagnostic tool = Low, non-previously established diagnostic tool = High, unclear = Unclear); ASD diagnostician (clinician = Low, non-clinician = High, unclear = Unclear); Intervention instructor (experienced = Low, inexperienced = High, unclear = Unclear); Assessment tool (reliable = Low, unreliable = High, unclear = Unclear); Rater-consistency (same pre/post = Low, different pre/post = High, unclear = Unclear).

Controlled and single-group pre-post studies were included in the same risk of bias assessment. In order to capture the increased risk of bias for single-group studies (compared to those with a control), a 'design' criterion was included (where single-group studies were classified as 'High risk' and controlled studies as 'Low risk'). For all criteria specifically relating to controlled studies (e.g., allocation concealment), single-group studies were automatically coded as 'High risk'. The quality of the control condition (from lowest to highest) was assessed by categorising it as either no treatment, minimal treatment, non-specific active control, active control, and evidence-based treatment (EBT) (where EBT was defined as there being at least one prior published study demonstrating a significant medium-sized effect). Risk of bias was assessed by two raters independently, based on the above criteria. Any coding discrepancies were discussed with reference to the relevant study until a consensus was reached.

Summary measures

The primary effect size measure was the standardised mean change (Cohen's *d*). In line with Becker (1988) and Morris (2008), the standardised mean change was calculated for the intervention and control groups separately, which meant the difference between effect sizes of each condition could be calculated along with the sum of sampling variances, giving an overall effect size for control group pre/post studies (CGPP). For single group pre/post studies (SGPP), the standardised mean change for the intervention group was calculated (Morris, & DeShon, 2002). Where correlation coefficients between pre and post were not available, a recommended conservative estimate ($r = .7$) was used (Rosenthal, 1993). All effect sizes were calculated from means and SDs, which were either extracted from the articles directly or obtained by way of contacting the authors. In instances were studies had more than one rater using the same scale (e.g., parent and teacher), raw scores were averaged, and effects sizes calculated. Where multiple

time points were available, only end-of-treatment (EoT) was included in any effect size calculation. This was mainly due to reasons of consistency as nearly all studies made measurements at only two time points.

Synthesis of results

All meta-analyses were conducted using the *metafor* package in R (Viechtbauer, 2010). A meta-analysis was carried out for each area of interest (Social, Communication & ASD), and included a separate sub-group analysis as defined by study design (SGPP, CGPP, ACPP). The standardised mean change, its 95% confidence interval (95% CI), and corresponding *z* and *p* values were estimated. All meta-analyses were specified as random-effects models, which allows for an adjustment in effect estimates, dependent on the extent of variation across different studies. Heterogeneity was assessed across studies in each group and sub-group using the I^2 and the *Q*-statistic (Higgins & Thompson 2002, Higgins, Thompson, Deeks & Altman, 2003). I^2 is particularly useful as it provides a percentage of effect size variability due to heterogeneity rather than sampling error. A rough guide for I^2 interpretation is as follows: 0% to 40%: might not be important; 30% to 60%: may represent moderate heterogeneity; 50% to 90%: may represent substantial heterogeneity; 75% to 100%: considerable heterogeneity (Higgins et al., 2003). The *Q*-statistic (based on χ^2) provides a test of significance of between-study heterogeneity. Subgroup analyses were carried out to investigate whether study design (e.g, SGPP vs CGPP vs ACPP) accounted for a proportion of the heterogeneity present. A random-effects model was used to estimate heterogeneity variance (I^2 and the Q-test).

Risk of bias across studies

Publication bias was assessed through visual inspection of funnel plots, where asymmetry of the distribution of effect size to standard error is suggestive of publication bias (Viechtbauer, 2010). Egger's test was used to assess the significance of asymmetry (Sterne & Egger, 2001). The trim-and-fill method was applied to any identified instances of asymmetry and effect sizes recalculated (Duval & Tweedie, 2000a; Duval & Tweedie, 200b). This technique estimates potentially missing studies due to publication bias, based on the assumption that the more extreme effect sizes are suppressed. These potentially suppressed studies (with corresponding effect sizes) can then be included in further meta-analysis re-calculations in order to gauge their impact (Shi & Lin, 2019).

Additional analyses

In line with the objectives of this meta-analysis, meta-regression was used to examine the relationship between dosage (moderator) and effect sizes of all treatment outcomes (Social, Communication, global ASD). Dosage was calculated by multiplying session length in minutes by frequency per week and overall treatment length. For studies that reported session time as a range, the mean of the range was used (e.g., a 30-40-minute session would be coded as 35 minutes). A random-effects models was used to estimate the model coefficients, providing corresponding *z* and *p* values, while the *Q*-statistic was used as the omnibus test of the model coefficients.

Results

Study selection

The search returns from all databases (N=1447) were assessed at title and abstract level for their suitability in terms of the inclusion criteria for this meta-analysis. As the abstract for some papers did not have the details to assess suitability of the research, the full text was assessed for eligibility. The selection process is presented in Figure 1.

(Insert Figure 1 here)

Study characteristics

The study characteristics along with Mean, Standard Deviation and Effect Size are presented in Table 1. The table is in alphabetical order by first author and includes the 16 studies included in this meta-analysis. The total number of participants was 489.

Single group pre- post (SGPP) design accounted for 4 studies, while 9 studies adopted no-treatment pre-post (CGPP) and 3 studies had active control pre- post (ACPP) design. All studies had measured either Social Interaction, Communication, Global ASD or a combination of measures. Studies have used a variety of validated and standardized measures.

(Insert Table 1 here)

Risk of bias within individual studies

The studies included in this meta-analysis were a combination of SGPP (25%), CGPP (56.2%) and ACPP (18.8%) designs. In general, the reporting of blinding procedures was low (i.e., resulting in a potential high risk of bias). Specifically, whether the outcome assessors and personnel were blind to the study hypotheses was unclear. Rater consistency was reported in 56% of the studies. The potential of bias in the quality of ASD diagnostician and diagnostic tool was low to moderate, with 56% deemed qualified diagnosticians (e.g., clinical/educational psychologist) and 69% employed reliable tools (e.g., previously validated). Outcome measures were considered to be low risk of bias, given that 100% of studies used established standardized measures.

(Insert Figure 2 here)

(Insert Figure 3 here)

Results of individual studies

A meta-analysis for each outcome (Social, Communication, Global ASD) along with sub-group comparisons are reported below. Means and SDs at all relevant measurement points along with standardized mean change effect sizes can be seen in Table 1.

Synthesis of results

Effect on social interaction

The results of the social interaction meta-analysis across nine studies (n = 360) can be seen in Figure 4. Overall, the results show a small statistically significant improvement in terms of social interaction (as estimated using *SMC*) as a consequence of AAIs (*SMC* = .21, *SE* = .07, z = 2.86, p<.01, CI[.07,.35]). Heterogeneity was low across all studies (I^2= 0%, Q = 6.73). The effect size for SGPP studies was small but statistically non-significant (*SMC* = .22, *SE* = .14, z = 1.56, p =.12, CI[-.06,.50]), for CGPP studies it was small and statistically significant (*SMC* = .24, *SE* = .11, z = 2.18, p =.03, CI[.03,.45]), and for ACPP studies it was small and statistically non-significant (*SMC* = .12, *SE* = .16, z = .73, p =.47, CI[-.19,.44]). There was no statistically significant difference across subgroups (I^2= 0%, p = .83).

(Insert Figure 4 here)

Effect on communication

The results for the communication meta-analysis across nine studies (n = 285) can be seen in Figure 5. Overall, the results show a small statistically significant improvement in terms of communication (as estimated using *SMC*) from AAIs (*SMC* = .26, *SE* = .09, z = 2.85, p<.01, CI[.08,.44]). Heterogeneity was moderate across all studies (I^2= 30.1%, Q = 11.02). The effect size for SGPP studies was small but statistically non-significant (*SMC* = .22, *SE* = .12, z = 1.84, p =.07, CI[-.02,.45]), for CGPP studies it was moderate and statistically significant (*SMC* = .34, *SE* = .17, z = 1.98, p =.05, CI[.00,.68]), and for ACPP studies it was small and statistically non-significant (*SMC* = .23, *SE* = .22, z = 1.05, p =.29, CI[-.19,.66]). There was no statistically significant difference across design-type (I^2= 0%, p = .84).

(Insert Figure 5 here)

Effect on global measures of ASD

The results for the ASD meta-analysis across seven studies (n = 148) can be seen in Figure 6. Overall, the results show a small non-statistically significant reduction in terms of ASD symptoms (as estimated using *SMC*) because of AAIs (*SMC* = -.19, *SE* = .11, z = -1.80, p =.07, CI[-.39,.02]). Heterogeneity was low across all studies (I^2= 0%, Q = 13.48). The effect size for SGPP studies was small and statistically non-significant (*SMC* = -.25, *SE* = .14, z = -1.78, p = .07, CI[-.52,.02]), for CGPP studies it was small and statistically non-significant (*SMC* = -.17, *SE* = .19, z = -.87, p =.38, CI[-.54,.21]), and for ACPP studies it was large and statistically significant in favour of the control group (*SMC* = 2.63, *SE* = .98, z = 2.67, p <.01, CI[.70,4.56]). There was a significant difference across study-type (SGPP vs CGPP vs ACPP) in terms of heterogeneity variance (I^2=96.7%, p = .02).

(Insert Figure 6 here)

Risk of bias across studies

Inspection of funnel plots (see Figure 7) suggests symmetry for Social and Communication outcomes but not for the ASD outcome (Viechtbauer, 2010). This was confirmed using Egger's test, where the distribution of effect sizes to standard error did not significantly deviate from symmetry for Social (z = 1.09, p = 0.28) or Communication (z = 0.68, p = 0.48), but did for ASD (z = 2.84, p <.01). In light of this, the trim-and-fill method was used to estimate the effect sizes of

potentially supressed studies for the ASD outcome and then the ASD meta-analysis was recalculated (Duval & Tweedie, 2000a; Duval & Tweedie, 200b). Using this technique, the results showed a marginal increase in ASD overall effect size (from -.19 to -.25 [SE =0.45, z = -0.56, p=.57]) but a decrease in significance. This is to be expected given that the estimated missing studies represent those with greater error (see Figure 7). Combined, these analyses suggest that the effect size estimates for Social and Communication were robust and not likely impacted by publication bias, whereas the estimate for ASD could potentially be biased.

(Insert Figure 7 here)

Additional analyses

Meta-regression results (dosage)

The meta-regression results showed no significant relationship between dosage (approximate mins of therapy time) and improvement in social interaction (β = .00, *SE* = .00, *z* = .68, *Q* = .47, p = .49), communication (β = .00, *SE* = .00, *z* =.11, *Q* = .01, p = .91), or Global ASD symptoms (β = -.00, *SE* = .00, *z* =-.42, *Q* = .17, p = .67). However, it should be noted that plots (see Figure 8) demonstrated a tentative trend towards expected relationships (e.g., improvement in social skills and reduction in ASD symptoms). Given that only one of the three outcomes achieved the minimum number of studies per moderator (i.e., 10) (Borenstein, Hedges, Higgins & Rothstein, 2009), the above findings should be taken with caution and require further investigation.

(Insert Figure 8 here)

Discussion

Meta-analytic methods allowed us to inspect the potential therapeutic value of Animal-Assisted Interventions (AAIs) for children with Autism Spectrum Disorder (ASD). This analysis examined sixteen unique AAI studies with a total of 489 ASD-diagnosed participants. Two core components of ASD symptomology thought to benefit from AAIs (social interaction and communication) as well as global ASD scores were examined.

The results showed a small effect (i.e., improvement) in a child's social interaction when all study types were combined (SGPP;CGPP;ACPP). However, only a small effect size for studies that included a non-active control group was statistically significant. The one study that included an active control (barn activity with no horses) showed no significant improvement in terms of social interaction (Gabriels et al., 2015). These results suggest that compared to passive activities

such as waitlist (e.g. Borgi et al., 2016; Gabriels et al., 2012), AAI may marginally improve social interaction for children with ASD. However, compared to an activity involving a related task (but without an animal) AAI demonstrates no improvement in social interaction. This suggests the role of the animal in improving social interaction for children with ASD may be limited.

The effect of AAI on communication was small and only statistically significant when all study types were combined. For studies using a passive control comparison (Borgi et al., 2016; Gabriels et al., 2012; Pan, Granger, Guérin, Shoffner & Gabriels, 2019), analysis showed a moderate improvement in communication as a result of AAI. However, this effect disappeared when comparing AAI to active controls (Gabriels et al., 2012- barn activity with no horses; Kwon et al., 2019- conventional therapy). This suggests AAI may have limited impact on improving communication for children with ASD above alternative interventions.

AAIs also appeared to show little reduction in terms of global ASD scores (i.e., those thought to capture multiple domains core to ASD). Specifically, the effect sizes for studies employing a passive control (Harris & Williams, 2017; Jenkins & DiGennare Reed, 2013; Kern et al., 2011) or those employing no control (Anderson & Meints, 2016; Holm et al., 2014; Ward et al., 2013) were both non-significant. The only study to employ an active control (dance) showed a significant and moderate effect size in favour of the control condition (Souza-Santos, dos Santos, Azevedo-Santos & Teixeira-Machado, 2018). Although only one study, it does suggest that alternative interventions may offer similar or greater reduction in global ASD symptoms compared to AAI.

The results from meta-regression analyses showed non-significant relationships between dosage and effect size. However, it should be noted that the sample size of studies was close to the minimum required for reliable analysis (Borenstein, Hedges, Higgins & Rothstein, 2009) and the direction of relationships were in line with that expected.

Recommendations for the field

Risk of Bias

When assessing the risk of bias within studies, it was evident that valuable information was often missing or unclear (e.g., only 56% of studies indicated whether it was the same rater at baseline and end of treatment). In order to reduce potential for bias, it is recommended that future research should report rater consistency [i.e., at baseline and end-of-treatment]; report the allocation

process for participants (e.g., randomized); report the level of assessor blinding; provide clear information relating to the ASD diagnostician; be clear as to how incomplete data were dealt with; and to ensure correct and thorough reporting of data. If implemented, these will undoubtedly increase the reliability of study findings and enhance future meta-analyses. In terms of bias across studies, the results generally showed low levels of heterogeneity, suggesting methodological (e.g., study design) and clinical (e.g., participants) differences had little impact on the meta-analysis results.

Future enquiry

As well as reporting factors that may impact risk of bias, it is also proposed that the field would benefit from improved study design. Out of the total number of unique studies included in this meta-analysis, 29% were single group pre-post designs, 53% used a passive control group, 18% included an active control condition and only 11% offered any type of follow-up assessment. Therefore, it would be beneficial for future studies to employ an active control design and seek to establish the potential long-term changes in AAI effects over greater time periods. It is also important that evidence-based active controls are selected in order to assess the cost-benefit of AAI. In other words, it is crucial to compare the benefit of AAI for children with ASD, whilst considering its financial and practical costs, relative to alternative interventions.

Overall, the findings of the current meta-analysis indicate that the effect of AAI for children with ASD is small. However, whether AAI's effectiveness varies dependent on currently untested factors is yet to be established. In future, the measuring and reporting of moderators such as age, dosage, extent of ASD symptoms, and sub-group characteristics could lead to targeted applications of AAI. This, combined with the use of evidence-based control comparisons, will surely provide a better understanding of AAI potential therapeutic use and AAI-specific mechanisms of change.

Limitations

Owing to the statistical nature of meta-analyses, observational and single-case-study research was excluded. However, combined with the current meta-analysis may provide a more complete picture as to AAIs effectiveness. The current meta-analysis, focusing on social interaction and communication, did not assess the entirety of symptoms associated with ASD (e.g., repetitive motor behavior). Only a limited number of studies provided sufficient data to conduct robust meta-regressions related to dosage. The studies included in the meta-analysis were rated to have

moderate risk of bias with some factors such as ‘random sequence generation’ and ‘allocation of concealment’ often being rated as high risk of bias. In addition, criteria such as ‘blinding outcome personnel and assessors’ were often rated as unclear, also suggesting a potential source of bias. However, results indicate low to moderate risk of bias for the meta-analysis findings themselves based on the fact there was little evidence of publication bias and estimates of heterogeneity were generally low.

Conclusion

The current meta-analysis examines the effect of AAIs on core behaviours related to children diagnosed with ASD. It also uniquely considers the role of dosage in terms of AAI efficacy. Overall, the findings show AAI offers small improvements in terms of social interaction and communication but no real reduction of global ASD symptoms. Based on the current analysis, there appears to be little evidence that dosage plays a role in the magnitude of AAI effect, however more data are needed to establish this concretely. This study also contributes several recommendations to the field regarding risk of bias reporting, study design, and potential avenues for future enquiry.

Reference List

Ajzenman, H.F., Standeven, J.W., & Shurtleff, T.L. (2013). Effect of hippotherapy on motor control, adaptive behaviors, and participation in children with autism spectrum disorder: a pilot study. *American Journal of Occupational Therapy, 67*(7), 653-663, DOI: 10.5014/ajot.2013.008383

All Party Parliamentary Group on Autism (2018). Autism Diagnosis Crisis. Retrieved on: 10.3.2020. Retrieved from: https://www.autism.org.uk/get-involved/media-centre/news/2018-07-18-autism-diagnosis-postcode-lottery-exposed.aspx

Anderson, K. L., & Olson, M. R. (2006). The value of a dog in a classroom of children with severe emotional disorders. *Anthrozoös. 19*(1): 35-49. DOI: 10.2752/089279306785593919

Anderson, S. & Meints, K. (2016). Brief Report: The Effects of Equine-Assisted Activities on the Social Functioning in Children and Adolescents with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders, 46*(10), 3344-3352. DOI: 10.1007/s10803-016-2869-3

Becker, B. J. (1988). Synthesizing standardized mean-change measures. *British Journal of Mathematical and Statistical Psychology*, 41(2), 257–278. doi:10.1111/j.2044-8317.1988.tb00901.x

Becker, J.L., Rogers, E.C.& Burrows, B (2017). Animal-assisted Social Skills Training for Children with Autism Spectrum Disorders. *Anthrozoös*, *30*(2), 307-326 DOI: 10.1080/08927936.2017.1311055

Borenstein,M., Hedges, L., Higgins, J., & Rothstein, H. (2009). *Introduction to meta-analysis*. Chichester, West Sussex: John Wiley & Sons.

Borgi, M., Loliva, D., Cerino, S., Chiarotti, F., Venerosi, A., Bramini, M., et al., (2016). Effectiveness of a Standardized Equine-Assisted Therapy Program for Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders, 46*(1), 1-9. DOI: 10.1007/s10803-015-2530-6

Brelsford, V.L., Meints, K., Gee, N. R., & Pfeffer, K. (2017). Animal-Assisted Interventions in the Classroom- A Systematic Review. *International Journal of Environmental Research and Public Health, 14*, 669. DOI: 10.3390/ijerph14070669.

Davis, T.N.; Scalzo, R.; Butler, E.; Stauffer, M.; Farah, Y.N.; Perez, S.; Coviello, L. (2015). Animal-assisted interventions for children with autism spectrum disorder: A systematic review. *Education and Training in Autism and Developmental Disabilities*, 50, 316–329.

Department of Education (2018). Special educational needs in England: January 2018. Retrieved on: 10.03.2020. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/729208/SEN_2018_Text.pdf

Duval, S., & Tweedie, R. (2000a). Trim and Fill: A Simple Funnel-Plot-Based Method of Testing and Adjusting for Publication Bias in Meta-Analysis. *Biometrics*, 56(2), 455–463. doi:10.1111/j.0006-341x.2000.00455.x

Duval, S., & Tweedie, R. (2000b). A Nonparametric "Trim and Fill" Method of Accounting for Publication Bias in Meta-Analysis. *Journal of the American Statistical Association*, 95(449), 89–98. doi:10.1080/01621459.2000.10473905

Fine, A. H. (Ed) (2015). Animal-assisted Therapy: Foundations and guidelines for animal-assisted interventions 4th ed. Elsevier, London, UK.

Friedmann, E., Katcher, A. H., Thomas, S. A., Lynch, J. J., & Messent, P. R. (1983). Social interaction and blood pressure: Influence of animal companions. *Journal of Nervous and Mental Disease, 171*(8), 461-465. DOI:10.1097/00005053-198308000-00002

Gabriels, R. L., Agnew, J. A., Holt, K. D., Shoffner, A., Zhaoxing, P., Ruzzano, S., et al., (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*, 578-588. DOI: 10.1016/j.rasd.2011.09.007

Gabriels, R. L., Pan, Z., Dechant, B., Agnew, J. A., Brim, N., & Mesibov, G. (2015). Randomized Controlled Trial of Therapeutic Horseback Riding in Children and Adolescents with Autism Spectrum Disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 54*(7), 541–549. DOI:10.1016/j.jaac.2015.04.007

García-Gómez, A., Risco, M.L., Rubio, J.C., Guerrero, E., & García-Peña, I.M. (2013). Effects of a Program of Adapted Therapeutic Horse-Riding in a Group of Autism Spectrum Disorder Children. *Electronic Journal of Research in Educational Psychology, 12*(1), 107-128. DOI: 10.14204/ejrep.32.13115

Harris, A., & Williams, J.M. (2017). The Impact of a Horse Riding Intervention on the Social Functioning of Children with Autism Spectrum Disorder. *International Journal of Environmental Research and Public Health, 14*(7), 776. DOI: 10.3390/ijerph14070776

Higgens, P.T.J. & Green, S. (2014). *Cochrane handbook for systematic reviews of interventions*. John Wiley & Sons Ltd, West Sussex, England.

Higgins, J. P. T., Thompson, S. G., Deeks, J. J. & Altman, D. G. (2003). Measuring inconsistency in meta-analyses, *BMJ,327*:557.DOI: 10.1136/bmj.327.7414.557

Higgins J.P.T & Thompson S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine,* 21, 1539–1558.

Holm, M. B., Baird, J. M., Kim, Y. J., Rajora, K. B., D'Silva, D., Podolinsky, L., et al. (2014). Therapeutic horseback riding outcomes of parent-identified goals for children with autism spectrum disorder: an ABA' multiple case design examining dosing and generalization to the home and community. *Journal of autism and developmental disorders*, *44*(4), 937–947. DOI: 10.1007/s10803-013-1949-x

Jenkins, S.R. & DiGennaro Reed, F.D. (2013). An experimental analysis of the effects of therapeutic horseback riding on the behavior of children with autism. *Research in Autism Spectrum Disorders*, *7*, 721-740. DOI: 10.1016/j.rasd.2013.02.008

Kern, J. K., Fletcher, C. L., Garver, C. R., Mehta, J. A., Grannemann, B. D., & Knox, K. R. (2011). Prospective trial of equine-assisted activities in autism spectrum disorder. *Alternative Therapies in Health and Medicine*, *17*(3), 14–20

Kwon, S., Sung, I.Y., KO, E.J. & Kim, H.S. (2019). Effects of Therapeutic Horseback Riding on Cognition and Language in Children with Autism Spectrum Disorder or Intellectual Disability: A Preliminary Study. *Annals of Rehabilitation Medicine*, *43*(3), 279-288. DOI: 10.5535/arm.2019.43.3.279

Lanning, B. A., Baier, M. E., Ivey-Hatz, J., Krenek, N. & Tubbs, J. D. (2014). Effects of equine assisted activities on autism spectrum disorder. *Journal of Autism and Developmental Disorders, 44*(8), 1897–1907.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration.*PLoS medicine*, *6*(7), e1000100. https://doi.org/10.1371/journal.pmed.1000100

Mapes, A.R., & Rosén, L. A. (2016). Equine-Assisted Therapy for Children with Autism Spectrum Disorder: A Comprehensive Literature Review. *Review Journal of Autism and Developmental Disorders*, 3, 377-386. DOI: 10.1007/s40489-016-0090-0

McNicholas, J. & Collis, G.M. (2000). Dogs as catalysts for social interactions: Robustness of the effect. *British Journal of Psychology*. 91: 61–70. DOI: 10.1348/000712600161673

Morris, S. B. (2007). Estimating Effect Sizes From Pretest-Posttest-Control Group Designs. *Organizational Research Methods*, 11(2), 364–386. doi:10.1177/1094428106291059

Morris, S. B., & DeShon, R. P. (2002). Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. *Psychological Methods*, 7, 105–125.

Nimer, J. & Lundahl, B. (2007). Animal-Assisted Therapy: A Meta-Analysis. *Anthrozoös, 20*(3), 225-238. DOI: 10.2752/089279307X224773

O'Haire, M. E. (2013). Animal-Assisted Intervention for Atism Spectrum Disorder: A Systematic Literature Review. *Journal of Autism and Developmental Disorders, 43*, 1606-1622. DOI: 10.1007/s10803-012-1707-5

O'Haire, M. E. (2017). Research on animal-assisted intervention and autism spectrum disorder, 2012–2015. *Applied Developmental Science, 31*(3), 200-216, DOI: 10.1080/10888691.2016.1243988

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. *Anthrozoös***,** *20*(3), 162-168. DOI: 10.1089/acm.2013.0165

Pan, Z.,Granger, D.A., Guérin, N.A., Shoffner, A. & Gabriels, R. L. (2019). Replication Pilot Trial of Therapeutic Horseback Riding and Cortisol Collection With Children on the Autism Spectrum. *Frontiers in Veterinary Science*, *5*:312. DOI: 10.3389/fvets.2018.00312

Prothmann, A., Ettrich, C., & Prothmann, S. (2009). Preference for, and responsiveness to, people, dogs and objects in children with autism. *Anthrozoös, 22*(2), 161–171.

Redefer, L. A., & Goodman, J. F. (1989). Brief report: Pet-facilitated therapy with autistic children. *Journal of Autism and Developmental Disorders*, 19(3), 461–467. doi:10.1007/bf02212943

Rosenthal, R. (1993). *Meta-analytic procedures for social research*. Newbury Park: Sage Publications.

Schuck, S. E., Emmerson, N. A., Fine, A. H., & Lakes, K. D. (2015). Canine-assisted therapy for children with ADHD: preliminary findings from the positive assertive cooperative kids study. *Journal of attention disorders, 19*(2), 125–137. DOI:10.1177/1087054713502080

Shi, L., & Lin, L. (2019). The trim-and-fill method for publication bias: practical guidelines and recommendations based on a large database of meta-analyses. *Medicine*, *98*(23), e15987. https://doi.org/10.1097/MD.0000000000015987

Society for Companion Animal Studies (2013). Animal-Assisted Intervention Terminology. Retrieved on: 10.08.20. Retrieved from: http://www.scas.org.uk/animal-assisted-interventions/174-2/

Souter, M. A. & Miller, M. D. (2007). Do Animal-Assisted Activities Effectively Treat Depression? A Meta-Analysis. *Anthrozoös, 20*(2), 167-180. DOI: 10.2752/175303707X207954

Souza-Santos, C., dos Santos, J. F., Azevedo-Santos, I. & Teixeira-Machado, L. (2018). Dance and equine-assisted therapy in autism spectrum disorder: Crossover randomized clinical trial. *Clinical Neuropsychiatry: Journal of Treatment Evaluation, 15*(5), 284–290.

Stefanini, M.C., Martino, A., Bacci, B. & Tani, F. (2016). The effect of animal-assisted therapy on emotional behavioural symptoms in children and adolescents hospitalized for acute mental disorders. *European Journal of Integrative Medicine, 8*(2), 81-88. DOI: 10.1016/j.eujim.2016.03.001

Sterne, J. A. C., & Egger, M. (2001). Funnel plots for detecting bias in meta-analysis: Guidelines on choice of axis. *Journal of Clinical Epidemiology*, 54(10), 1046–1055

Stevenson, K., Jarred, S., Hinchcliffe, V., & Roberts, K. (2015). Can a dog be used as a motivator to develop social interaction and engagement with teachers for students with autism? *Support for Learning, 30*(4), 341–363. DOI: 10.1111/1467-9604.12105.

Viechtbauer, W. (2010). Conducting meta-analyses in R with the *metafor* package. *Journal of Statistical Software*, 36(3), 1-48. http://www.jstatsoft.org/v36/i03/.

Ward, S.C., Whalon, K., Rusnak, K., Wendell, K., & Paschall, N. (2013). The association between therapeutic horseback riding and the cocial communication and sensory reactions of children with Autism. *Journal of Autism and Developmental Disorders, 43,* 2190-2198.

Figure Captions

Fig 1 Flow Diagram of the Study Selection Process

Fig 2 Risk of bias for all individual studies organized by risk of bias criteria

Fig 3 Risk of bias table for each study across all criteria

Fig 4 Meta-analysis of AAI effect sizes for social interaction

Fig 5 Meta-analysis of AAI effect sizes for communication

Fig 6 Meta-analysis of AAI effect sizes for global ASD scores

Fig 7 Funnel plots for Social, Communication and ASD scores (left to right) with pseudo 95% CIs

Fig 8 Meta-regression plots showing the relationship between AAI dosage (mins of animal contact) and standardized mean change effect size

Figure 1 top

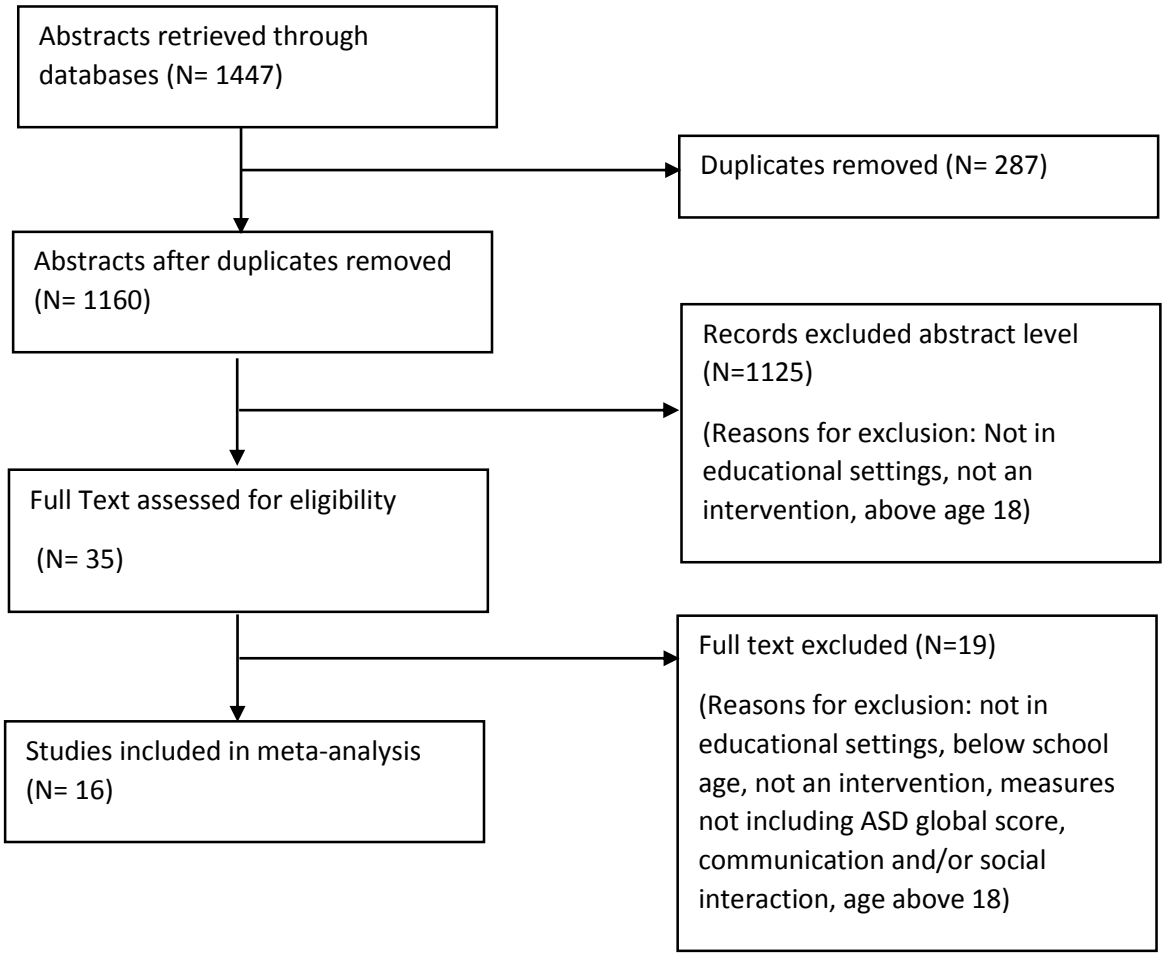

Abstracts retrieved through databases (N= 1447)
Duplicates removed (N= 287)
Abstracts after duplicates removed (N= 1160)
Records excluded abstract level (N=1125)
(Reasons for exclusion: Not in educational settings, not an intervention, above age 18)
Full Text assessed for eligibility
(N= 35)
Full text excluded (N=19)
(Reasons for exclusion: not in educational settings, below school age, not an intervention, measures not including ASD global score, communication and/or social interaction, age above 18)
Studies included in meta-analysis (N= 16)

Figure 2 top

Program used to create figure: R, Metafor package

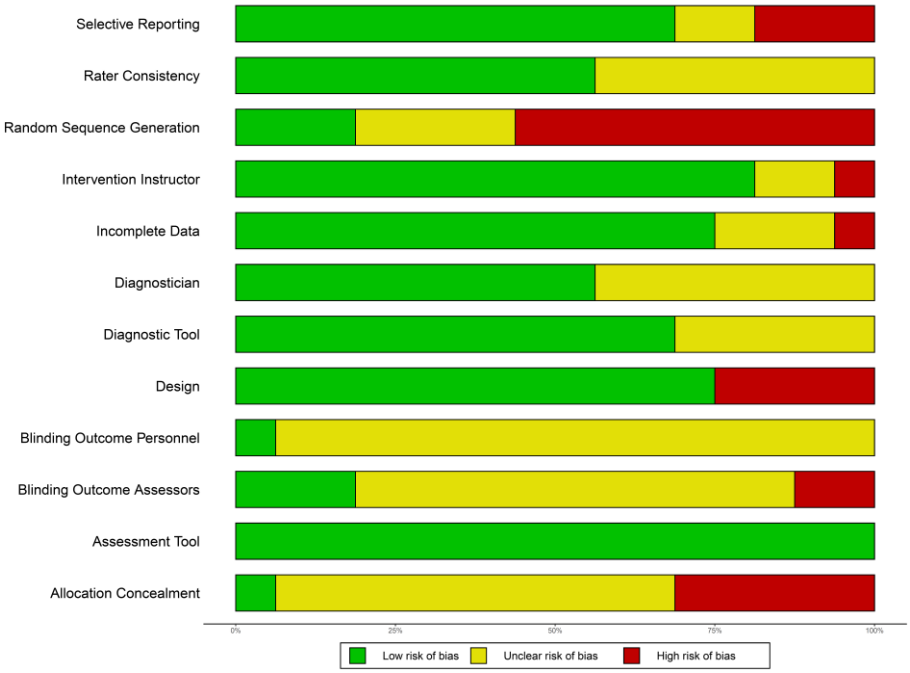


Figure 3 top

Program used to create figure: R, Metafor package

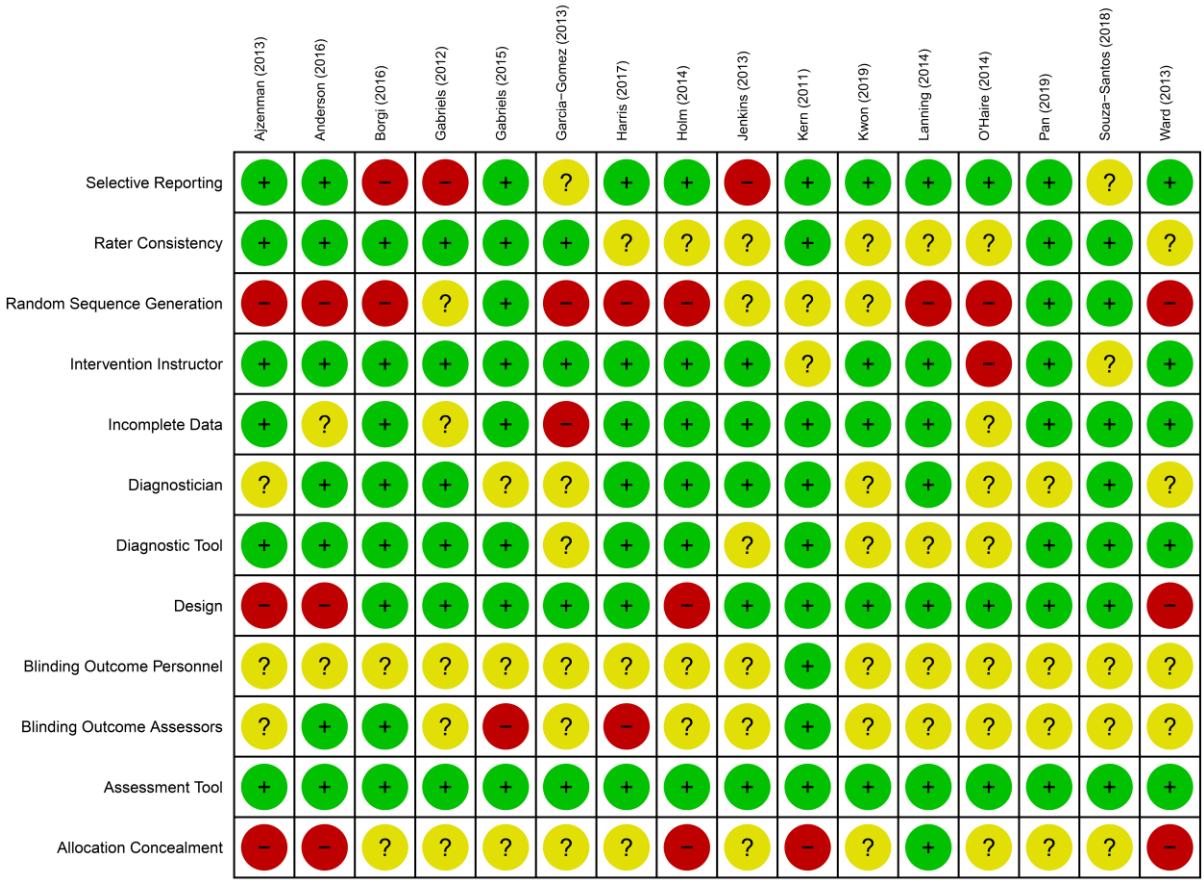


Figure 4 top

Program used to create figure: R, Metafor package

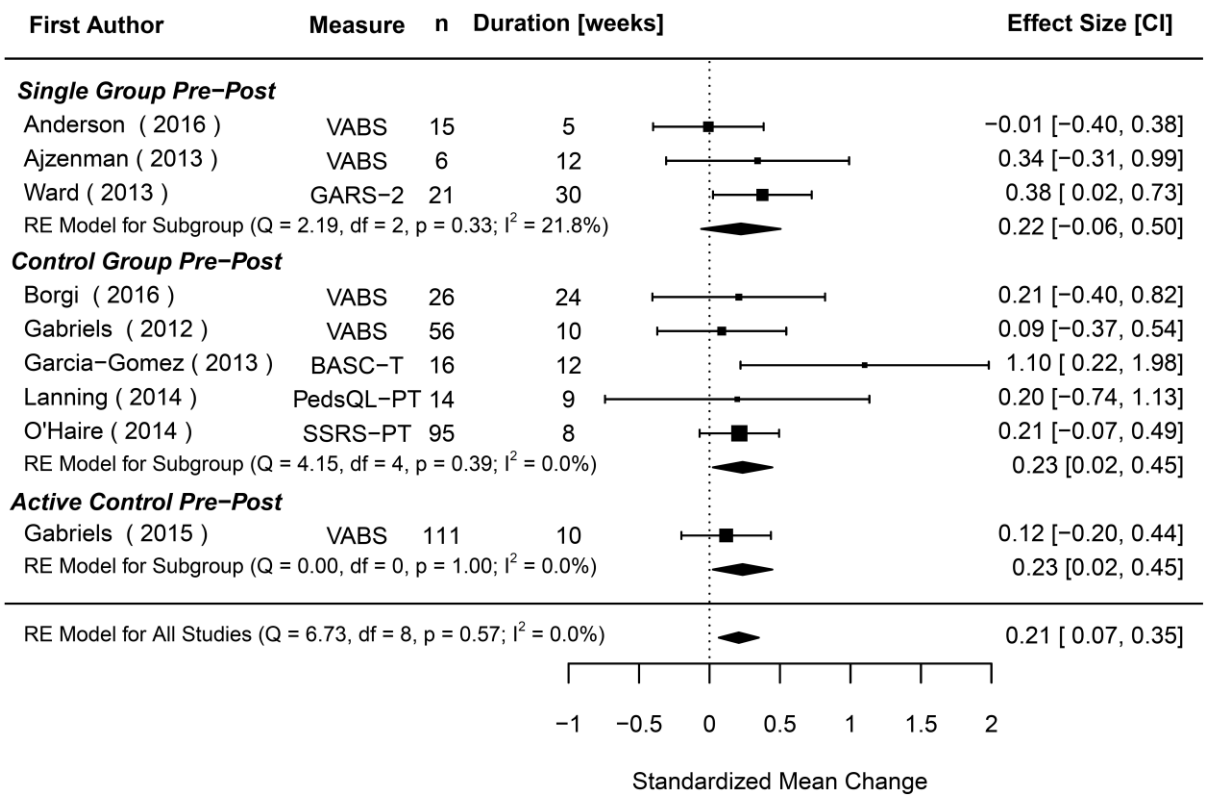


Figure 5 top

Program used to create figure: R, Metafor package

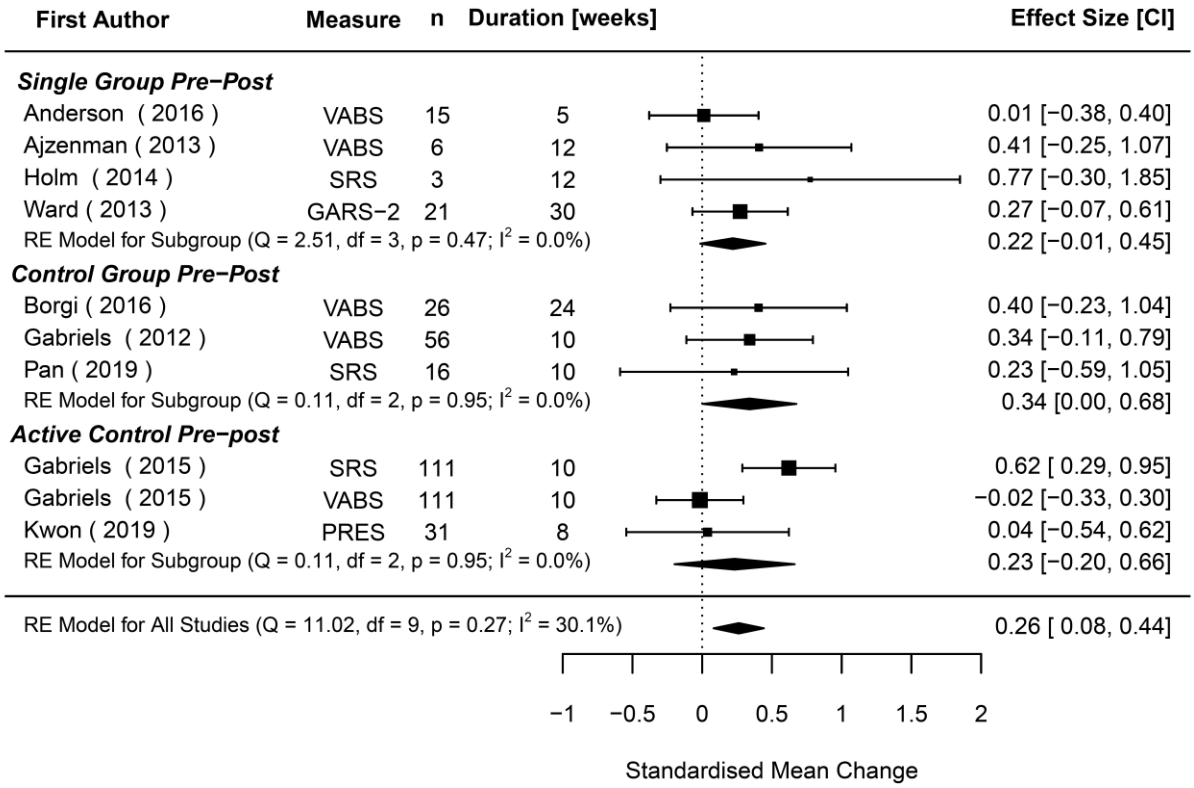


Figure 6 top

Program used to create figure: R, Metafor package

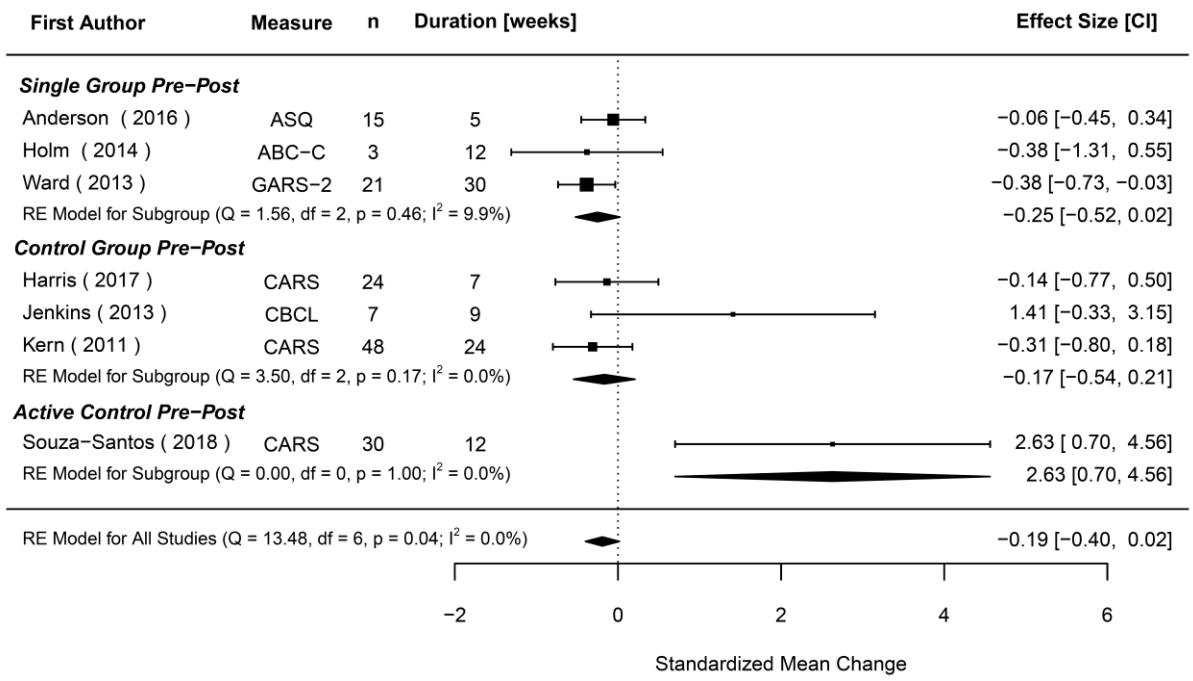
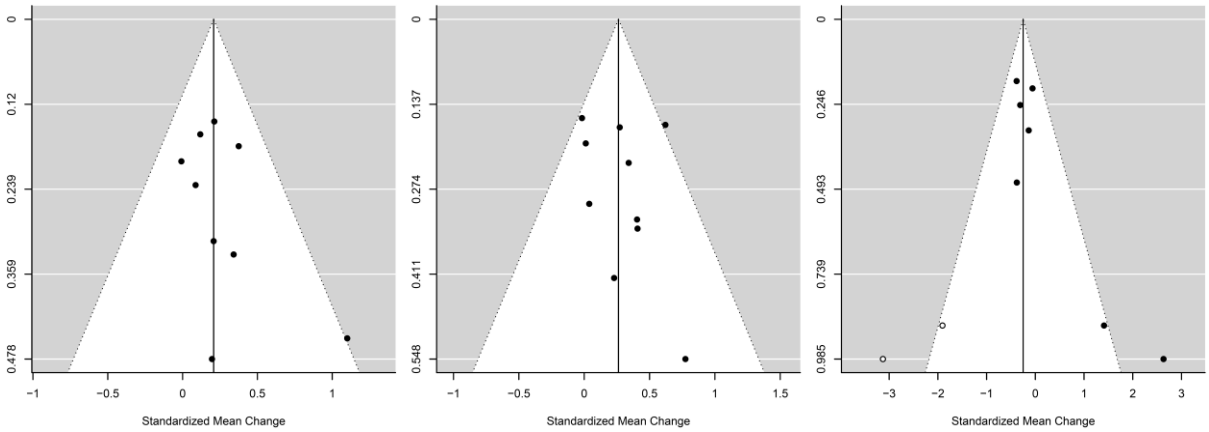


Figure 7 top

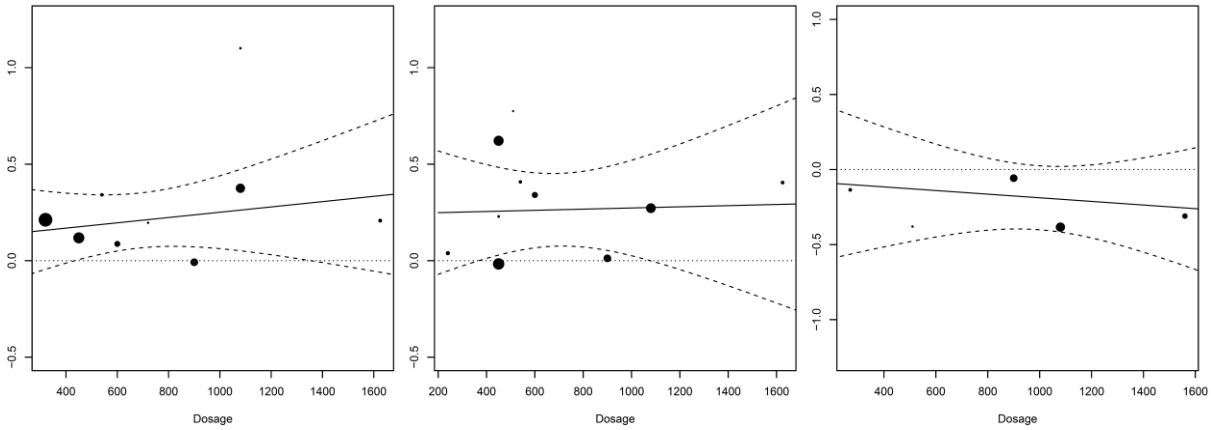
Program used to create figure: R, Metafor package



Note: estimated missing studies are represented with hollow circles

Figure 8 top

Program used to create figure: R, Metafor package



Note: some data points may not be visible in the plots for purposes of ease of visualization, but have been included in all necessary calculations

Tables

Table 1

Characteristics of all studies included in the meta-analysis

Study (First Author, Year)	Participant Information			Tx (n)	Comparison (n) (Control/ Waitlist/ Active)	AAI Tx (duration, frequency)	Measures (social, com., ASD)	Intervention		Comparison		*Effect Size*
	Diagnosis (N)	Age (yrs)	Sex					Pre: Mean (*SD*)	Post: Mean (*SD*)	Pre: Mean (*SD*)	Post: Mean (*SD*)	
Ajzenman 2013	ASD (N= 7)	5-12	M= 4 F= 3	Hippo-therapy (n= 7)	-	1x45 min/wk 12 wks	Social: VABS Com: VABS	61.11 (*17.67*) 65 (*18.54*)	68.17 (*21.52*) 74 (*19.52*)	- -	- -	*0.34* *0.41*
Anderson 2016	ASD (N=15)	5-16	M= 11 F= 4	THR (n= 15)	-	1x3 hrs/wk 5 wks	Social: VABS Com: VABS ASD: ASQ	45.27 (*23.21*) 44.2 (*31.19*) 62.13 (*24.2*)	45.07 (*22.48*) 44.6 (*30.39*) 60.66 (*24.19*)	- - -	- - -	*-0.01* *0.01* *-0.06*
Borgi 2016	ASD (N=28)	6-12	M= 28	EAT (n= 13)	Waitlist (n= 15)	1x60-70mins/wk 25 wks	Social: VABS Com: VABS	5.2 (*2.3*) 7.5 (*2*)	5.9 (*2.1*) 18.6 (*2*)	7.1 (*2.3*) 8.3 (*2.4*)	7.3 (*2.8*) 8.6 (*2.2*)	*0.21* *0.40*
Gabriels 2012	ASD (N=42)	6-16	M= 36 F= 6	THR (n= 42)	Waitlist pre-start (n= 16)	1x1hr/wk 10wks	Social: VABS Com: VABS	104.9 (*29.9*) 143.6 (*24.9*)	113.2 (*27.4*) 149 (*24.8*)	104.25 (*30.08*) 147.69 (*31.58*)	110.13 (*33.35*) 143.44 (*32.85*)	*0.09* *0.34*
Gabriels 2015	ASD (N=127)	6-16	M= 101 F= 15	THR (n= 63)	Barn Activities (n= 64)	1x45 min/wk 10wks	Social: VABS Com: SRS Com: VABS	95.4 (*35.53*) -36.8 (*10.04*) 135.4 (*33.75*)	107 (*37.6*) -30.2 (*8.75*) 140.9 (*36.93*)	102.9 (*28.55*) -33.9 (*11.38*) 133.3 (*34.95*)	108.8 (*30.78*) -33.6 (*11.38*) 139.6 (*31.87*)	*0.12* *0.62* *-0.02*

Garcia-Gomez 2013	ASD (N=32)	7-14	M= 13 F= 3	THR (n= 8)	Control (n= 8)	2x45 min/wk 12 wks	Social: BASC-T	6.17 (*5.49*)	7.5 (*9.40*)	12 (*3.26*)	8.75 (*3.09*)	*1.10*
Harris 2017	ASD (N=26)	6-9	M= 22 F= 4	THR (n=10)	Waitlist (n=14)	5-7x45 min each	ASD: CARS	40.95 (*6.07*)	40.05 (*5.57*)	42.61 (*7.52*)	42.61 (*7.52*)	*-0.14*
Holm 2014	ASD (N= 3)	5-13	M= 3	THR (n= 3)	-	1,3or5 sessions/ wk 4wks	Com: SRS ASD: ABC-C	-81.67 (*1.69*) 87.10 (*4.75*)	-79.33 (*4.49*) 83.87 (*6.42*)	- -	- -	*0.77* *-0.38*
Jenkins 2013	ASD (N= 7)	6-14	M= 6 F= 1	THR (n=4)	Waitlist (n= 3)	1x60 min/wk 9 wks	ASD: CBCL	59.88 (*3.57*)	58.88 (*6.47*)	62.5 (*0.41*)	61.33 (*6.20*)	*1.41*
Kern 2011	ASD (N=41)	3-12	M=18 F= 6	EAA (n= 20)	Waitlist pre-start (n= 24)	1x60 min/wk 24 wks	ASD: CARS	36.68 (*4.73*)	34.24 (*4.32*)	37.74 (*5.54*)	36.68 (*4.73*)	*-0.31*
Kwon 2019	ASD (N=31)	6-13	M= 16 F= 13	THR (n= 18)	Active: Conventional Therapy (n= 11)	1x 30min/wk 8wks	Com: PRES	15.58 (*13.13*)	17.17 (*14.1*)	10.88 (*10.44*)	11.75 (*10.08*)	*0.04*
Lanning 2014	ASD (N=25)	4-15	M= 21 F= 4	EAA (n= 13)	Active: Social Circles (n= 12)	1x60 min/wk 12 wks	Social: PedsQL-PT	49.90 (*25.54*)	71.20 (*26.51*)	57.82 (*20.24*)	70.14 (*21.07*)	*0.20*
O'Haire 2014	ASD (N=64)	5-12	M= 50 F= 14	AAI (n= 27)	Waitlist (n= 37)	2x20 min/wk (16 sessions) 8wks	Social: SSRS-PT	80.3 (*35.53*)	84.55 (*15.7*)	79.5 (*14.95*)	80.3 (*15.85*)	*0.21*
Pan 2019	ASD (N=16)	6-16	M= 13 F= 3	THR (n=8)	Active: Barn Activities	1x45 min/wk 10 wks	Com: SRS	-37.4 (*13.41*)	-34.57 (*3.95*)	-30.75 (*10*)	-31.29 (*10.98*)	*0.23*

					(n=8)							
Souza-Santos 2018	ASD (N=45)	5-12	M= 36 F= 9	EAT (n=15)	Active: Dance (n=15) EAT & Dance (n=15)	2x60min/wk 12 wks for EACH INTERV.	ASD: CARS	36.6 (*1.76)*	32.7 (*1.64*)	39.8 (*1.7*)	31.3 (*3.71*)	*2.63*
Ward 2013	ASD (N=21)	8 (mean)	M= 15 F= 6	THR (n=21)	-	1x 1hr/wk 18 wks	Social: GARS-2 Com: GARS-2 ASD: GARS-2	-7.9 (*3.59*) -9.6 (*3.89*) 90.5 (*19.8*)	-6.5 (*4.08*) -8.5 (*4.19*) 82.6 (*27.03*)	- - -	- - -	*0.38* *0.27* *-0.38*

Author Note

Both authors' (Dr. Mirena Dimolareva and Dr. Thomas J. Dunn) affiliation at the time of completing this paper was Bishop Grosseteste University (Psychology division), Lincoln, Lincolnshire, UK.