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## Differences between Siblings, Adults, Peers, and Apps Mediated Effects in Autism-Related Single Subject Designs: A Comparative Study Using ANOVA

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### Abstract

*In the area of autism spectrum disorder (ASD) and other learning disabilities, numerous single-subject design studies have evidenced the effective mediation of siblings, peers, adults, and apps to help children diagnosed with ASD and comorbidities function better. Yet, the existing literature base suggests that potential studies that could tell the most effective mediation are almost non-existent. This study aimed to compare the different effects achieved by children diagnosed with ASD with the mediation of their siblings, adults, peers, or Apps. To achieve this objective, the effect sizes of 407 children and adolescents (ages ranged from one to 17 years with an average age of 4.71 (SD = 2.07)) diagnosed with ASD and its comorbidities, retrieved and computed from 131 single-subject design published journals were used to conduct an analysis of variance (ANOVA). Whereas the descriptive statistics suggested medium to strong effect sizes, the results of the ANOVA and follow-up post-hoc analysis suggested that apps could be better predictors/mediators of achievement for children diagnosed with ASD. The researchers discussed the findings and made suggestions for future studies regarding the development and utilization of more sophisticated ASD-related apps, specifically designed to meet the mediation needs of children and adolescents alongside human interventionists.*

**Keywords:** Autism Spectrum Disorder, Mediator, Analysis of Variance, Single-Subject Design, Intervention.

### Introduction

Autism spectrum disorder (ASD) is well-defined and characterized as an intense neurodevelopmental condition that provokes substantial sicknesses in people. It affects their close relatives and the neighborhoods in which they live (Christensen et al. 2018). Past scientific research endeavored to gauge how normally developing siblings and peers help improve social skills in individuals diagnosed with ASD. The research suggested that these developmentally healthy youngsters possess the capability to learn and use behavior modification tactics to better the social communications of their peers or siblings who have ASD (Oppenheim-Leaf et al., 2012). In this light, substantial investigations have been led, using siblings as mediators.

Many studies have been undertaken to successfully measure the effectiveness of brothers' and sisters' interventions also known as meditations. Most investigations found similar outcomes which were assembled in methodical literature reviews (Banda, 2015; Shivers & Plavnick 2015). Similarly, in a systematic literature review, Shivers and Plavnick (2015) reviewed 17 articles to appraise the helpfulness of the inclusion of normally developing sisters and brothers in the treatments of their brothers and sisters diagnosed with ASD. The findings revealed that children with ASD improved their social, play, communication, and functional skills. The findings also

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suggested that normally developing siblings acquired the skills of meditation. In addition to siblings, peers also have been used as mediators in single-subject design studies.

Past studies have supported the use of substitute instructional plans to teach typical peers to mimic suitable insight and social deeds for their peers who were diagnosed with disabilities (Campbell et al. 1983). It was suggested that when properly executed, peer-mediated instructional tactics can simplify active learners' engagement; regular occasions to reply; and deliver feedback for improvement, encouragement, and advice. These approaches comprise whole-class training, small-group coaching, instructor-to-peer coaching, and self-regulated work time (Friedlander, 2009). Peer-mediated instruction arrangement was perceived as involving teaching neuro-typically developing peer(s) to model and strengthen pre-determined school or socially related behaviors (Dugan et al. 1995; Krebs et al. 2010). The technique can be linked to the social cognitive theory that advocates and emphasizes observational learning.

Clearly, peer-mediated interventions in single-subject design studies extend to social learning theory, a leading learning theory by Bandura (1977). The mentioned theory emphasizes that learning may occur within a social setting, and implies learning by observing, imitating other people, or modeling. The theory lays the foundation for peer-mediated instructional techniques (Bandura 1977; Bhat et al. 2011). With significant outcomes across studies, it was argued that peer-mediated interventions are promising strategies for improving the academic and social skills of children diagnosed with ASD. In addition to siblings, and peers, adult individuals have been utilized as mediators, in the existing literature base, sometimes alongside other siblings and peers.

In many studies, adults such as teachers, interventionists, and parents of children who have ASD and other developmental disabilities also were used as mediators whereas other studies utilized Apps. Regarding parent-mediated interventions, many investigations that focused on Enhanced Milieu Teaching (EMT) conducted over the past years were restricted to youngsters whose ages ranged from 1.5 to five years. Parent participants in the studies received EMT training as mediators (McLeod et al. 2017). Meta-analyses (Bene,2024) suggested that parent-mediated interventions were effective and promising. Like in normally developing children and adolescents, the relationship between teachers and students resulted in better achievement (Luo, et al. 2024). Regarding the use of Apps, a substantial body of research emphasized the mediation of modern technologies.

In recent years, the use of technology, predominantly video modeling (VM) has arisen as a successful instructional method to teach various skills to children and adolescents who were diagnosed with ASD. It was suggested that VM is an evidence-based practice by the National Autism Center (NAC, 2009). This instructional technique emphasizes learning through the observation and mimicry of others. The instructional tactic encompasses the presentation of a recorded sample of a model engaging in a sequence of scripted activities and/or expressions. The student with ASD or developmental disabilities then demonstrates the observed behavior. Hine and Wolery (2006) asserted that VM can incorporate edited images of suitable behavior presented on a monitor to a child with disabilities, frequent clips of the targeted behavior presented to the participant, isolated practice sessions, role-playing of the novel abilities, and evaluation of skills generalization. Although VM implies the use of technology, it suggests learning by observing a model. Other technologies, however, have been used in studies, and then in meta-analyses as mediators including tablets, iPads, and smartphones.

Al-Rashaida et al. (2022) undertook a systematic review of literature on devices such as tablets,

iPads, and smartphones as mediators in teaching curricula designed for young children diagnosed with ASD. The findings suggested that the devices are useful high-tech supports for youngsters with ASD. The included studies revealed that mobile devices can be effectively used in educational curricula to target children's expressive, academic, and social skills.

Likewise, Toma et al. (2024) conducted a meta-analytic study to provide descriptive literature on the effectiveness of virtual reality (AR) alongside mixed reality methodologies as therapeutical approaches used among children diagnosed with ASD. The findings suggested a growth in publications associated with apps for youngsters with ASD. Most investigations in the study emphasized mobile AR solutions for Android Apps developed using the Unity 3D platform and the Vuforia engine. Based on the findings, it was suggested that these technological packages are suitable to be used as therapeutical devices for children diagnosed with ASD. Furthermore, multiple studies revealed a different trend toward the utilization of AR technology as an educational instrument for individuals diagnosed with ASD. More specifically, the trend encompasses multidisciplinary collaboration alongside a unified research method and a focus on all-inclusive scientific appraisals and technology integrities.

### **Theoretical Framework**

The authors selected Vygotsky's (1978) theory of the Zone of Proximal Development (ZPD) as the theoretical framework for this study as it clarifies children's performance alone and their achievement when they receive help or mediation from others. Vygotsky himself described the concept of ZPD as the gap between a youngster's true developmental stage gauged by their ability to solve a problem alone on the one hand and their superior capability to solve a problem, as measured through problem-solving when guided by an adult or a peer with higher capabilities on the other hand. ZPD was quoted as "The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86)

Similarly, in ASD-related single-subject design studies, the child's performance is usually measured in the alone condition named baseline, which performance is also later measured in the intervention condition. The interventionist or mediator who intervenes in the intervention condition as a model, to provide guidance or motivation is either an adult, a sibling, or a peer. The ZPD theory seems to be the best fit for describing children's performances as measured by the different effect sizes. In other words, children's performance is possible if they receive the appropriate social help.

### **Purpose of the study**

Children's and adolescents' mental health and academic achievements have been subjects of supreme attention (Monzonis-Carda et al. 2024). Although most ASD-mediated interventions that used siblings, adults, peers, and apps as interventionists suggested significant improvements in the required tasks of children with ASD, very little is known about the mediating agent that provides the strongest effectiveness. An almost thorough literature review did not suggest any past or present studies that compared the effects of mediated interventions between siblings, adults, peers, and apps with substantially large sample sizes. Only a few meta-analytic studies included some *t*-tests that compared the effect sizes of children diagnosed with ASD across genders and across periods of intervention in published journals based on Single-subject designs. The main aim of the present study was to assess the ASD-mediated effect sizes of siblings,

adults, peers, and apps. The first objective of the study was to describe the effect sizes of the different interventionists. The second objective was to compare the different effect sizes achieved by children diagnosed with ASD across the mediation of their siblings, adults, peers, or apps. The study attempted to answer the following questions.

1. What are the descriptive characteristics of the ASD-mediated intervention effect sizes of siblings, adults, peers, and apps?
2. Are there any significant differences between the mediated effects between siblings, adults, peers, and apps?
3. Which of the four ASD-mediated interventions of siblings, adults, peers, and Apps produces the highest effect sizes?

## **Method**

### **Participants**

The sample size included 407 child participants from 131 published single-subject design journal articles with an average of 3 participants per article. Several included journal articles were meta-analytical and proposed participants' data alongside their effect sizes. Most data, however, were furthermore calculated from journal articles that were not included in meta-analyses. Most participants were diagnosed with ASD, many of them were additionally diagnosed with ASD comorbidities, and at least 31 were female participants. Ages ranged from one to 17 years with an average age of 4.71 (SD = 2.07). See Table 1 for additional statistics on participant demographics. Further participants who acted as mediators/interventionists in the selected journal articles included normally developing siblings, peers, parents, teachers, and health providers. The latter were not included in the present study.

### **Measures**

The study was intended to compare the effect sizes between the mediations of siblings, adults, peers, and apps. The mediated effect sizes were extracted from published single-subject design studies presenting AB graphs. Most of these published single-subject design investigations utilized the Nonoverlap of all pairs (NAP) as Effect Sizes (ES) (Parker & Vannest, 2009). The authors calculated NAP for articles that provided AB design graphs but not the NAP effect sizes.

The Effect sizes for each child from each task displayed in graphs were computed for each published journal and Dissertation. The tasks were performed with the mediation of a sibling, a peer, an adult, or an app. The performance was described in an AB design graph, displaying at least a baseline and intervention conditions. Numerical data were therefore required. The researchers preferred the NAP hand-computation method, thereby using it to compare every baseline phase A data point with every intervention phase B data point. To accomplish this, the total possible pairs (total N) were first computed. The total possible pair is described as the amount of data points in baseline A multiplied by intervention phase B ( $NA \times NB$ ). In the second phase, all overlapping pairs were totaled by allocating 1 point to each overlap and 0.5 points to each tie. Next, the researchers deducted overlapping pairs from the total possible pairs to get the non-overlap count. In the final stage, the non-overlap sum was divided by the total possible pairs to achieve the NAP effect size (Parker & Vannest, 2009). Data points on the graph reveal the mediated performance of the child with ASD or the child's achievement with the intervention of his/her sibling, peer, parent, teacher, interventionist, or apps.

The rationale for using the NAP technique to estimate effect size (Parker & Vannest 2009) was because the NAP was said to be an index of data overlap between conditions in a single-subject design investigation. The NAP is deep-rooted and verified multiple times with 200 published AB design differences. The NAP is said to be an advanced application of established effect size for single-subject design research and possesses numerous forms including Area Under the Curve (AUC), the Common Language Effect Size (CL), the Probability of Superiority (PS), the Dominance Statistic (DS), Mann–Whitney’s U, and Sommers D. It was furthermore argued that the NAP’s major hypothetical advantage is that it is an all-inclusive test of all possible foundations of data overlap. Every baseline is gauged against every treatment data point, with a probability mark, usually ranging from 0.5 to 1 (Parker & Vannest 2009). NAP was designated as a robust procedure in that it differentiates better between results from a large collection of published investigations and yields fewer human mistakes when compared to the other hand-calculated indices such as the Percent of Non-Overlapping Data Points (PND), the Percent of Non-Overlapping Data (PAND), and the Percent of Data Exceeding the Median (PEM)]. Another benefit of the NAP existed. It was found to be a stronger validation by R2 which was perceived as the chief effect size in published manuscripts (Parker & Vannest 2009).

### **Procedure**

The investigators undertook systematic searches to select experimental studies that used single-subject designs and that produced AB design graphs. The initial search included sentences such as “The effect of Enhanced Milieu Teaching on the performance of children diagnosed with ASD/ Autism”, “Peer-mediated instructional arrangement and ASD/Autism”; “Sibling/ Brothers and sisters-mediated intervention and ASD/Autism”; “The effects of Apps on the performance of children diagnosed with ASD/autism” The researchers also used similar terms with meta-analyses. The search for published journal articles, dissertations, and theses (gray literature) took place in EBSCOhost which also encompasses Social Sciences, SAGE, Elsevier, Index, ERIC PsycINFO, Routledge, Psychological Abstracts Springer, PsycINFO, and more in Google Scholar. The investigators also conducted ancestral investigations for further articles below the reference section of every journal they included for data collection. The researchers then calculated the effect sizes (NAP) per the included articles and classified the statistics as, pertaining either to siblings, adults, peers, or apps mediation. Finally, the calculated effect sizes were transferred to Excel to be screened for outliers.

To estimate the appropriate sample sizes for this research, the researchers relied on the Desired Accuracy with a Confidence Level of 95% (Gill et al., 2010) that calculated and proposed specific sample sizes based on population sizes. For a population of 1000000, a sample size of 384 participants was deemed enough. The present study enrolled 407 participants’ data. For the comparison of several means using ANOVA, the G\*Power software offers the result of a suitable sample size of 10 per group (Kim, 2016). In other literatures about 52 participants were required per group to run ANOVA, whereas others suggested that there are no set numbers.

### **Statistical Analysis**

Using descriptive statistics, the researchers first computed the averages, standard deviations, and modes of effect sizes per type of mediation to answer the first question. Next, the researchers ran ANOVA to detect any possible differences between the different types of effect sizes and checked the test’s multiple assumptions. Whereas the ANOVA was meant to answer question two, a follow-up post-hoc analysis (Bonferroni adjusted pairwise comparison) was also conducted to answer the last question, by determining the mediator with the strongest effect size.

444 *Differences between Siblings, Adults, Peers, and Apps Mediated*

The verified assumptions were Normality by which each sample is to be drawn from a normally distributed population. The assumption of Equal Variances stipulates that the variances of the populations that the samples come from are equal, and the assumption of Independence by which the observations in each group must be independent of each other and the observations within groups must be obtained by a random sample. All the assumptions were met. The results were therefore reported and interpreted.

**Results**

Mediators	Sample Size	Mean of Effects	Standard Dev.	Mode	Minimum	Maximum	Confidence Interval (95%)
<b>Siblings</b>	49	0.83	0.12	0.83	0.55	1.00	0.06
<b>Peers</b>	113	0.85	0.18	1.00	0.26	1.00	0.06
<b>Adults</b>	121	0.90	0.10	1.00	0.59	1.00	0.03
<b>Apps</b>	124	0.96	0.09	1.00	0.58	1.00	0.03

Table 1: Descriptive Statistics

Groups	Count	Sum	Average	Variance
<b>Siblings</b>	18	15.01	0.83	0.016
<b>Peers</b>	40	34.13	0.85	0.033
<b>Adults</b>	39	35.2	0.90	0.010
<b>Apps</b>	38	36.49	0.96	0.009

Table 2: ANOVA Summary

Source of Variation	SS	df	MS	F	P-value	F crit
<b>Between Groups</b>	0.30155069	3	0.100516897	5.690146142	0.001078	2.673748
<b>Within Groups</b>	2.31412571	131	0.017665082			
<b>Total</b>	2.6156764	134				

Table 3: ANOVA Results

The study compared the effects of four mediating agents and methods, including siblings, adults, peers, and apps, on the performance of children and adolescents diagnosed with ASD. See Table 2 for the ANOVA Summary. A one-way ANOVA revealed a significant effect of the mediating method on the performance of children and adolescents diagnosed with ASD,  $F(3,131) = 5.69$ ,  $p < 0.001$ . See Table 3 for the significant effect. The effect size, eta squared ( $\eta^2$ ), was 0.022, indicating a small effect. A follow-up post-hoc analysis (Bonferroni adjusted pairwise comparison) showed that the mediation of apps ( $M = 0.96$ ;  $SD = 0.09$ ) was significantly higher/stronger than peers' intervention ( $M = 0.85$ ;  $SD = 0.18$ ). The mediation of apps ( $M = 0.96$ ;

SD = 0.09) was also significantly better than siblings' mediation (M = 0.83; SD = 0.13). Peers (M = 0.85; SD = 0.18) did not significantly differ from siblings (M = 0.83; SD = 0.13). Siblings (M = 0.83; SD = 0.13) did not significantly differ from adults (M = 0.90; SD = 0.10). Peers (M = 0.85; SD = 0.18) did not significantly differ from adults (M = 0.90; SD = 0.10), adults (M = 0.90; SD = 0.10) did not significantly differ from apps (M = 0.96; SD = 0.09).

## Discussion

NAP effect sizes were interpreted according to general guidelines (Parker & Vannest, 2009). It was argued that NAP values ranging from 0 to 0.65 are weak, those ranging from 0.66 to 0.92 have medium effects, and those ranging from 0.93–1.00 are large or possess strong effects. Furthermore, altering NAP to a zero-chance level causes the subsequent consistent ranges: weak effect sizes range from 0 to 0.31. Medium effect sizes range from 0.32 to 0.84, and large or strong effect sizes range from 0.85 to 1.0. In this regard, the researchers interpreted the overall effect sizes of each group respectively as strong, except for siblings which were interpreted as medium. See Table 1 for descriptive statistics.

This study compared mediating effects between siblings, adults, peers, and apps. The findings suggested that only apps significantly help children diagnosed with ASD to perform better on tasks that they are motivated or taught to accomplish. Apps were found to mediate with targeted participants better than siblings and peers separately. Although apps were equal to the adults' mediation, the findings suggested that apps led to the highest ASD-related children and adolescents' achievements when required to demonstrate mastery of a given task.

Much literature exists that shows the presence and effectiveness of different types of apps used to help children and adolescents who have ASD and other types of cognitive and physical disabilities accomplish specific tasks. In this light, Granich et al. (2016) argued that the growth of technology in ASD intervention and treatment has offered transportability, accessibility, low cost, and social acceptance for the procurement of information and instruction through the existing technology. Al-Rashaida et al. (2022) undertook a systematic review of literature on devices such as tablets, iPads, and smartphones as mediators in teaching curricula designed for young children diagnosed with ASD. The findings suggested that the devices are useful high-tech supports for youngsters with ASD. The included studies revealed that mobile devices can be effectively used in educational curricula to target children's expressive, academic, and social skills.

Likewise, Toma et al. (2024) conducted a meta-analytic study to provide descriptive literature on the effectiveness of virtual reality (AR) alongside mixed reality methodologies as therapeutic approaches used among children diagnosed with ASD. The findings suggested a growth in publications associated with apps for youngsters with ASD. Most investigations in the study emphasized mobile AR solutions for Android apps developed using the Unity 3D platform and the Vuforia engine. Based on the findings, it was suggested these technological packages are suitable to be used as therapeutic devices for children diagnosed with ASD. Furthermore, multiple studies revealed a different trend toward the utilization of AR technology as an educational instrument for individuals diagnosed with ASD. More specifically, the trend encompasses multidisciplinary collaboration alongside a unified research method and a focus on all-inclusive scientific appraisals and technology integrities.

Regarding single-subject design research, abundant literature suggests functional relations between conditions. A study explored the effect of a technological package, an app-based virtual

manipulative in unification with clear instruction on learners' achievement and generalization. The targeted objective was for students to solve problems that include the division of whole numbers with remainders. In the study, three secondary school students diagnosed with disabilities were enrolled who participated in this numerous baseline, multiple probes across participants design investigation. The findings suggested that every participant student learned mathematical performance, that is being capable of solving divisions with remainder problems. The results suggested that a functional relation was established between the intervention package of explicit teaching and the Cuisenaire Rods app-based manipulative (Bouck et al., 2020).

Another single-subject design study scrutinized the impact of Video Self-Monitoring, delivered using a video iPad, on the learning attitude of a secondary school student diagnosed with ASD alongside intellectual disability comorbidity during science courses. The results showed effective treatment effects. The student augmented correct and voluntary academic replies. They continuously showed increases during conditions in which the interventions were made and decreases when interventions were removed, suggesting functional relations (Hart & Whalon, 2012). Some limitations were, however, suggested regarding the positive effects of application-related interventions.

To discuss the limitations of apps, Moon et al. (2020) asserted that it was not time yet to uphold the effectiveness of Apps, although numerous investigations are displaying promise for the treatment of children with ASD through apps. In the same vein, Allen et al. (2016) conducted a review of the literature and supported the view, from a strict perspective, that electronic platforms do not provide better intervention than traditional books that include pictures. They suggested that integrating the demonstration of various cases into clinical and educational practices irrespective of apps such as picture-based PECS systems and iPad communication apps could enable the understanding of individuals with children with ASD. At the time when Vygotsky (1978) developed the concept of ZPD, technology as perceived, defined, and utilized today did not exist. The mediations were carried out by adults or more knowledgeable peers. A redefinition of ZPD or scaffolding is suggested that incorporates the concept of apps to adults and more knowledgeable peers, since it seems clear that technology has become part of humanity.

### **Limitations**

Regarding this study, as a whole, a few limitations were emphasized, including the data's single-subject design nature, suggesting that studies that investigated the effect of siblings, parents, peers, and apps using large sample sizes in group design or experimental studies were not included in this study on purpose. Another limitation can be the extent to which NAP is accepted as an effect size. Some studies suggest other types of effect sizes and do not accept NAP as such. Nevertheless, in Single-subject design research, NAP and the methods of Effect size computations are rigorous measures.

### **Conclusion**

Based on the above findings, the investigators highly recommend the creation of apps that can address the numerous needs of children diagnosed with ASD and other comorbidities. Normally developing children and adolescents, including school children, seem to like apps both in schools and homes. Children with ASD seem not to be different. Compared to human mediators such as siblings, peers, and even adults, apps seem to provide better help in socialization, communication, play, motivation, mathematics, living skills, modification/reduction of

ritualistic and unwanted behaviors, interactions, and imitation abilities. The list of the areas of intervention is not exhaustive. The creation and development of uniquely ASD-based technology can contribute significantly to the area of ASD, as a neurodevelopment disability that requires intensive, sometimes, long-lasting interventions, not as tools to completely replace siblings, adults, and peers but as complementary assistive technological devices. In addition to social support (Suleman, et al. 2024) that is needed to cope with the difficulties of neurodevelopmental disabilities, apps can provide both pleasure and improved treatment. No one should be left out of the interconnection of society that is currently facing the acute challenge of mental health. Effective mental functioning is deeply organized with both bodily and public active interconnection and health results (Hamid & Bhat, 2022).

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### **Conflict of Interest**

The author declares no conflict of interest.

### **Data Availability Statement**

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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