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Autism Spectrum Disorder and Face Identity Recognition Deficit across Ages

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The purpose of this review was to assess the face identity recognition deficit and the developmental difference that manifested in autism spectrum disorder (ASD) compared to their typically developing (TD) peers. Based on the meta-analysis using a random-effect model of 94 studies, with 144 effect sizes, for both adult and pediatric subjects with simultaneous and delayed face identity recognition paradigms, the underperformance in ASD was significant and persistent across ages. In addition, a higher level of deficit was found in adult ASD when performing simultaneous face-matching tasks while other subgroups showed homogenous effect sizes. This suggested a dissociation between the difficulties of the two mechanisms of face recognition: face perception (perceiving identity from the face with minimal memory load required) and face memory (recall of identity from the face that requires memory load), which was only shown in adults but not in children. The result indicated the possibility of using face identity recognition deficit as a diagnostic trait for ASD.

Autism spectrum disorder, or ASD, is a neurodevelopmental disorder with symptoms such as difficulties in social communication and social interaction, and restricted patterns in behaviors, interests, and activities (APA, 2022). According to the Centers for Disease Control and Prevention, around one in 44 children has a diagnosis of ASD, and the prevalence has been continuously increasing (CDC, 2022). When the concept of autism was first brought up in 1908 by Swiss psychiatrist Eugen Bleuler, it was considered a cognition and behavior style that occurs in patients with schizophrenia (Evans, 2013), and was recognized as childhood-type schizophrenia in the second version of Diagnostic and Statistical Manual of Mental Disorders, DSM-II (Kendhari et al., 2016). In DSM-III, published in 1980, autism was officially recognized and introduced as an isolated disorder of pervasive developmental disorders. The diagnostic criteria were further specified in the later revised version of DSM-III, DSM-III-R (Volkmar et al., 1988). In 1994, the fourth version of DSM specified autism as autistic disorder, Asperger's disorder, and pervasive developmental disorder, not otherwise specified (PDD-NOS), which were then all classified as autism spectrum disorders, ASD, in the current version of DSM (Harker & Stone, 2014).

Although diagnostic labels and criteria change drastically for ASD, the core deficit presented in the disorder remains the same. Impaired social cognition, debilitated communication skills, and ritualized behavior patterns are core deficits commonly occurring in ASD (Faras et al., 2010). These deficits are included in the diagnostic manual for ASD, for their potentially discriminative characteristics from other disorders, and can significantly impact daily functioning. Many aspects of manifestation of these deficits, including facial emotion recognition deficit (Uljarevic & Hamilton, 2013; Lozier et al., 2014; Keung, 2022), delay in language development (Mitchell et al., 2006; Landa & Mayer, 206; Eigsti et al., 2010), reading comprehension deficit (Norbury & Nation, 2010; Ricketts, 2013) and other impairment have been extensively studied. They have shown different underlying mechanisms and developmental trajectories for these shortfalls, but all contributed to the dysfunction of the disorder.

Face perception, which is an essential part of social interaction and communication, is an innate ability that occurs as early as 9 minutes after birth. It is defined as the ability to recognize, process, and integrate information from faces, which include direction of gazing, expression, identity, hostility, etc. (Ward & Bernier, 2013; Palermo & Rhodes, 2006). Disruption in the systems, or unsuccessful face processing, can elicit prominent changes in social behaviors in some psychiatric disorders including ASD (Lopatina et al., 2018). The social functioning deficit in people with diagnosed ASD may partially be explained by the impairment in face perception, which manifested as unsuccessful extraction of identification, emotion, and psychological information from faces during interpersonal interaction (Todorv et al., 2012). The manifestation of the deficit in face perception in the early stage of the face perception in ASD is the tendency of avoiding eye contact. This is also an early indication of children presenting symptoms of ASD, if they present an aversion to direct eye contact from caregivers and others. The avoidance of eye contact is also directly linked to socioemotional dysfunction in ASD (Kliemann et al., 2010). Two general models were proposed data on the face identity process. After duplicates were removed, full-text articles were screened for eligibility.

Inclusion Criteria

The inclusion for the final meta-analysis: a) is an empirical study published in English. b) included an ASD group with diagnosed ASD, autism, Asperger, or PDD-NOS. c) include a typically developing, chronological age-matched, comparison group. d) include data on participants' age. e) include a homogenous adult or pediatric group of participants or have separate data for different age groups (Categorization of adult and pediatric groups used an age cutoff of 18 years of ages). f) used static images with real human faces that are not the participants' own faces. g) include data on the types of tests performed, face identity recognition tasks or face identity discrimination tasks. h) reported accuracy data of participants' performance on the tasks.

Data Extraction

Data was extracted from every paper that satisfied the inclusion criteria, and all data were input onto Microsoft Excel sheets. Results for studies with adult or pediatric participants were recorded separately, but the categories of data extracted were the same as follows: a) Authors and year the article was published. b) demographic data of ASD and TD control groups, including sample size, gender distribution, mean age, and the standard deviation of age, Intelligence quotient, the standard deviation of IQ, and the diagnostic tool implemented. For studies that were carried out with multiple groups of participants, data were recorded independently and classified in accordance with their characteristics. c) Type of task implemented on face identity recognition or discrimination ability. The tasks implemented for each study were categorized into simultaneous or delayed categories. The simultaneous face identity recognition test, which is also categorized as the simultaneous face identity discrimination test, was a simultaneous match-to-sample test, in which, the target stimuli and test stimuli were presented simultaneously. This type of task was adopted in the widely used face identification task, Benton facial recognition test. The simultaneous match-to-sample task did not require memory load to perform an accurate matching of faces (Duchaine & Weidenfeld, 2002; Duchaine & Nakayama, 2004). On the other hand, a delayed match-to-sample task, which in Weigelt et al. (2013) and Griffin et al. (2021) was also identified as face discrimination, did require memory load and the amount of memory load required was directly related to the length of time delayed between the presentation of the stimulus (Anderson & Colombo, 2019). Therefore, the rationale behind the categorization was the requirement of memory load. The simultaneous task demanded no memory load and the delayed task required at least some memory load to perform. Studies that used both types of tests were recorded individually in each section. d) Effect size of the difference in accuracy performance between ASD and TD groups. If effect sizes were not provided, statistical data required to calculate the standardized mean difference were extracted. Sample sizes, means, and standard deviations of behavioral results for both groups were extracted for calculating the effect sizes. If these data were not provided, inferential statistics of comparison between groups were collected to estimate effect size. For studies that performed multiple experiments, the data for each experiment was recorded separately based on their participants' characteristics or the type of task performed.

For studies that reported demographic information and performance results individually for each participant, the mean and standard deviation data were calculated manually for pediatric and adult participants groups. In some cases where neither the effect size nor specific data of results were textually available, but graphic representations of data were presented, the online application, WebPlotDigitizer was used to extract the necessary data. Numerous studies had shown consistent validity and reliability of numerical results extracted from graphic inputs using WebPlotDigitizer (Drevon et al., 2016; Aydin & Yassikaya, 2022).

The calculation of standardized mean differences was done manually by inputting equations with Excel functions. Most of the studies provided effect sizes in Cohen's d value as the standardized effect size. It has been noticed that Cohen's d values tend to overestimate the actual effect sizes when sample sizes are small. On the other hand, Hedges' g removes the bias with a correction factor. (Lin & Aloe, 2021; Durlak, 2009) Most studies included in the current meta-analysis did not have large sample sizes. Therefore, it might be prone to an upward bias if using Cohen's d for calculating the effect sizes. On the other hand, Hedges's g, which can easily be transformed from Cohen's d, was more reliable in the current meta-analysis. Therefore, for other studies that require manual calculation, Cohen's d values were first calcu lated and then transformed into Hedge's g together.

The formula for calculating the Cohen's d was (Cohen, 1998; Lipsey, 2001):

$$Cohen's\ d = \frac{\bar{x}_2 - \bar{x}_1}{\sigma_{pooled}} \quad (1)$$

where and were mean values and the pooled standard deviation, σ_{pooled} is calculated as:

$$\sigma_{pooled} = \sqrt{\frac{(N_1-1)\sigma_1^2+(N_2-1)\sigma_2^2}{N_1+N_2-2}} \quad (2)$$

where N_1 and N_2 are sample sizes, and σ_1 and σ_2 are standard deviations for each group. For studies that did not provide sample size, mean, or standard deviation, the equation used to convert values from f-test (3) or t-test (4) value to Cohen's d were (Thalheimer & Cook, 2002; Lipsey, 2001):

$$d = \sqrt{F\left(\frac{N_1+N_2}{N_1N_2}\right)} \quad (3) \qquad d = t\sqrt{\frac{(N_1+N_2)}{N_1N_2}} \quad (4)$$

After all Cohen's d were calculated, the calculated effect sizes were then converted into Hedges' g value, along with the provided Cohen's d effect sizes. The conversion formula used was (Hedges, 1981; Borenstein et al., 2011):

$$g = d\times\left(1 - \frac{3}{4(df)-1}\right) \quad (5)$$

Where df = $N_1 + N_2 - 2$. The standard errors of Hedges' g (6; Hedges, 1981; NIST, 2018) were calculated for further analysis:

$$g_{se} = \sqrt{\frac{N_1+N_2}{N_1N_2} + \frac{g^2}{2(N_1+N_2)}} \quad (6)$$

Risk of Bias Evaluation and Quality Assessment

An evaluation matrix of the studies' design and methodology was adapted from previous meta-analyses (Griffin et al., 2021; Yeung, 2022; Tang et al., 2015). For every study, their evaluations were based on the quality of participants' selection procedures and the characteristics of the instruments implemented. For assessing the reliability of the sample subjects representing the intended target population, the demographic characteristics were assessed and compared to ensure the result performance data extracted were a representation of the group difference with minimal mediation from other properties. Whether data on participants' age, gender, and IQ were provided for both ASD and TD groups, and whether these characteristics are matched to control for effects that can potentially bias the result, were significant determinants of the studies' quality.

On the other hand, aside from many established tests targeting face identity recognition measurement: CFMT (Cambridge Face Memory Test), Benton Facial Recognition Test, NEPSY-II (Developmental Neuropsychological Assessment, Second Edition), face subtest, etc., many studies developed their own testing procedures evaluating the performance. Within established tests, the materials used and courses of action varied largely from each other. There was not a general consensus on which test was best in reliability and validity in rating the identity recognition ability specified in the ASD population (Duchaine & Weidenfeld, 2002; Albonico et al., 2017). However, some material characteristics were preferred that tend to be more consistent in conveying reliable results. Compared to black-and-white, or grayscale photos of faces, colored photos had been shown to carry more information that was not related to faces. For instance, when photos of faces were presented in color, chunking areas of faces according to different tones or shades became possible. Instead of remembering and recognizing a person's face from their facial features, the mechanism then became remembering patterns of color segments (Bindemann & Burton, 2009; Yip & Sinha, 2010; Bobak et al., 2019). Similarly, photos of full faces, including hair and clothing, provided excessive information that was not related to facial features when testing the identification ability. More significantly, when subjects were not able to extract sufficient information from facial features alone, they were more likely to rely on external information, hairstyle, brow shapes, etc (Duchaine & Weidenfeld, 2003). In addition, different facial expressions also were shown to impact identity recognition (Chen et al., 2015). With the ASD population, whose recognition of facial affect is impaired, the ambivalent effect can lead to biased results. Therefore, for achieving consistent reliable results, the method implemented with grayscale photos of inner face features alone with neutral expression was preferred. The evaluation is done in rating format. Each criterion is marked as one point for each study on whether it provides the necessary information for each criterion. The study's quality is the sum of scores on each criterion and the maximum quality score is 12 points.

Statistical Analysis

With the calculated Hedges's g and standard error of Hedges's g value, the data were input into SPSS v. 28 for meta-analysis. Analysis was performed using a random effect model with the Hunter-Schmidt method (Hunter & Schmidt, 1990). Fixed-effect model hypothesized a universal effect size for all studies and proposed a similar methodology across studies in the meta-analysis (Field & Gillett, 2010). On the other hand, the random-effect model assumed that every study estimated a different inherent relation and appraised both between-study and within-study variability (Kock, 2009; Tufanaru, 2015). The Hunter-Schmidt method is a method using a random-effect model and it was shown to produce the most accurate and reliable estimates when heterogeneity exists in effect sizes (Cornwell & Ladd, 1993; Field, 2001). In addition, forest plots and funnel plots were produced with SPSS plotting functions for meta-analysis. Forest plots provide a vivid visual representation of the overall effect of the meta-analysis and effect size of individual studies used to generate the results. The meta-analyses were performed in accordance with these procedures.

First, an overall meta-analysis of every study was performed to estimate the difference in accuracy performance on face identity recognition between ASD and TD populations. Random-effect meta-analysis was performed with all data included and forest plots were produced. In addition, evaluation of heterogeneity and homogeneity were carried out to inspect the variability across studies. Furthermore, an assessment of publication bias was also implemented to further specify and solidify the results.

Then, a meta-analysis of studies within each age group and a comparison of results across ages were inspected. Similar procedures that were executed for evaluating the overall effect size were performed for the pediatric group and the adult group. The comparison between groups was assessed with an estimation of the homogeneity of the two groups as a subgroup analysis of the overall effect. Additionally, subgroup analyses of methodology effects within each age group were performed. This analysis examines whether the two kinds of face perception, with and without memory load, show different performance between ASD and TD at different age stages.

On the other hand, a hypothesis by Weigelt et al. (2013) was tested. Weigelt et al. (2013) proposed that face identity recognition deficit in ASD was specific to face memory deficit, in which the higher demands in memory load would lead to worse performance in ASD. For tests that did not require face memory, the performance between ASD and TD should be the same. Even though Griffin et al. (2021) had shown results opposite to this hypothesis, Griffin et al. (2021) studies examined the difference between face identity recognition and face identity discrimination tasks. The divergence between these two tasks was not clearly defined in either the Weigelt et al. (2012) or Griffin et al. (2021) study. As mentioned in Tang et al. (2015), the definition of face discrimination was ambiguous. Therefore, a dichotomy classification was used to be more robust and specific.

Evaluation of Publication Bias

To evaluate potential publication bias, a funnel plot and Egger's regression were used. A funnel plot is a visual representation of comparing the sizes of trials to their effect size. Usually, studies without publication biases would produce a plot that is symmetric and shaped like a funnel. If the resulting plot was significantly asymmetric, this indicated a potential publication bias (Lee & Hotopf, 2012; Simmonds, 2015). Interpretation from graphics alone can be unreliable so egger's test is also used. Egger's regression test is a test based on a linear regression model comparing the intercept, which evaluates the asymmetricity of the funnel plot. Egger's test examines the hypothesis of zero linear intercept, which represents a symmetric funnel plot with no publication biases (Egger et al., 1997).

Results

Study Selection

The literature selection and screening process was shown in the flow diagram, Figure 1. An initial database and references search gave 7,432 results, including 1,975 from PubMed, 5,345 from PsycINFO, and 112 from Griffin et al. (2021) references list. With the PsycINFO filter, 299 articles that were not written in English and 1,151 articles that were not empirical research studies were removed. Then, a total of 5,602 studies were eliminated because they did not include information on ASD or face processing. After removing 82 duplicate papers, 298 unique papers related to autism spectrum disorder and face processing were reviewed in full-text screening. 204 papers, in total, were eliminated based on inclusion and exclusion criteria: a) 15 articles were not empirical research papers. b) 30 papers were not studying face processing in the ASD population or did not include participants with diagnosed ASD. c) 13 studies did not have a comparison group or did not compare to the typically developing population. d) Seven papers did not provide informa tion on participants' age range, and e) 19 papers have a heterogenous age that include a mix of adult and pediatric participants. f) Six studies did not use static real human faces, whereas three studies studied self-recognition. i) 114 studies involved face processing in ASD but did not include behavioral results concerning their face identity recognition or discrimination ability.

A total of 94 studies satisfied all the inclusion criterias and were included in current meta-analysis, with 4,849 total number of individual participants, 2,351 with ASD and 2,498 TD comparisons. The general characteristics of participants in the 94 studies are shown in Table 1. The overall average age of pediatric ASD participants was 10.99 (*SD*=2.51), and pediatric TD participants with mean age of 10.64 (2.93). The mean age between the ASD and TD groups did not differ significantly; $t(144)=0.768$, $p=.444$. The overall mean age of adult ASD participants was 28.48 (*SD*=4.6), ranging from 20.60 to 43.2; the mean age for adult TD subjects was 28.19 (*SD*=4.52), with a range of 21.6 to 44. The mean ages between the two groups did not differ significantly; $t(58)=0.249$, p=.8041.

Studies were also categorized based on the test characteristics, either a delayed design or a simultaneous presentation design. The number of studies with different characteristics is shown in Table 2.

Overall Face Identity Recognition Ability

First, the overall difference in face identity recognition was evaluated. Meta-analysis was performed with a total of 94 papers and 144 pairs of results of effect size between ASD and TD. All results were included to assess the overall difference in facial identity recognition ability between the ASD and TD groups. Of the 144 effect sizes from studies, 17 reported a positive effect size, which indicates a comparatively higher performance in ASD than the TD control group. In addition, three studies reported an effect size of 0, which indicated an equal level of performance between the two subject groups. All other 124 results showed a lower level of performance in ASD subjects than in TD control subjects.

Figure 3 shows the forest plot representing the result of a random-effect meta-analysis on overall face Identity Recognition ability in ASD. The results show a large overall effect size, Hedges's $g = -.716$, 95% CI [- .835, - .597], $p<.0001$. Indicating a significant overall deficit in ASD population on face identity recognition.

On the other hand, the heterogeneity measures of all 144 effect sizes from the studies show a significant heterogeneity, $\tau^2= .405$, $I^2 = .803$. The homogeneity test also confirmed the variances between the studies' effect sizes, $Q(143) = 731.35$, $p = .00$. These results show a large heterogeneity in effect sizes. In addition, the I^2 result confirmed that 80.3% of variances can be attributed to the heterogeneity of studies.

The funnel plot in Figure 2 shows the studies are roughly symmetrical, which indicates no potential publication bias. In addition, Egger's regression-based test also confirmed the absence of biases with an intercept of 0.325, 95% CI [-0.151, 0.8], $t = 1.348$, $p=.180$.

Face Identity Recognition in Adult Samples

A total of 39 studies from 30 papers, with statistics from total sample sizes of 1316 participants, were included in the random effect meta-analysis on the adult group. The resulting overall negative effect size on face identity recognition performance between ASD and TD, Hedges' $g = -.753$, showed a significant deficit in the identification ability in ASD subjects. Figure 4 showed the forest plot displaying the effect sizes of each study, which presented an overall lower performance in ASD than in TD. Furthermore, subgroup analysis on the type of test performed were also included. The statistics and visual representations in the forest plot both indicated an outstanding negative effect size. Hedges' $g= -.753$, 95% CI [-.931, -.575], $p<.0001$.

Heterogeneity tests indicated a substantial variation in effect sizes between studies. $\tau^2 = .211$, $I^2 = .682$. The test of homogeneity also confirmed the disparity. $Q(38)= 123.499$, $p<.001$. The I^2 connoting 68.2% of heterogeneity explained by studies' differences was lower than the overall heterogeneity in data with both children and adult data. Egger's regression test of intercept = 0.070, 95% CI [-0.774, 0.915], $p=.867$, which suggested a high level of robustness.

In addition, consistent results were shown in subgroup analysis for both delayed and simultaneous tests. Of the 39 studies' results, 29 studies were performed with delayed recognition tasks, and 10 studies were implemented with simultaneous designs. Heterogeneity testing indicated that for both categories classified based on test procedure, the heterogeneity between studies was on a similar level. For delayed tests, $\tau^2 = .185$, $I^2 = .678$; for simultaneous design, $\tau^2 = .308$, $I^2 = .674$, which both indicated a high level, 67.8% and 67.4% of heterogeneity from variation between studies. However, publication biases were not significant in either design. For delayed tests, in tercept = -0.451, 95% CI [-1.457, 0.555], p=.366; for the simultaneous test, intercept = 2.036, 95% CI [-0.591, 4.664], *p*=.112. Therefore, no studies were excluded from the analysis. Figure 5 presented a funnel plot image for all studied among adult participants, and different methodologies used were labeled with different colored dots.

For studies with adult samples and implemented delayed identity recognition tests, the overall Hedge's g effect size was -.697, 95% CI [-.891, -.504], p<.001. For studies with simultaneous design methods, the overall effect size was Hedges' *g* = -.954, 95% CI [-1.377, -.531], *p*<.001. Although the overall effect size for the simultaneous test, *g*=-.954, was larger than the delayed test, *g*=-.697, the Homogeneity test between these two subgroups shows an insignificant effect, *Q*(1)=1.17, *p*=0.28. On the other hand, both significantly negative effect sizes results suggested a deficit in both delayed and simultaneous face identity recognition ability in adult ASD compared to typically developing controls.

Face Identity Recognition in Children Samples

A total of 66 papers with 104 studies of children were included in the random-effect meta-analysis for identity recognition performance difference between ASD and TD. The overall result showed a similar level of effect sizes to the overall effect size with adult subjects. Hedges' *g*= -.701, 95% CI [-.851, -.551], *p*=.000. A subgroup analysis comparing homogeneity of overall effect sizes between ASD and TD for adult and children subjects showed *Q*(1)=.187, *p*=.666. This result indicated no significant difference between the distribution of the two subgroups, children and adults.

In addition, Egger's regression test showed a large but insignificant publication bias. Intercept = 0.43, 95% CI [-0.15, 1.011], *p*=.144. On the other hand, similar to prior results, the heterogeneity across studies included in the analysis was still pronounced. The resulting funnel plot is also shown in Figure 7. Heterogeneity measures show an overall 82.6% of heterogeneity from variation between studies. τ^2 = .482, I^2 = .826. The Homogeneity measure also confirmed the significance. *Q*(103)=601.67, p=.000. Figure 6 displayed all effect sizes included in the analysis for the children subject group.

Although publication was not significant in the overall analysis of studies, when subgroup analyses were performed for studies implementing delayed and simultaneous design within the children group, the publication bias estimated by Egger's Regression test predicted a high likelihood of publication bias in the delayed condition, intercept=0.598, 95% CI [-0.067, 1.263], *p*=.07. The result is not statistically significant with *p*=.05, but the borderline significant result indicated a high likelihood of effect of biases from extreme data. After eliminating five sets of data with extreme effect sizes, the possibility of publication bias became minimal and thus the results were more robust and funnel plots are symmetric. Figure 8 displayed the funnel plots before and after extreme data were removed. For delayed groups, Intercept = 0.141, *p*=.65; for simultaneous group, intercept = -0.349, *p*=.55; and for all studies with children, intercept = 0.005, *p*= .987.

The resulting heterogeneity measures were smaller but still significant. For overall effect: τ^2 = .281, I^2 = .742; delayed condition: τ^2 = .283, I^2 = .75; simultaneous condition: τ^2 = .273, I^2 = .715. The estimated effect sizes for both conditions are similar and all negatively significant. For the delayed face recognition condition, the effect size was Hedges' *g* = -.628, 95% CI [-.776, -.48], *p*=.000. For the simultaneous condition, the hedge's g effect size was -.607, 95% CI [-.837, -.377], p<.001. The results indicated a noticeable shortfall in face identity recognition in children with ASD compared to TD regardless of memory load requirement of tests, delayed or simultaneous. The subgroup homogeneity test also provided the result that the distribution of performance for delayed and simultaneous conditions was highly similar. *Q*(1)=0.022, *p*=.881.

Furthermore, after removing extreme effect sizes, the evaluated effect size of overall performance for children became slightly less negative. Hedges' *g* = -.622, 95%CI [-.746, -.498], *p*=0.000. Additionally, the result for subgroup homogeneity tests between children and adult subgroups, although still insignificant, decreases, indicating a lower level of similarity of distribution across the two groups. *Q*(1) = 1.393, *p*=.238. Therefore, although removing outlier data increased the robustness of studies data included in the analysis, it did not change the overall underperformance in children with ASD, or the homogeneity in results between children and adult subgroups.

Additional Analysis

Meta-regression analysis weighting the mean age of each study on the heterogeneity of performance for overall result data, and for delayed and simultaneous identity recognition tasks showed small mediating effects. The largest mediating effect observed was in simultaneous design where of the 71% of heterogeneity, the mean age of participants could account for 3.2% of the variation.

In addition, subgroup analysis was performed on assessing the difference of age groups in different methodology groups. The homogeneity test of studies with children and adult subjects on simultaneous face identity recognition test gave the result, $Q(1)=1.998$, $p=.157$. The test on the homogeneity of studies for both groups on the delayed face identity recognition test resulted in, $Q(1)=0.100$, $p=.752$.

Discussion

The current study examined facial identity recognition ability in Autism Spectrum Disorder, ASD, whether there were changes across developmental stages, and whether there was a difference depending on specific aspects of face recognition. The result from the meta-analysis indicated an overall underperformance in face identity recognition in ASD compared to typically developing control and the deficit was significant.

The overall effect size (Hedges' g = -.716) presented a significantly lower performance in the ASD group on identifying faces. For studies that were performed with adult subjects or children participants, the deficits were consistent in both groups. The effect sizes for adult and children groups respectively were Hedges' g = -.753, and Hedges' g = -.622. Both indicate a significant underperformance in ASD children and adults compared to their TD control. Although the effect size for adults was larger than the effect size for the children's group, which represented a higher level of deficit in the adult population than in children, the homogeneity test shows insignificant results. Therefore, the difference between the results cannot be statistically interpreted as a noticeable change across ages.

Additional subgroup analysis on the interaction between age group and type of test showed a variation in effect size between delayed and simultaneous tests in adult samples but not in children. In addition, only the effect size of performance on simultaneous identity-matching tasks in adults was considered to present a large effect size with Hedges' g = -.954 (Cohen, 1998). The effect sizes showing underperformance in other interactive groups showed similar results, which indicates an indistinguishable level of deficits.

The general result of an overall deficit in ASD compared to TD was consistent with results found in most research studies and concluding remarks from the prior meta-analysis (Weigelt et al., 2012; Tang et al., 2015; Griffin et al., 2021). Of the 144 pairs of effect sizes data extracted from 94 studies for the current meta-analysis, 20 results found either no difference or slightly better results in performance in the ASD group. The differences in findings can be a mixed effect from the differences in the subject's selections and disparity in the quality of the experimental paradigm adopted by the studies. On the other hand, majorities of the studies concluded a deficit in ASD face recognition performance, which is also aligned with results from the current meta-analysis. The consistent deficit suggested a case of developmental prosopagnosia that can potentially be considered as an endophenotype of ASD. There have been continual reports of cases of patients with ASD having difficulties in face recognition (Kracke, 2008; Pietz et al., 2007). In addition, subsets of patients with developmental prosopagnosia also present significant levels of autistic traits (Minio-Paluello et al., 2020; Cook et al., 2015). Therefore, research may need to consider this co-occurrence of the two disorders and potentially the face recognition deficit as an intermediate phenotype of ASD.

Subgroup analysis revealed subtle development changes in performance, which suggested a persistent deficit in face recognition in ASD across ages. The difference in effect sizes occurred only in adults on simultaneous face- matching tasks rather than delayed face recognition tasks, but was not found in children samples, which implied an isolated face perception and face recognition in adults but not in children. This difference could potentially explain the contraction found in the results for Weigelt et al. (2013) and Griffin et al. (2021). Weigelt et al. (2013) initially proposed the deficit depended on memory demand, and Griffin et al. (2021) challenged the hypothesis by showing a significant deficit in both face discrimination and face recognition tasks. Since most studies investigating ASD deficits were performed in children, the overall results with systematic studies would likely present persistent results since ASD children showed constituent deficits across tasks. Although the deficit persists on average, the underlying mechanism of performance differs across ages. Similar results were presented in studies on developmental prosopagnosia, which presented a dissociation in performance between face perception and face memory in adults but not in children (Dalrymple et al., 2014). In addition, studies in typically developing populations on simultaneous face identity match-to-sample tasks also indicate a decrease in accuracy performance as age increases (Megreya et al., 2015; Schretlen et al., 2001).

On the other hand, the limitations of the accuracy of results for the current meta-analysis also need to be considered. The majority of studies on ASD were conducted with children for it is a neurodevelopmental disorder. The drastic modification of diagnostic criteria of ASD also made the selection and classification of ASD participation complicated. Of the 144 studies included, only 39 studies data were performed on adult participants, and only 10 pairs of data were assessing the simultaneous face-matching ability in adult ASD. With a limited number of studies, the high effect size for adults on simultaneous tasks may be biased. In addition, the difference in studies results can also contribute to heterogeneities in studies results. For future studies, the implementation of a random-effect size model is necessary since the heterogeneity in studies was substantial. A possible resolution can be the inclusion of single design studies in the inclusion criteria, for instance, using only CFMT or Benton for assessing face memory and face perception. However, these limiting criteria would be prone to having a minimal sample size. Therefore, for future research studies, there should be a consideration of the material and procedure used to perform the studies to have reliability and validity across studies and populations. Another limitation of this study was that the study process, including literature search, review, and meta-analysis, was done by the author alone so the inter-reviewer reliability was not assessed for the current study.

Conclusion

Overall the result was significant in that ASD presented a significantly lower level of accuracy in face identity recognition than their typically developing peers. In addition, the deficit persists across age, which may imply potential comorbidity of ASD and developmental prosopagnosia. Nevertheless, the difference in results from the subgroups analysis showing a difference in performance on simultaneous face matching tasks and delayed face recognition tasks indicated a dissociation between face perception and face memory that was only manifested in adults but not children with ASD. However, more studies focusing on the adult ASD population is necessary to specify the mechanism of this divergence. In general, studies on face identity recognition ability in ASD should consider these factors when deciding on the studies' participants and materials.

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Table 1

Demographic Characteristics of the Studies Included in the Current Meta-Analysis

Group	*N*	ASD		TD	
		N	Age(Std)	*N*	Age(Std)
Children	66	1701	10.99(2.51)	1832	10.64(2.93)
Adult	30	650	28.48(4.60)	666	28.19(4.52)
Total	96*	2351		2498	

Note. ASD = Autism Spectrum Disorder; TD = Typically Developing; *N* = Number; Std = standard deviation.

* = Two studies had both adult and children participation groups and were included in both categories.

Table 2

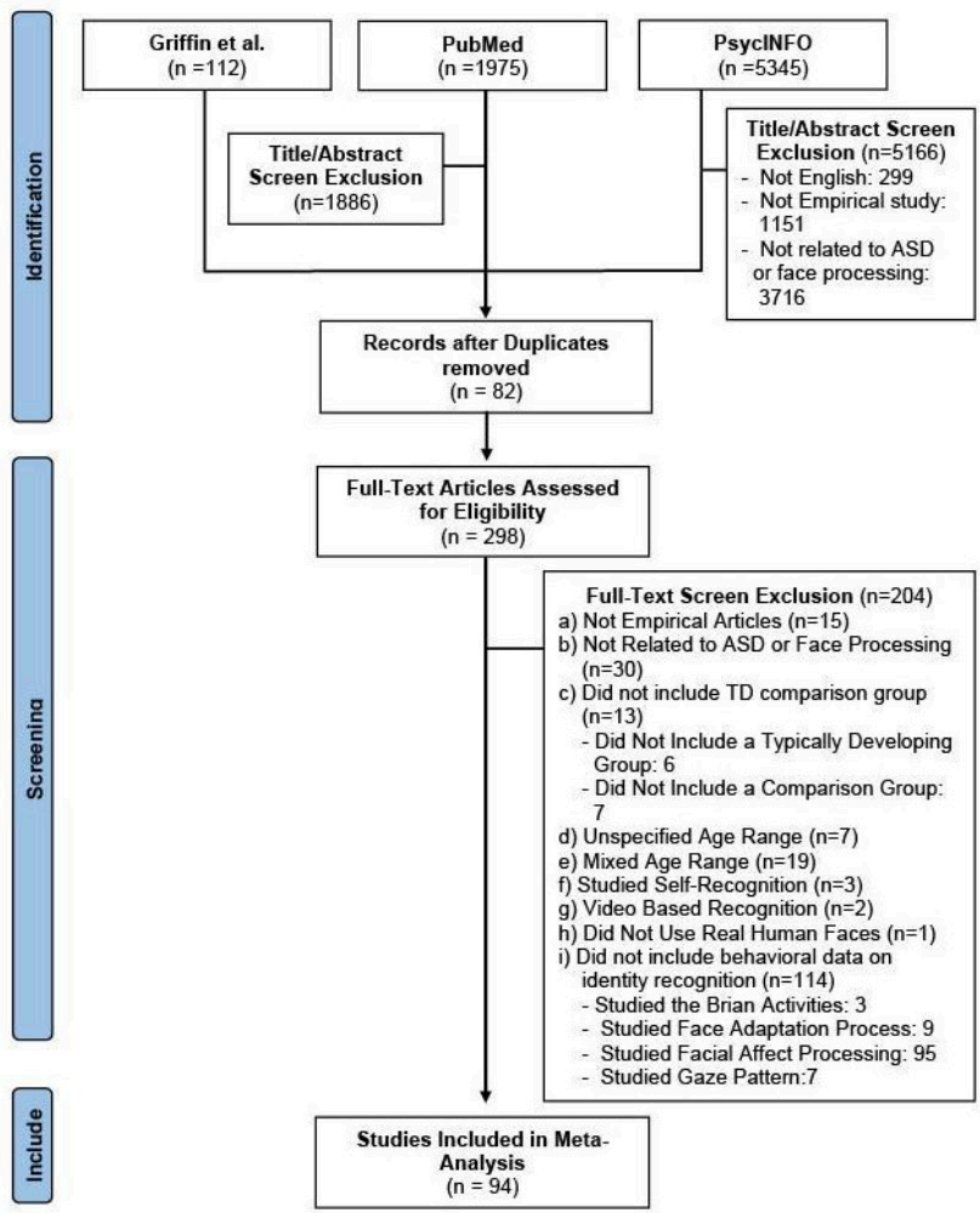
Design Characteristics of Studies Included in the Current Meta-Analysis

Design	*N*	Children	Adult
Delayed	71	48	23
Simultaneous	25	18	7

Note. The number indicates the number of studies in each category.

Figure 1

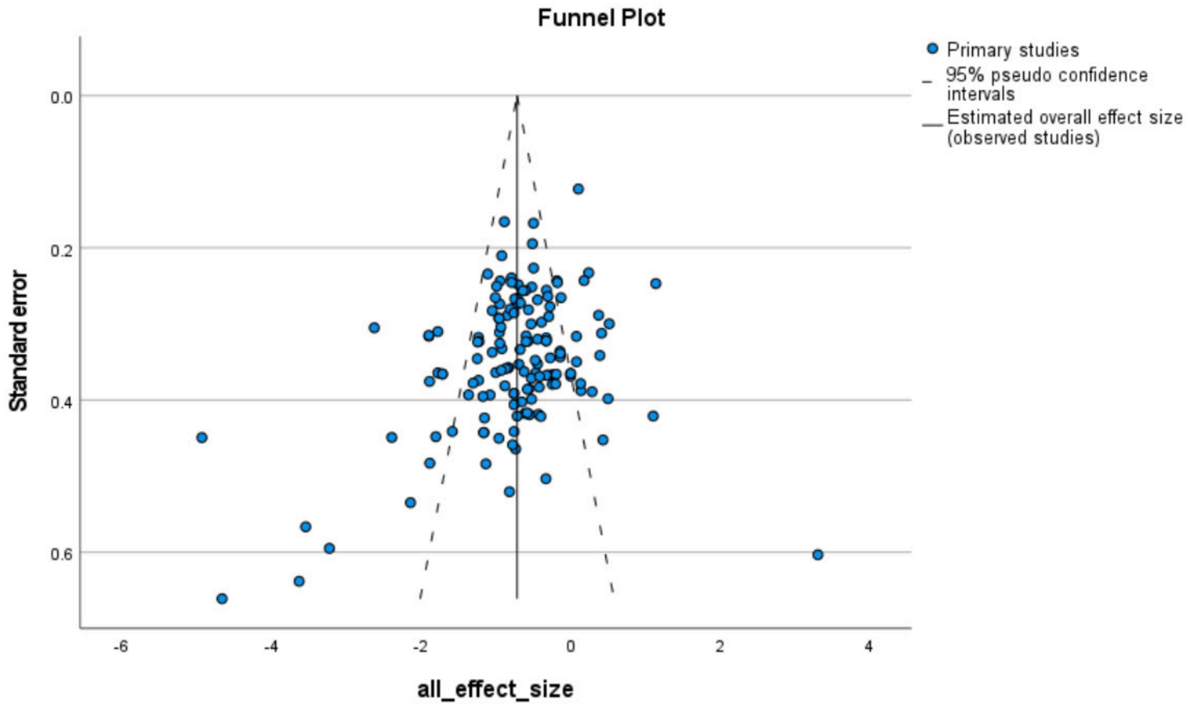
PRISMA 2020 Flow Diagram Showing the Literature Identification and Screening Process



Note. ASD = Autism Spectrum Disorder; TD = Typically Developing.

Figure 2

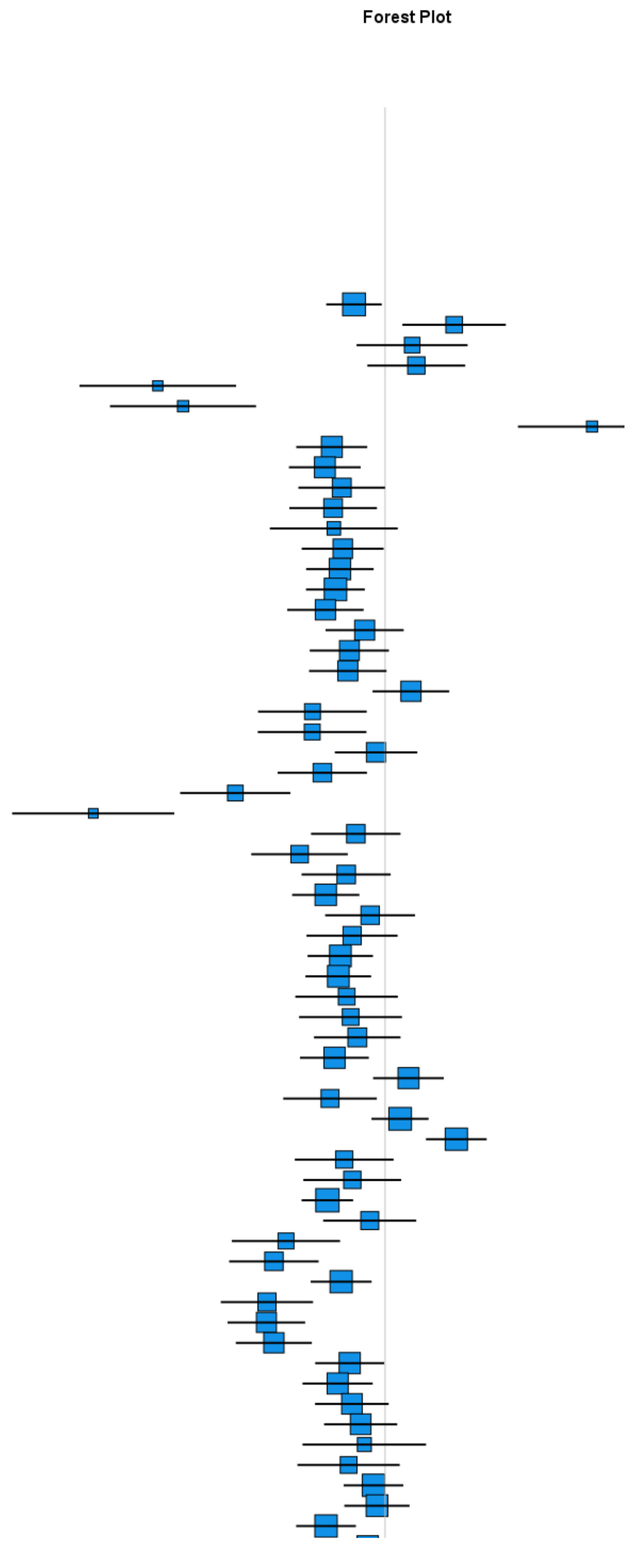
Funnel Plot of Effect Sizes of all Studies over Standard Errors for Overall Face Identity Recognition



Note. Egger's linear regression test result of t = 1.348, p = .180 indicated overall symmetricity of all studies used in the current meta-analysis.

Figure 3

Forest Plot of the Overall Effect Size of Face Identity Recognition Ability Difference Between ASD and TD Groups



ID	Effect Size	Lower	Upper	Weight	Weight (%)
Barron-Linnankoski et...	-0.50	-0.94	-0.05	2.19	0.80
Campbell et al._2006	1.10	0.28	1.93	1.72	0.63
Celani et al_1999	0.43	-0.45	1.32	1.64	0.60
Chien et al._2014	0.50	-0.28	1.28	1.78	0.65
	-3.63	-4.88	-2.38	1.23	0.45
	-3.23	-4.39	-2.06	1.32	0.48
	3.31	2.12	4.49	1.30	0.48
Corbett et al._2014	-0.85	-1.42	-0.28	2.05	0.75
	-0.96	-1.53	-0.39	2.04	0.75
de Gelder et al._1991	-0.69	-1.38	0.00	1.89	0.69
	-0.83	-1.53	-0.13	1.88	0.69
Ewing et al._2018	-0.82	-1.84	0.20	1.48	0.54
Ewing et al._2013	-0.68	-1.33	-0.02	1.94	0.71
Hauck et al._1998	-0.72	-1.26	-0.18	2.08	0.76
Hedley et al._2011	-0.79	-1.26	-0.32	2.16	0.79
Hooper et al._2006	-0.95	-1.56	-0.34	1.99	0.73
Joseph et al._2008	-0.33	-0.95	0.30	1.98	0.72
	-0.57	-1.20	0.06	1.97	0.72
Joseph & Tanaka_2003	-0.60	-1.21	0.02	1.98	0.73
	0.41	-0.20	1.03	1.99	0.73
Key & Corbett_2014	-1.16	-2.03	-0.29	1.67	0.61
	-1.16	-2.03	-0.30	1.66	0.61
Li et al._2017	-0.14	-0.80	0.52	1.93	0.71
López et al._2004	-1.00	-1.71	-0.29	1.86	0.68
	-2.39	-3.27	-1.51	1.65	0.60
	-4.66	-5.96	-3.36	1.19	0.44
López et al._2008	-0.47	-1.18	0.25	1.86	0.68
McPartland et al._2011	-1.36	-2.14	-0.59	1.79	0.65
	-0.62	-1.33	0.09	1.87	0.68
Narzisi et al._2013	-0.95	-1.48	-0.41	2.09	0.76
Planche & Lemonnier_2012	-0.24	-0.96	0.48	1.86	0.68
	-0.53	-1.25	0.20	1.84	0.68
Reinvall et al._2013	-0.71	-1.24	-0.19	2.10	0.77
	-0.75	-1.27	-0.22	2.10	0.77
Rhodes et al._2014	-0.61	-1.43	0.21	1.73	0.63
Rhodes et al._2015	-0.55	-1.37	0.27	1.72	0.63
Rose et al._2007	-0.44	-1.13	0.25	1.89	0.69
Sanna et al._2011	-0.81	-1.36	-0.26	2.07	0.76
	0.37	-0.19	0.94	2.05	0.75
Scherf et al._2015	-0.88	-1.63	-0.13	1.82	0.67
Serra et al._2003	0.24	-0.22	0.70	2.18	0.80
	1.14	0.65	1.62	2.15	0.79
Tessier et al._2015	-0.65	-1.44	0.14	1.76	0.65
	-0.52	-1.30	0.26	1.77	0.65
Weigelt et al._2013	-0.92	-1.33	-0.51	2.23	0.82
Whyte et al._2016	-0.24	-0.99	0.50	1.82	0.67
Wilson et al._2010	-1.58	-2.45	-0.72	1.67	0.61
Wilson et al._2010	-1.77	-2.49	-1.06	1.86	0.68
Wilson et al._2011	-0.70	-1.19	-0.21	2.14	0.79
Yi et al._2013	-1.89	-2.62	-1.15	1.83	0.67
Yi et al._2016	-1.89	-2.51	-1.28	1.98	0.73
	-1.78	-2.38	-1.17	2.00	0.73
Fedor et al._2018	-0.56	-1.12	-0.01	2.07	0.76
	-0.76	-1.32	-0.20	2.06	0.75
	-0.53	-1.12	0.06	2.02	0.74
	-0.39	-0.97	0.19	2.03	0.74
O'Hearn et al._2010	-0.33	-1.32	0.66	1.52	0.56
	-0.58	-1.40	0.23	1.73	0.63
Guy et al._2017	-0.18	-0.66	0.29	2.16	0.79
Falker et al._2016	-0.13	-0.65	0.39	2.10	0.77
Greimel et al._2014	-0.94	-1.42	-0.47	2.16	0.79

Hanley et al._2020	-0.28	-0.82	0.27	2.08	0.76
	-0.18	-0.66	0.30	2.15	0.79
Jiang et al._2015	-1.05	-1.71	-0.39	1.93	0.71
Lajiness-O'Neill et al...	-1.88	-2.83	-0.94	1.57	0.57
Oerlemans et al._2013	0.10	-0.14	0.34	2.38	0.87
Robel et al._2004	-0.60	-1.23	0.04	1.96	0.72
	-0.92	-1.57	-0.27	1.94	0.71
Southwick et al._2011	-1.11	-1.57	-0.65	2.18	0.80
wilson et al._2012	-2.14	-3.19	-1.09	1.45	0.53
wilson et al._2007	-0.84	-1.54	-0.14	1.88	0.69
	-0.47	-1.15	0.21	1.90	0.70
Zaki & Johnson_2013	-0.32	-0.82	0.18	2.13	0.78
Tehrani-Doost et al._2012	-0.30	-1.02	0.42	1.85	0.68
	-0.19	-0.91	0.52	1.86	0.68
Ewing et al._2013	-4.93	-5.81	-4.05	1.65	0.60
Parish-Morris et al._2013	-0.51	-0.89	-0.13	2.26	0.83
Herrington et al._2015	-1.08	-1.85	-0.31	1.79	0.65
	0.00	-0.72	0.72	1.85	0.68
Deruelle et al._2004	-0.76	-1.62	0.11	1.67	0.61
Song & Hakoda_2012	0.08	-0.61	0.76	1.90	0.70
Ewing et al._2013	-2.62	-3.22	-2.03	2.01	0.74
Rondan et al._2003	-0.76	-1.53	0.01	1.79	0.66
Pierce & Redcay_2008	-0.96	-1.84	-0.08	1.65	0.60
Krebs et al._2011	-0.29	-0.86	0.28	2.05	0.75
Davies et al._1994	-1.13	-2.08	-0.18	1.57	0.57
	-0.74	-1.65	0.17	1.61	0.59
	0.14	-0.62	0.90	1.80	0.66
	0.29	-0.48	1.05	1.80	0.66
Riby et al._2008	-0.44	-1.07	0.19	1.97	0.72
	0.08	-0.54	0.70	1.98	0.73
Rosset et al._2010	-0.14	-0.81	0.53	1.91	0.70
Tehrani-Doost et al._2012	-0.32	-1.04	0.40	1.85	0.68
	-0.42	-1.14	0.31	1.85	0.68
Leonard et al._2011	-1.23	-1.86	-0.61	1.98	0.72
Dimitriou et al._2015	-0.33	-0.96	0.30	1.97	0.72
	-1.71	-2.43	-1.00	1.86	0.68
Yerys et al._2018	-0.44	-0.97	0.08	2.10	0.77
Ozonoff et al._2990	0.13	-0.61	0.88	1.83	0.67
	-0.20	-0.94	0.54	1.82	0.67
	-0.76	-1.55	0.04	1.76	0.64
	-1.15	-1.98	-0.32	1.71	0.63
Herrington et al._2016	-0.50	-0.83	-0.17	2.31	0.85
Annaz et al._2009	-0.33	-0.96	0.30	1.97	0.72
	-1.71	-2.43	-1.00	1.86	0.68
Borowiak et al._2020 [1]	-0.87	-1.57	-0.17	1.87	0.69
Borowiak et al._2020 [2]	-0.93	-1.64	-0.22	1.87	0.68
Churches et al._2012	0.00	-0.72	0.72	1.86	0.68
Dwyer et al._2019	-0.52	-1.01	-0.03	2.14	0.78
Ewbank et al._2017	0.00	-0.72	0.72	1.86	0.68
Hedley et al._2012	-0.60	-1.11	-0.10	2.13	0.78
Ipser et al._2016	-1.25	-1.93	-0.57	1.91	0.70
Kirchner et al._2011	-0.95	-1.58	-0.31	1.96	0.72
Minio-Paluello et al._...	-0.89	-1.21	-0.56	2.31	0.85
Oruc et al_2018	0.18	-0.30	0.66	2.16	0.79
Reed et al._2007	-0.43	-1.25	0.39	1.72	0.63
Schelinski et al._2014	-0.56	-1.31	0.20	1.81	0.66
Schelinski et al._2017	-1.17	-1.95	-0.40	1.78	0.65
Sterling et al._2008 [1]	-0.14	-0.80	0.53	1.93	0.71
Sterling et al._2008 [2]	0.39	-0.28	1.06	1.92	0.70
Walsh et al._2016	0.52	-0.07	1.10	2.02	0.74
Fedor et al_2018 [1]	-1.22	-1.86	-0.59	1.96	0.72
Fedor et al_2018 [2]	-1.24	-1.88	-0.61	1.96	0.72
O'Hearn et al._2010	-1.80	-2.68	-0.92	1.65	0.60
Blair et al._2002	-0.71	-1.54	0.11	1.72	0.63
Faja et al._2009 [1]	-0.99	-1.48	-0.50	2.14	0.78
Faja et al._2009 [2]	-0.79	-1.27	-0.31	2.15	0.79
Falker et al._2010	-0.93	-1.53	-0.34	2.01	0.74
Hedley et al._2015 [1]	-1.90	-2.51	-1.28	1.98	0.73
Hedley et al._2015 [2]	-0.31	-0.82	0.21	2.11	0.77
Webb et al._2010 [1]	-1.05	-1.60	-0.49	2.06	0.76
Webb et al._2010 [2]	-0.67	-1.21	-0.14	2.09	0.76
Webb et al._2012 [1]	-1.01	-1.53	-0.49	2.11	0.77
Webb et al._2012 [2]	-0.64	-1.14	-0.14	2.13	0.78
Humphreys et al._2007	-0.78	-1.67	0.12	1.63	0.60
Conturo et al._2008 [1]	-0.42	-1.17	0.33	1.81	0.66
Conturo et al._2008 [2]	-1.23	-1.96	-0.50	1.84	0.67
Nishimura et al._2008 [1]	-0.27	-0.95	0.40	1.91	0.70
Nishimura et al._2008 [2]	-1.30	-2.04	-0.56	1.83	0.67
Wallace et al._2010	-0.96	-1.53	-0.38	2.04	0.75
Domes et al._2013	-0.76	-1.52	0.01	1.79	0.66
O'Brien et al._2014	-0.58	-1.33	0.18	1.81	0.66
Rigby et al._2018	-3.54	-4.65	-2.43	1.38	0.50
Latinus et al._2019	-0.40	-1.22	0.43	1.72	0.63
Overall	-0.72	-0.83	-0.60		

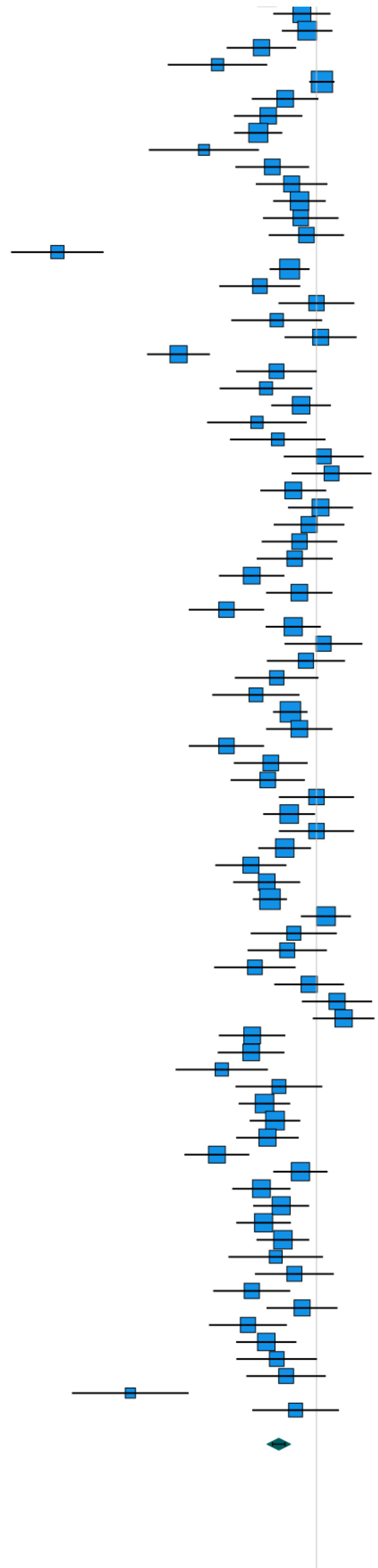
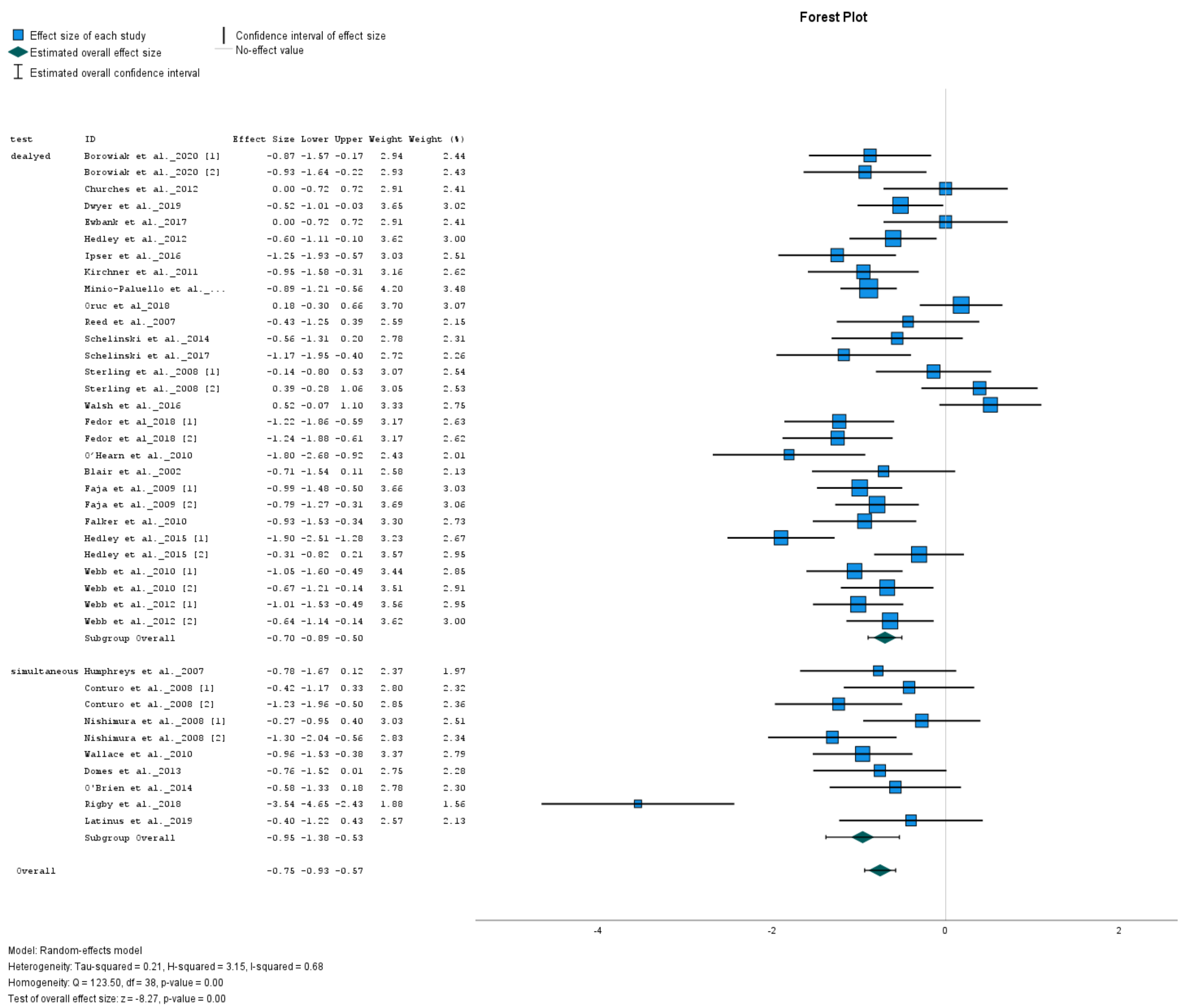


Figure 4

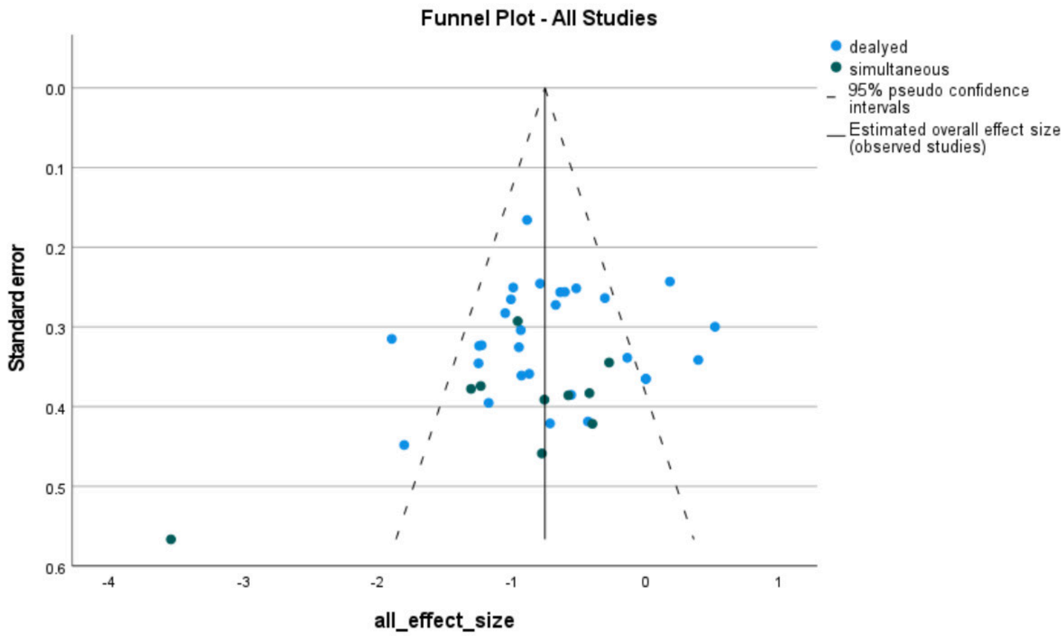
Forest Plot of Overall Face Identity Recognition Performance in Adult ASD and TD Groups



Note. Forest plot from the meta-analysis using a random-effect model on all studies with adult participants. Overall Hedge's g value= -.76; delayed subgroup, Hedges' *g* = -.70; simultaneous subgroup, Hedges' g = -.95.

Figure 5

Funnel Plot of Overall Studies with Adult Participants

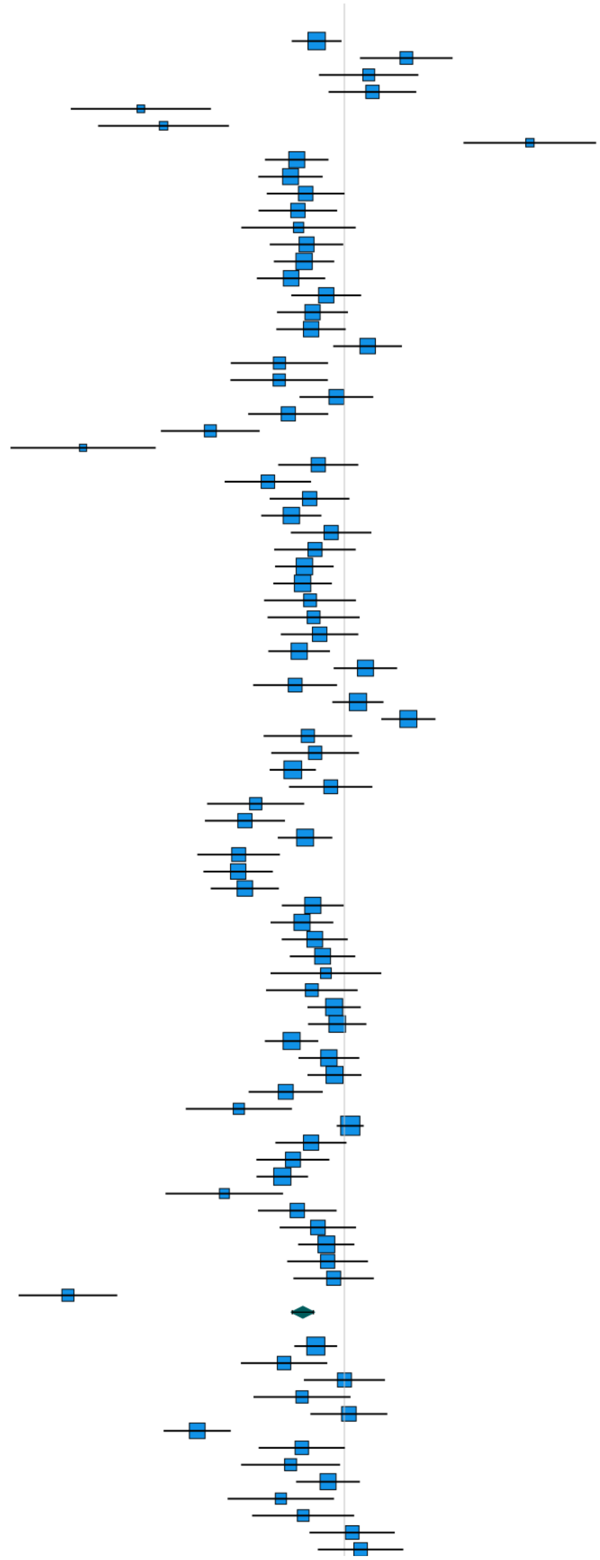


Note. Egger's Regression-based test with an overall result of t=0.169, p=.867, indicated an overall symmetric funnel plot.

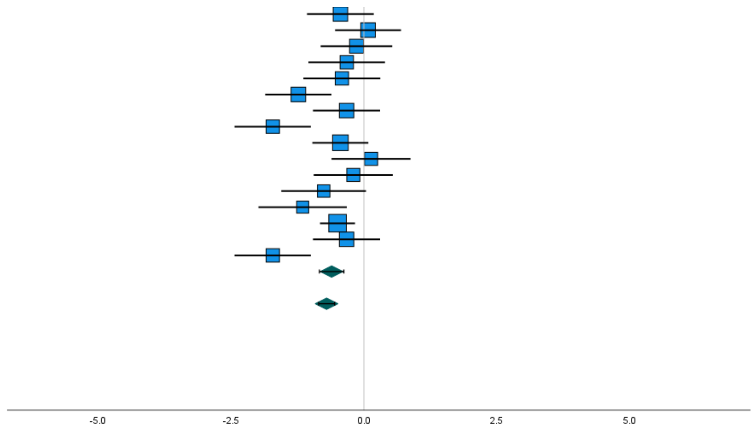
Figure 6

Forest Plot of Overall Identity Recognition Performance in Children with ASD and TD

test	ID	Effect Size	Lower	Upper	Weight	Weight (%)
delayed	Barron-Linnankoski et...	-0.50	-0.94	-0.05	1.88	1.10
	Campbell et al._2006	1.10	0.28	1.93	1.52	0.89
	Celani et al_1999	0.43	-0.45	1.32	1.46	0.85
	Chien et al._2014	0.50	-0.28	1.28	1.56	0.91
		-3.63	-4.88	-2.38	1.13	0.66
		-3.23	-4.39	-2.06	1.20	0.70
		3.31	2.12	4.49	1.18	0.69
	Corbett et al._2014	-0.85	-1.42	-0.28	1.77	1.04
		-0.96	-1.53	-0.39	1.76	1.03
	de Gelder et al._1991	-0.69	-1.38	0.00	1.65	0.97
		-0.83	-1.53	-0.13	1.64	0.96
	Ewing et al._2018	-0.82	-1.84	0.20	1.33	0.78
	Ewing et al._2013	-0.68	-1.33	-0.02	1.69	0.99
	Hauck et al._1998	-0.72	-1.26	-0.18	1.79	1.05
	Hooper et al._2006	-0.95	-1.56	-0.34	1.73	1.01
	Joseph et al._2008	-0.33	-0.95	0.30	1.72	1.00
		-0.57	-1.20	0.06	1.71	1.00
	Joseph & Tanaka_2003	-0.60	-1.21	0.02	1.72	1.01
		0.41	-0.20	1.03	1.73	1.01
	Key & Corbett_2014	-1.16	-2.03	-0.29	1.48	0.86
		-1.16	-2.03	-0.30	1.48	0.86
	Li et al._2017	-0.14	-0.80	0.52	1.68	0.99
	López et al._2004	-1.00	-1.71	-0.29	1.63	0.95
		-2.39	-3.27	-1.51	1.46	0.86
		-4.66	-5.96	-3.36	1.09	0.64
	López et al._2008	-0.47	-1.18	0.25	1.63	0.95
	McPartland et al._2011	-1.36	-2.14	-0.59	1.57	0.92
		-0.62	-1.33	0.09	1.63	0.96
	Narzisi et al._2013	-0.95	-1.48	-0.41	1.80	1.05
	Planche & Lemonnier_2012	-0.24	-0.96	0.48	1.62	0.95
		-0.53	-1.25	0.20	1.61	0.95
	Reinvall et al._2013	-0.71	-1.24	-0.19	1.81	1.06
		-0.75	-1.27	-0.22	1.81	1.06
	Rhodes et al._2014	-0.61	-1.43	0.21	1.52	0.89
	Rhodes et al._2015	-0.55	-1.37	0.27	1.52	0.89
	Rose et al._2007	-0.44	-1.13	0.25	1.65	0.97
	Sanna et al._2011	-0.81	-1.36	-0.26	1.78	1.05
		0.37	-0.19	0.94	1.77	1.04
	Scherf et al._2015	-0.88	-1.63	-0.13	1.59	0.93
	Serra et al._2003	0.24	-0.22	0.70	1.87	1.09
		1.14	0.65	1.62	1.84	1.08
	Tessier et al._2015	-0.65	-1.44	0.14	1.55	0.91
		-0.52	-1.30	0.26	1.56	0.91
	Weigelt et al._2013	-0.92	-1.33	-0.51	1.90	1.11
	Whyte et al._2016	-0.24	-0.99	0.50	1.60	0.94
	Wilson et al._2010	-1.58	-2.45	-0.72	1.48	0.87
	Wilson et al._2010	-1.77	-2.49	-1.06	1.63	0.95
	Wilson et al._2011	-0.70	-1.19	-0.21	1.84	1.08
	Yi et al._2013	-1.89	-2.62	-1.15	1.61	0.94
	Yi et al._2016	-1.89	-2.51	-1.28	1.72	1.01
		-1.78	-2.38	-1.17	1.73	1.01
	Fedor et al._2018	-0.56	-1.12	-0.01	1.78	1.04
		-0.76	-1.32	-0.20	1.78	1.04
		-0.53	-1.12	0.06	1.75	1.02
		-0.39	-0.97	0.19	1.75	1.03
	O'Hearn et al._2010	-0.33	-1.32	0.66	1.36	0.80
		-0.58	-1.40	0.23	1.53	0.89
	Guy et al._2017	-0.18	-0.66	0.29	1.85	1.08
	Falker et al._2016	-0.13	-0.65	0.39	1.81	1.06
	Greimel et al._2014	-0.94	-1.42	-0.47	1.85	1.08
	Hanley et al._2020	-0.28	-0.82	0.27	1.79	1.05
		-0.18	-0.66	0.30	1.85	1.08
	Jiang et al._2015	-1.05	-1.71	-0.39	1.68	0.98
	Lajiness-O'Neill et al...	-1.88	-2.83	-0.94	1.40	0.82
	Oerlemans et al._2013	0.10	-0.14	0.34	2.01	1.18
	Robel et al._2004	-0.60	-1.23	0.04	1.71	1.00
		-0.92	-1.57	-0.27	1.69	0.99
	Southwick et al._2011	-1.11	-1.57	-0.65	1.86	1.09
	wilson et al._2012	-2.14	-3.19	-1.09	1.30	0.76
	wilson et al._2007	-0.84	-1.54	-0.14	1.64	0.96
		-0.47	-1.15	0.21	1.66	0.97
	Zaki & Johnson_2013	-0.32	-0.82	0.18	1.83	1.07
	Tehrani-Doost et al._2012	-0.30	-1.02	0.42	1.62	0.95
		-0.19	-0.91	0.52	1.62	0.95
	Ewing et al._2013	-4.93	-5.81	-4.05	1.46	0.86
	Subgroup Overall	-0.74	-0.93	-0.55		
simultaneous	Parish-Morris et al._2013	-0.51	-0.89	-0.13	1.93	1.13
	Herrington et al._2015	-1.08	-1.85	-0.31	1.57	0.92
		0.00	-0.72	0.72	1.62	0.95
	Deruelle et al._2004	-0.76	-1.62	0.11	1.48	0.87
	Song & Hakoda_2012	0.08	-0.61	0.76	1.66	0.97
	Ewing et al._2013	-2.62	-3.22	-2.03	1.74	1.02
	Rondan et al._2003	-0.76	-1.53	0.01	1.58	0.92
	Pierce & Redcay_2008	-0.96	-1.84	-0.08	1.46	0.86
	Krebs et al._2011	-0.29	-0.86	0.28	1.77	1.04
	Davies et al._1994	-1.13	-2.08	-0.18	1.40	0.82
		-0.74	-1.65	0.17	1.43	0.84
		0.14	-0.62	0.90	1.58	0.93
		0.29	-0.48	1.05	1.58	0.93



	Riby et al._2008	-0.44	-1.07	0.19	1.71	1.00
		0.08	-0.54	0.70	1.72	1.01
	Rosset et al._2010	-0.14	-0.81	0.53	1.67	0.98
	Tehrani-Doost et al._2012	-0.32	-1.04	0.40	1.62	0.95
		-0.42	-1.14	0.31	1.62	0.95
	Leonard et al._2011	-1.23	-1.86	-0.61	1.72	1.01
	Dimitriou et al._2015	-0.33	-0.96	0.30	1.71	1.00
		-1.71	-2.43	-1.00	1.63	0.95
	Yerys et al._2018	-0.44	-0.97	0.08	1.81	1.06
	Ozonoff et al._2990	0.13	-0.61	0.88	1.60	0.94
		-0.20	-0.94	0.54	1.60	0.94
		-0.76	-1.55	0.04	1.55	0.91
		-1.15	-1.98	-0.32	1.51	0.89
	Herrington et al._2016	-0.50	-0.83	-0.17	1.96	1.15
	Annaz et al._2009	-0.33	-0.96	0.30	1.71	1.00
		-1.71	-2.43	-1.00	1.63	0.95
	Subgroup Overall	-0.61	-0.84	-0.38		
Overall		-0.70	-0.85	-0.55		



Model: Random-effects model

Heterogeneity: Tau-squared = 0.48, H-squared = 5.76, I-squared = 0.83

Homogeneity: Q = 601.67, df = 103, p-value = 0.00

Test of between-subgroup homogeneity: Q = 0.78, df = 1, p-value = 0.38

Figure 7

Funnel Plot of Overall Studies with Children Participants

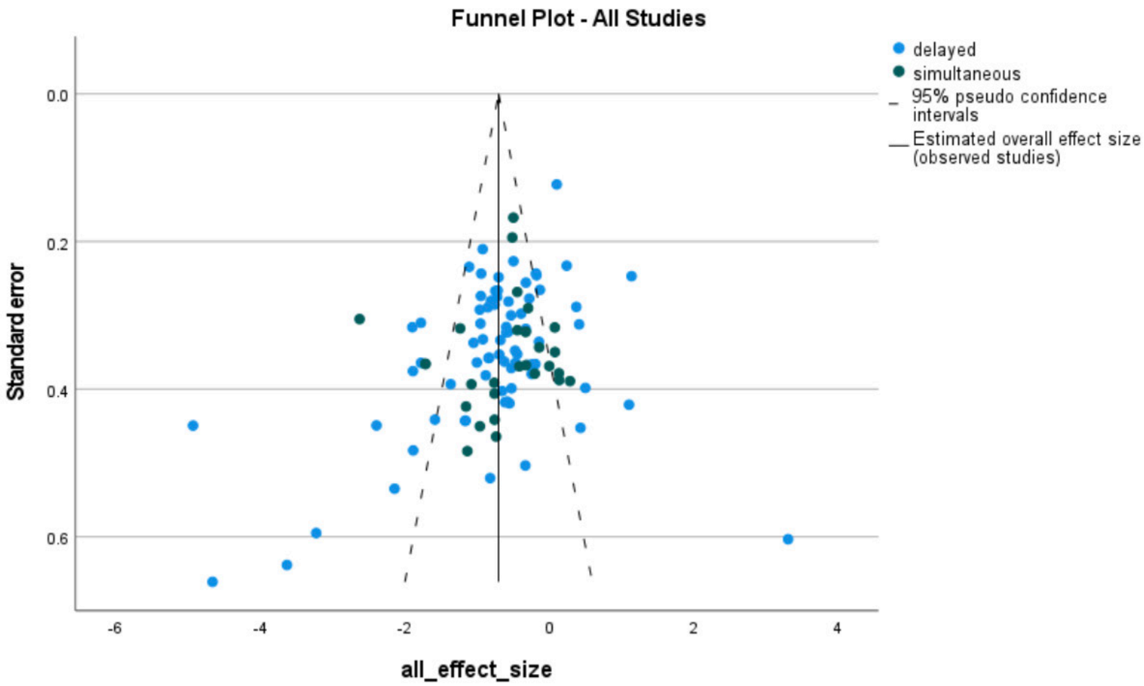
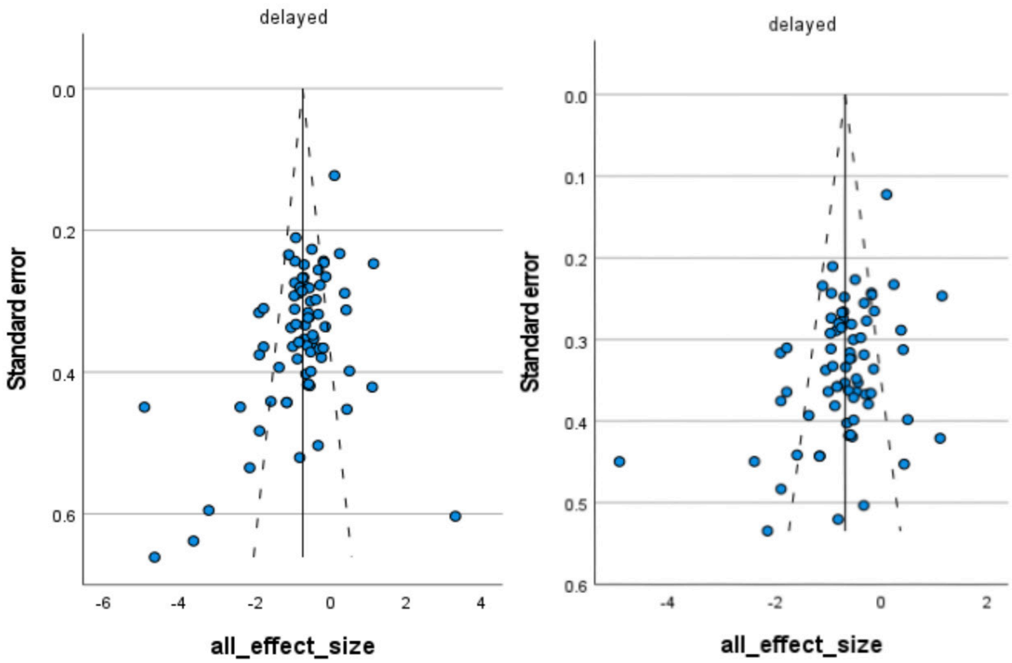


Figure 8

Funnel Plot of Studies on Children with Delayed Face Identity Recognition Test Before and After (Extreme Data were Removed)



Note. The plot on the left showed the funnel plot prior to modification. The plot on the right showed the funnel plot after five studies' data with extreme effect sizes removed.