



General figure and face-specific closure ability: predictors of trait-autism?

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Abstract

Little research has examined the association between general figure closure speed, a stratum I ability within the Cattell-Horn-Carroll (CHC) model of intelligence, and face-specific closure ability; an important consideration, as some research suggests face processing is independent of other abilities. Additionally, figure closure ability (general and face) may correlate negatively with trait-autism, due to theorised autism-related difficulties in global processing. Therefore, in addition to developing a psychometrically robust short-form Mooney face detection task, we administered the Gestalt Figure Completion Test and the Autism Spectrum Quotient to a sample of 263 general community adults. We found convergent validity between face-specific and general figure closure ability ($r = .44$, 95%CI:[.30, .58]). Furthermore, based on a latent variable model, general figure closure ability was directly, and face-specific figure closure ability indirectly, negatively associated with trait-autism (i.e., nonverbal communication). We conclude that face detection ability evidences convergent validity with general figure closure ability and can be measured reliably in less than four minutes. Finally, a general, rather than face-specific, figure closure process may tap more directly into autism-like nonverbal communication ability, supporting the notion that global processing abilities of non-face objects may better reflect the requirements to ‘fill in the gaps’ in social contexts.

Introduction

Closure speed represents individual differences in the cognitive capacity to apprehend disconnected, incomplete or obscured stimuli to envision the whole (Carroll, 1993).¹ Although individual differences in closure speed ability have been investigated across both visual and auditory modalities, most of the research has focused on visual figure-based stimuli. Figure closure speed represents "...the ability to unite an apparently disparate perceptual field into a single concept" (Ekstrom et al., 1976, p. 25). Occasionally referred to as a “real world” spatial ability (Von Karolyi et al., 2003), figure closure ability is commonly measured by the Gestalt Completion Test, a test where participants view an incomplete image comprised of black blotches or lines, and they

must mentally fill in the gaps to apprehend the image as a whole (Ekstrom et al., 1976). In addition to visual processing, successful completion of the test items may be expected to rely upon spatial representations in long-term memory, as the stimuli tend to be familiar objects (e.g., animals, words, furniture). General figure closure ability has been found to associate positively with other cognitive abilities; in particular, visualisation (Vz), perceptual speed (P), and flexibility of closure (CF)² (Pemberton, 1952).

The Mooney Face Test (Mooney, 1957) may be considered a test of figure closure ability specific to faces, as it measures an individual’s ability to detect a degraded face in a visual scene. Specifically, each trial presents three different degraded black and white images and the participant determines which of the three images contains a face. Each Mooney Face Test image has obstructions of the important local, featural and relational information (e.g., eyes, nose, mouth), requiring participants to combine the white and black areas to apprehend and detect the face. That is, participants must fill in the gaps to discern the nature of the image.

¹ Although the word ‘speed’ is included in the term ‘closure speed’, speed of processing is not a common characteristic of tests designed to measure figure closure ability.

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² Flexibility of closure represents the “...ability to identify a visual figure or pattern embedded in a complex distracting or disguised visual pattern or array, when knowing in advance what the pattern is” (Newton & McGrew, 2010, p. 624). We focus only on figure closure ability.

Mooney (1957) found that humans were relatively accurate at detecting faces when obscured, which surpasses even our most advanced computer-based programs (Aljaafreh et al., 2022). The Mooney Face Test has been considered a measure of face detection ability within the context of individual differences in face processing, and it is considered a distinct process from face perception and face memory (Robertson et al., 2017).

Face recognition has been suggested to be essentially distinct from other cognitive processes (e.g., Wilmer et al., 2014). Specifically, it has been argued that face recognition is not correlated with other cognitive abilities, as they are dependent upon neurological and neurophysiological systems dedicated to faces. For example, neurological studies have located a cortical region of the brain (i.e., fusiform face area) that has been linked specifically to face perception (Kanwisher & Yovel, 2006). Correspondingly, it has also been suggested that a dedicated neurophysiological system may exist for face detection, distinct from what is required to detect other objects (Decramer et al., 2021; Lewis & Ellis, 2003). However, in a recent review, Walker et al. (2023) suggested that face detection was at least theoretically associated with other cognitive abilities (e.g., visual spatial ability and comprehension-knowledge), on the basis that detecting an ambiguous face, such as presented in the Mooney Face Task, requires an individual to create a mental image of the face and draw upon knowledge acquired throughout their lifetime. Furthermore, Walker et al. (2023) estimated the meta-analytic correlation between face detection ability (specifically, the Mooney Face Task) and general cognitive ability to be $r=0.17$ ($p=0.044$). Importantly, however, Walker et al. identified only two studies that included face detection ability and another cognitive ability. Consequently, Walker et al. encouraged more empirical research to help determine whether face detection ability was an essentially independent cognitive process, or a partly dependent cognitive ability, like most other cognitive abilities (McGrew, 2009).

There has also been limited convergent/discriminant validity research on the association between general figure closure ability and face-specific figure closure ability. Foreman (1991) failed to find a significant correlation between general figure closure ability (Gollin Incomplete Figures Test) and the Mooney Face Test, suggesting that face processing is an independent ability. However, only a relatively small ($N=127$) and range restricted university sample was used. By contrast, Wasserstein et al. (2004) found that the Gestalt Completion Test and the Mooney Face Test loaded positively onto the same factor; however, again, only a small ($N=63$) non-general population sample (brain injured) was used.

Therefore, further research is required to help evaluate the convergent validity between general figure closure ability and face-specific closure ability, in order to evaluate if

the process of detecting face stimuli is distinctly different to the process of detecting non-face stimuli. A positive correlation between general figure closure test scores and face-specific figure closure test scores would imply some shared cognitive processes. By contrast, the absence of a correlation would imply entirely distinct cognitive processing mechanisms.

General figure closure ability and trait-autism

Defining characteristics of autism include impairments in nonverbal communication, socialisation, and engagement in repetitive behaviours (American Psychiatric Association, 2013). In addition to a diagnosis of autism, trait-autism (also known as the Broader Autism Phenotype) is considered to be a continuum observed in the general population (Baron-Cohen et al., 2001). One of the most common measures of trait-autism is the Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001). The 28-item version (Russell-Smith et al., 2011) of the AQ measures three dimensions: (1) communication; (2) social; and (3) attention to detail—aligning with the symptom clusters of clinical diagnosis of autism. Example items from each respective dimension include: “I find it difficult to work out people's intentions”, “I would rather go to a library than a party”, and “I notice patterns in things all the time”. The social dimensions of trait-autism have been found to be essentially uncorrelated with the attention to detail dimension (Dworzynski et al., 2009).

There is evidence that autistic people³ tend to show unique perceptual characteristics. As one example, weak central coherence theory postulates an information processing bias, where local processing is more readily utilised to the detriment of global processing (Mottron et al., 2006). Correspondingly, on average, autistic people show relatively lower performance on figure closure tasks (Booth & Happé, 2018). Additionally, Jolliffe and Baron-Cohen (2001) reported that high functioning autistic people had difficulty integrating single elements in order to perceive a meaningful whole. By contrast, on average, autistic people show a pattern of enhanced performance on local processing tasks; such tasks require participants to ignore the “bigger” picture and focus on the smaller parts (local features; Mottron et al., 2006).

Given the biological and etiological links between diagnosed autism and trait-autism (Bralten et al., 2018), a local processing bias may also be expected to be observed in neurotypical individuals who are high in trait-autism. To date,

³ This is the preferred terminology of the autism community and is recommended by Monk et al. (2022)

the results are mixed, across the different dimensions of trait-autism. In one study, Russell-Smith et al. (2012) found that the social aspects of trait-autism were associated with better local processing, as measured by an embedded figures task, supporting the weak central coherence theory. By contrast, Walter et al. (2009) found that the non-social aspects of trait-autism were associated with better local processing. Unfortunately, both studies were based on range restricted university students. Given these mixed results, and sample limitations, further investigation is merited. Consequently, this study investigated whether the social and/or non-social aspects of trait-autism were associated with general figure closure ability. Furthermore, as previous studies focused on tasks involving local processing ability, it was considered valuable to employ a task focused on global processing ability (i.e., validity generalisation). If the weak central coherence theory is supported, a negative correlation between the social and/or non-social aspects of trait autism and general figure closure ability will be observed, i.e., would provide further support for the local processing bias (i.e., global processing deficit) in neurotypical individuals with trait-autism. Stated alternatively, individuals with higher-levels of trait-autism may struggle to fill in the gaps when perceiving incomplete stimuli in a figure, similar to how they tend to struggle with mindreading (filling in the gaps) during conversations (Morrison et al., 2019).

Face-specific closure ability and trait-autism

Autistic people may exhibit the same, or perhaps an even more substantial, bias for local processing of social stimuli (i.e., faces), in comparison to general figures. As a group, autistic people may experience difficulties in visually processing faces. Difficulties include, but are not limited to, face memory (Minio-Paluello et al., 2020) and face expression recognition (Harms et al., 2010). Research has found that a majority of autistic adults fixate less on the eyes and more on the lower portion of the face, which could negatively affect their overall face processing (Ashwin et al., 2007; Klin et al., 2002). Specifically, given that a majority of autistic people have poorer socialisation skills, they may tend to focus inordinately on specific face features to the detriment of processing the face as a whole (Deruelle et al., 2004).

Empirically, there is one study ($N=29$) to suggest that autistic adults perform differently on face-specific closure tasks (i.e., elevated reaction times; reduced detection rates; Sun et al., 2012) as compared to allistic (non-autistic) people. Face processing deficits are also seen in neurotypical individuals with higher-levels of trait-autism, without clinical diagnosis of autism. For example, Halliday et al. (2014) found that individuals with more autistic-like traits had poorer face memory ability. Similarly, Bothe et al.

(2019) found that the social aspects of autism in neurotypical individuals were negatively associated with expression recognition ability. It remains unclear if these deficits in face processing occur due to a local processing bias in neurotypical individuals with higher-trait autism. The Mooney Face Test has been found to be correlated positively with other face processing abilities (e.g., $r=0.31$ between the Mooney Face Task and a face memory task; see Verhallen et al., 2017), and face-specific closure is arguably the most basic function of face processing. To the authors' knowledge, there have been no studies that have investigated the association between trait-autism and face-specific closure ability. Therefore, the observation of a negative association between Mooney Face Task performance and trait-autism in neurotypical individuals would support the notion of a local processing bias when viewing faces.

Development of the short-form Mooney face test

The original Mooney Face Test consisted of 40 items (Mooney, 1957). Verhallen and Mollon (2016) developed an improved image quality test with 144 items that requires approximately 10 min to complete. In comparison to other tests of cognitive ability, which are typically based on 10 to 40 test items (e.g., WAIS-IV; Wechsler, 2008), 144 test items is uncharacteristically large. Such a large amount of test items may affect negatively test motivation and possibly induce test fatigue, two outcomes that can negatively impact the psychometrics of a test (Meade & Craig, 2012). Additionally, researchers may be less inclined to include the measurement of face detection ability in their studies, given the testing time required, which may partly explain why Walker et al. (2023) identified so few face detection ability studies in their meta-analytic investigation. Importantly, respectable levels of reliability and validity may be achieved with fewer test items (i.e., <50) and require less testing time (<4 min). Therefore, a psychometrically robust version of the revised Mooney test with fewer test items would be valuable to establish: a goal of this investigation.

Summary and purpose

In summary, it is not yet clear whether face detection is a unique process, essentially distinct from other cognitive abilities. To date, inconsistent results on the association between face-specific closure ability and general figure closure ability have been reported. More research is required with the use of community-based samples and adequate sample sizes. Furthermore, there is some evidence to suggest that autistic people, and neurotypical

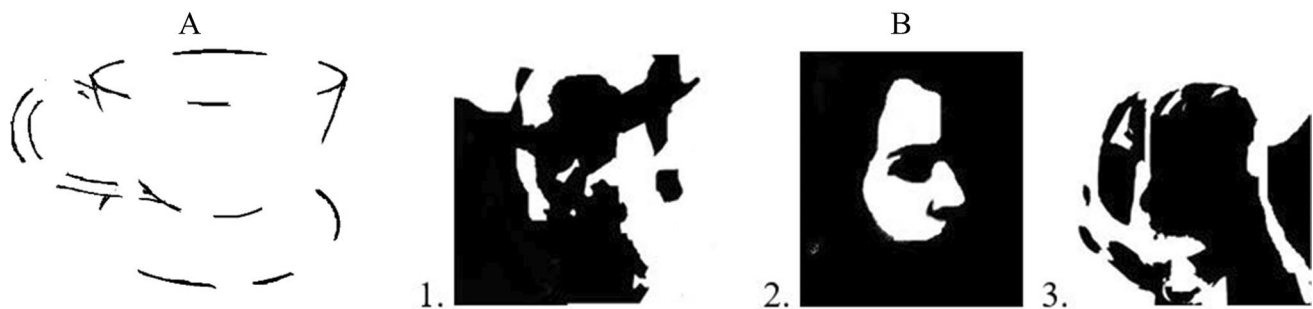


Fig. 1 Illustrative Example of a Gestalt Figure Completion Test item (Panel A) and Mooney Face Test Item with Two Distractors (1 and 3) and One Face Image (2) (Panel B)

individuals who score higher on trait-autism, have superior local processing ability, to the detriment of global processing ability. However, research into trait-autism and local/global processing in the neurotypical population is mixed, and it has focused on the measurement of local processing, rather than the measurement of global processing. Though limited, the existing research suggests that a negative association between trait-autism and both general figure closure and face-specific closure ability may exist. We sought to test this hypothesis. Finally, this study aimed to develop a psychometrically robust short-form measure of face-specific closure ability, allowing for easier incorporation of face detection ability into test batteries that include face processing measures.

Method

Participants

A total of 264 participants were recruited via the Testable Minds platform (“verified minds”) and were reimbursed \$1.50 USD. One participant failed to adequately answer the attention questions and was removed. Therefore, data from 263 participants (90 females, 173 males, mean age $M = 30.7$ years, $SD = 10.1$, range = 18 to 67) were analysed. The primary reported ethnicities were white (54%) and Asian (38%). Additionally, the primary nationalities were India (22%), UK (18%), Philippines (8%), Portugal (6%) and Italy (5%). Education levels were: less than high school education (0.4%), high school education (14%), vocational training (15%), bachelor’s degree (51%), and Master’s degree or higher (17%).

A power analysis via Jamovi (The Jamovi Project, 2021) determined a sample size of 199 participants as sufficient to detect a typical effect size of $r = .201$ (Gignac & Szodorai, 2016) as significant ($p < 0.05$) with 80% power.

Materials

Questionnaires

Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001) The 28-item version of the AQ, reported by Russell-Smith et al. (2011), was used within this study to measure three dimensions of self-reported (5-point Likert scale) autistic-like traits: Attention to detail, communication/ mindreading and social skills. Higher scores on the attention to detail questions reflect a greater propensity to attend to details and pattern; higher scores on the communication/ mind-reading and social skill questions reflect difficulties in communication/ mindreading and socialisation. For our sample, the three subtests, attention to detail, communication and social, yielded good internal consistency reliability ($\omega = 0.81$, $\omega = 0.75$ and $\omega = 0.89$, respectively).

Gestalt Figure Completion Test (Ekstrom et al., 1976) Individual differences in figure closure ability were measured with the Gestalt Completion Test (Ekstrom et al., 1976). Participants were shown 20 fragmented and incomplete images of objects, animals or people and asked to identify what they were in a free-response format (see Fig. 1, Panel A for illustrative example). Items were split into two sets of 10 items (Part A and B), and participants were allowed two minutes to complete each part. Higher scores on this task reflect better figure closure ability. The free text responses were scored by DW and GG and any discrepancies were resolved via discussion. This task showed near respectable internal consistency reliability ($\omega = 0.64$).

Mooney Face Test Short-Form (48-item) A pilot study identified 48-items (three images per item) from the Mooney-Verhallen test (Verhallen & Mollon, 2016) that ranged in difficulty (see Table S1). These 48-items were administered

in this study to evaluate the psychometrics of a short-form. For each of the 48 items, participants were presented with three degraded black and white images (five seconds to respond). One image contained a degraded face whilst the other two images were distractors. In this three-alternative force-choice task, participants were asked to select which image was a face by selecting the 1, 2 or 3 button on their keyboard (see Fig. 1, Panel B).

Procedure

Participants with an active TestableMinds account were able to join the study online via a compatible device, such as a desktop computer or laptop. After reading and accepting an informed consent form, participants calibrated their screen so that all images and questionnaires were presented in the correct size and format. Next, the participants were instructed to minimise any distractions (e.g., set their phone to silent) and position themselves at arm's length from the screen without slouching. Participants were also reminded to wear any corrective eye wear if required. Participants completed demographic questions, the AQ, followed by the Gestalt Completion Test, and finally, the Mooney Face Test (short-form). Participants were asked an attention question after the Gestalt Completion Test and the Mooney Face Test (short-form): "To show us that you were paying attention, can you explain in one sentence what we asked you to do in this part of the study?". Finally, participants were asked whether there was any reason not to use their data in this study, such as not understanding the instructions or technical issues. On average, testing required 19 min. This study's procedure was approved by the University of Western Australia's Human Research Ethics Committee (2019/RA/4/1/6704).

Data analysis

All analyses were conducted with Jamovi and *R* (The Jamovi Project, 2021; R Core Team, 2021). An unrestricted factor analysis (maximum likelihood) was conducted on the Mooney test items via the EFAutilities package (version 2.1.1; Zhang et al., 2019) for *R*. The number of factors to extract was determined via parallel analysis (95th percentiles; via online engine, see supplementary materials Fig. S1; Vivek et al., 2017). Statistical significance of factor loadings was determined via 95% confidence intervals and 2,000 bootstrapped resamples. Internal reliability coefficient omega (point-estimate and 95% confidence intervals) was estimated via the MBESS package (version 4.9.0; Kelley, 2007) for *R*. To estimate internal consistency reliability across the spectrum of face detection ability, a total information curve was estimated with the MIRT package (version 1.36.1; Chalmers, 2012) for *R*. Correlations

between key variables were estimated via observed scores and latent variables. The latent variables were defined by item parcels (see supplementary materials for further details). The latent variable analyses were conducted with the lavaan package for *R* (version 0.6.9; Rosseel, 2012).

Results

All data and scripts available at <https://osf.io/a5ybx/>.

Data screening

For the total scores, the data were sufficiently normally distributed (skew <|2.0| and kurtosis <|9.0|) for the purpose of parametric analysis (Bishara & Hittner, 2012) and no outliers were identified according to the outlier inter-quartile range rule with a 3.0 multiplier (Hoaglin & Iglewicz, 1987). However, the Mooney item distributions were substantially skewed (see Table S2, supplementary materials). We used bootstrapping to estimate confidence intervals, an estimation technique that does not assume any level of normality (Awang et al., 2015).

Psychometrics: Mooney Face Test (short-form)

The Mooney item descriptive statistics are reported in Table S2. Item means ranged from 0.47 to 1.0 ($M=0.73$, $SD=0.15$). Although, there was some variability in item level difficulty, only 2.1% of items were associated with an item difficulty of less than 60%. The overall test mean was 35.20 ($SD=7.87$) or 73.3%, with variability evident in Fig. 2, (coefficient of variation was 0.22). Two participants performed at ceiling.

Next, the factorability of the 48-item Mooney Face Test was examined. First, the mean inter-item correlation was 0.14. Secondly, the Bartlett's Test of Sphericity was significant ($\chi^2=2838.65$, $df=1081$, $p<0.001$) and the KMO was equal to 0.822, suggesting data that could be factor analysed justifiably. Item one was excluded from the factor analysis as it lacked variability (i.e., all participants answered item one correctly). On the basis of the parallel analysis results, only the first eigenvalue from the raw (field) data was found to be larger than the rank ordered random data eigenvalues; therefore, one factor was extracted (see Table S3).

The factor loadings (λ) ranged from 0.16 to 0.57, thus, all items loaded onto the single-factor positively (see Table S2). The mean item factor loading was equal to 0.38. Internal consistency reliability was estimated at $\omega=0.89$, 95%CI[0.87, 0.90]. Additionally, as can be seen in Fig. 3, the total test score information (i.e., reliability) was respectable across most levels of ability, although at

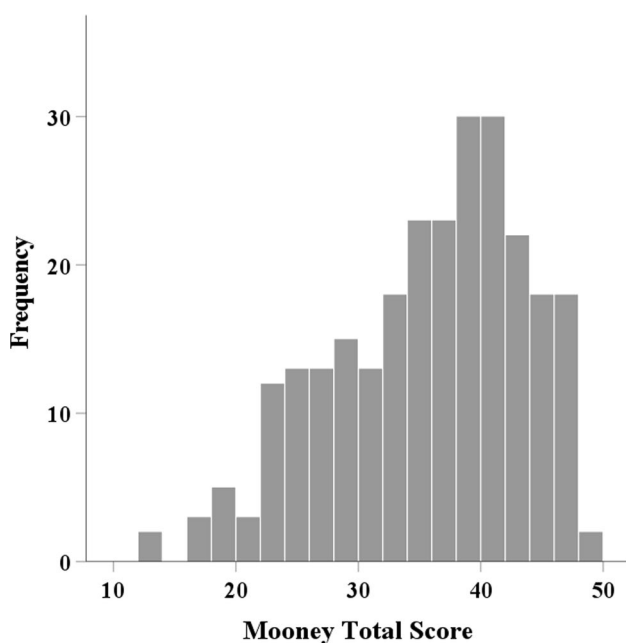


Fig. 2 48-Item Mooney test total score histogram

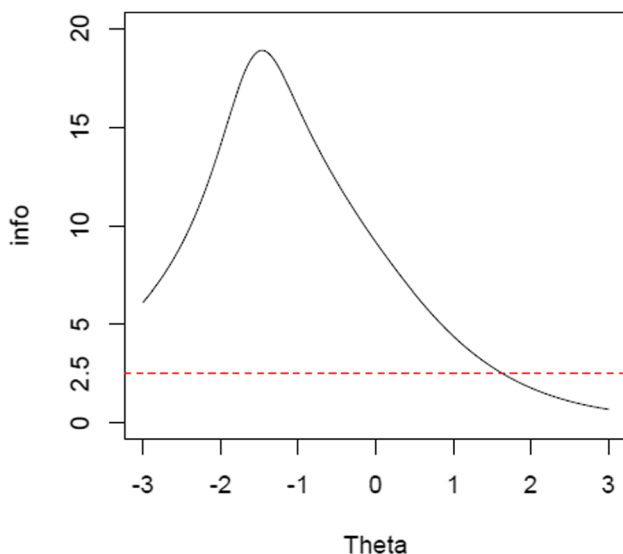


Fig. 3 Total Information Curve for Mooney Face Test (short-form) Total Scores. *Note.* Total information curve for Mooney total test scores; *x*-axis represents measurement of the latent trait in standard deviation units (theta), with higher values indicative of higher levels of face detection ability; a *y*-axis value of 2.5 corresponds to test score reliability of 0.60

theta levels greater than ≈ 1.75 standard deviations above the mean, the total test score reliability was questionable (i.e., less than 0.60).⁴

⁴ Reliability = $1 - (1/\text{information})$

Descriptive statistics: Gestalt Completion Test and AQ

Descriptive statistics and correlations between the Gestalt Completion Test, Mooney Face Test (short-form) and AQ subscales are presented in Table 1. The mean number of correct responses on the Gestalt Completion Test was 12.12 ($SD = 2.71$) or 60.6% (coefficient of variation = 0.22). The AQ-Social subscale had a mean score of 2.85 ($SD = 0.76$), implying a mean response between “somewhat disagree” and “neither agree nor disagree”. Similarly, the AQ-Communication subscale had a mean score of 2.31 ($SD = 0.59$) and the AQ-Detail subscale had a mean score of 3.16 ($SD = 0.78$).

Convergent validity: observed scores and latent variables

The Mooney Face Test (short-form) scores correlated positively and statistically significantly with the Gestalt Completion Test scores at $r = 0.32$, $p < 0.001$; 95% CI: [0.42, 0.21], suggesting convergent validity. The corresponding latent variable correlation was $r = 0.44$, 95% CI: [0.30, 0.58], implying 19.4% of the true score variance was shared (see Fig. S2). Furthermore, the Gestalt Completion Test scores were significantly and negatively correlated with the AQ-Communication subscale scores, $r = -0.16$, $p < 0.01$, 95% CI: [-0.04, -0.27], implying higher levels of general figure close ability were associated with lesser levels of autistic-like nonverbal communication difficulties. The corresponding latent variable intercorrelation between the Gestalt and AQ-Communication dimensions was also significant, $r = -0.23$, $p < 0.001$, 95% CI [-0.39, -0.06], again, suggesting that higher general figure closer ability was associated with fewer nonverbal communication problems. However, the Gestalt was not significantly correlated with the other two AQ subscales (see Table 1). Additionally, the Mooney Face Test (short-form) did not correlate statistically significantly with any of the three AQ subscales, contrary to expectations (see Table 1; see Table S4 for all latent variable CIs).

Structural equation modelling

Next, we tested whether both general figure close ability (Gestalt) and the face-specific closure ability (Mooney) predicted AQ-communication uniquely. The multiple regression model was associated with excellent levels of model close-fit, $\chi^2(24) = 19.64$, $p = 0.717$, RMSEA = 0.001, TLI = 1.01, CFI = 1.00. As can be seen in Fig. 4 (Panel A), general figure closure ability was associated with a significant standardised beta weight, $\beta = -0.25$, $p = 0.012$, 95% CI: [-0.44, -0.01], controlling for the effects of the face-specific closure ability. By contrast, the face-specific figure closure ability beta-weight

Table 1 Descriptive Statistics, Observed Score Correlations (below main diagonal) and Latent Variable Correlations (above main diagonal) between the Gestalt Completion Test, Mooney Face Test (short-form) and AQ Subscales

Task	1	2	3	4	5	<i>M</i>	<i>SD</i>	Min	Max	Skew	ω
1. Gestalt Completion Test		0.44*	0.03	-0.13	-0.23*	12.12	2.71	3.0	17.5	-0.53	0.64
2. Mooney Face Test (short-form)	0.32*		0.01	-0.06	-0.05	35.20	7.87	13.0	48.0	-0.54	0.89
3. AQ Social	0.03	0.02		-0.21*	0.59*	2.85	0.76	14.0	65.0	0.11	0.89
4. AQ Detail	-0.08	-0.05	-0.19*		-0.01	3.16	0.78	7.0	35.0	-0.26	0.81
5. AQ Communication	-0.16*	-0.04	0.49*	-0.02		2.31	0.59	8.0	33.0	0.18	0.75

N = 263. **p* < 0.05; *AQ* Autism Quotient; ω McDonald’s coefficient omega

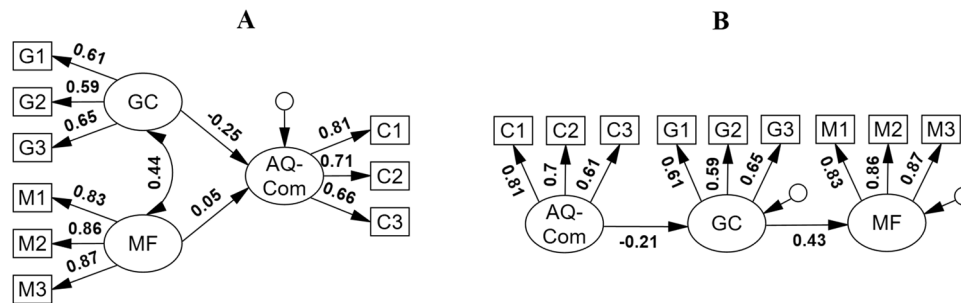


Fig. 4 Structural Equation Models. *Note.* Panel **A**=general figure closure ability (Gestalt Completion Test; GC) and face-specific closure ability (Mooney Face Test (short-form); MF) predicting trait-autism communication (AQ-Com); Panel **B**=trait-autism commu-

nication predicting general figure closure ability, and general figure closure ability predicting face-specific closure ability; all coefficients are fully standardized and statistically significant, *p* < 0.05

was not significant, $\beta = 0.05$, $p = 0.532$, 95%CI [-0.12, 0.23]. A total of 5.2% the AQ-Communication true score variance was explained, $R^2 = 0.052$, $p = 0.003$, 95%CI[0.01, 0.15].

Given the results above, and the fact that some researchers specify trait-autism (nonverbal communication) as a predictor of face processing ability (e.g., Bothe et al., 2019), we tested a supplementary model whereby AQ-Communication was a predictor of general figure closure ability, and general figure closure ability was a predictor of the face-specific figure closure ability (see Fig. 4, Panel B). Both direct effects were significant statistically, AQ-Communication: $\beta = -0.21$, $p = 0.009$, 95%CI [-0.05, -0.37]; Gestalt: $\beta = 0.43$, $p < 0.001$, 95%CI [0.29, 0.57]. Furthermore, the indirect effect between AQ-Communication and the Mooney was significant, $\beta = -0.09$, $p = 0.022$, 95%CI: [-0.18, -0.01]. Thus, lower levels of communication difficulties were associated with higher levels of face recognition ability via general figure closure ability. The model was associated with excellent close-fit, $\chi^2(25) = 20.03$, $p = 0.745$, RMSEA = 0.001, TLI = 1.01, CFI = 1.00.

Discussion

The present study investigated the associations between face-specific closure ability, general figure closure ability and autistic-like traits, as well as the psychometric properties

of a new short-version of the Mooney Face Test. Global and face-specific closure ability evidenced appreciable convergent validity. Furthermore, trait-autism communication was uniquely predicted by general figure closure ability, but not face-specific closure ability. Based on supplementary model, trait-autism communication was found to have an indirect effect onto face detection ability. Finally, the Mooney Face Test (short-form) showed good factorial validity and excellent internal consistency reliability.

Convergent validity: general figure closure ability

Face-specific figure closure ability was found to be positively correlated with general figure closure ability, and the effect size was relatively large (Gignac & Szodorai, 2016). Our study is the first to establish the convergent validity between face-specific and general figure closure ability in a large, representative sample. Two previous studies yielded inconsistent results and were based on small, unrepresentative samples (Foreman, 1991; Wasserstein et al., 2004). Thus, the findings of this study support the conclusions of Walker et al. (2023). Specifically, while face detection ability may be associated with some uniqueness, it may not be uniquely unique (cf. Wilmer, 2017), in that it shares some positive variance with other cognitive abilities, as per many other cognitive abilities (Carroll, 1993).

Convergent validity: trait-autism

Although in the predicted direction, face-specific closure ability failed to correlate significantly with the three trait autism dimensions. By contrast, general figure closure ability was a significant, unique predictor of the AQ-Communication dimension. Thus, higher levels of general figure closure ability were associated with fewer trait-autism nonverbal communication problems. On the basis of our results, we might predict that decoding and interpreting social conversations (i.e., including nonverbal communication) requires the generation of a number of inferences, i.e., ‘filling in gaps’ across a number of stimuli (Hall et al., 2019), but this remains to be tested.

Furthermore, the results of our study provide some support for the weak central coherence theory specific to the nonverbal communication of trait-autism and the processing of non-face objects. That is, higher trait-autism (communication) scores were associated with lower levels of global processing ability. Thus, our study’s results are essentially consistent with the findings of Russell-Smith et al. (2012) who found that the social dimensions of trait-autism were associated with better local processing (opposite of global processing) of non-face objects, another aspect of weak central coherence theory. As global figure closure ability is correlated positively with general intelligence (Sholl & Egeth, 1982) and trait-autism appears to be essentially uncorrelated with general intelligence (Walker et al., 2022), it would be useful to estimate the effects between global/local processing and trait-autism, controlling for general intelligence, in order to estimate the magnitude of the global/local processing effects better.

Although we failed to identify a direct effect between face-specific closure ability and trait-autism, based on a supplementary model, we found that nonverbal communication ability was indirectly related to face-specific closure ability via general figure closure ability. Such a result is partially consistent with Bothe et al. (2019) who found AQ-Communication was indirectly associated with poorer facial expression recognition ability via alexithymia. Furthermore, Halliday et al. (2014) found a total effect between face identity recognition (i.e., face perception) and autism spectrum quotient scores, including nonverbal communication. In the context of the weak central coherence theory, it is possible that face detection ability deficits interact with other, higher perceptual or cognitive abilities, such as face memory (Minio-Paluello et al., 2020) and face expression recognition (Harms et al., 2010). Thus, in addition to general figure closure ability, more complex face processing abilities than face-specific closure ability (e.g., face perception and face memory) may interact with face detection ability, with respect to predicting AQ-Communication directly and uniquely. Further research is encouraged.

Psychometrics

In addition to measuring a single factor, suggesting factorial validity, the Mooney Face Test (short-form) exhibited excellent internal consistency ($\omega = 0.89$), roughly comparable to that reported for the long-form (i.e., = 0.97; Verhallen & Mollon, 2016). Furthermore, mean performance (73.3%) was slightly lower than that reported for the long-form (i.e., 77.6%), a reflection of the fact that we selected the more difficult items from the long-form to enhance discriminability.

The coefficient of variation for the Mooney Face Test (short-form) was estimated at 0.22, a value comparable to that reported for the Cambridge Face Memory Test (CFMT), i.e., ≈ 0.15 to 0.20 (Duchaine & Nakayama, 2006; Germine et al., 2011), a well-established test of face processing. Therefore, we believe the short-form of the Mooney Face Test is associated with respectable basic psychometric properties for individual differences research, although the addition of a few more difficult items may help increase test score discrimination further.

Limitations

One limitation of this study is the sample was relatively educated (70% university education). Thus, some range restriction may have underestimated the effect sizes. Furthermore, trait-autism was measured via self-report. Therefore, the trait-autism scores may have been imbued with socially desirable responding which may have attenuated effects.

Additionally, we used only one test to measure each of the cognitive dimensions (face and general figure closure ability). It remains to be determined whether our results generalise to other measures. Finally, it remains unclear whether face-specific closure tasks are affected by the own-race bias, where performance on specific face processing tasks is typically better when the race of the participants matches the race of the images, arguably due to greater experience with faces of one’s own-race (Meissner & Brigham, 2001; Verhallen & Mollon, 2016). As our sample was not restricted to any specific ethnicity, and it is unknown what race is depicted in each of the Mooney images, the other-race effect could not be tested.

Conclusion

A general figure closure process (i.e., filling in the gaps for non-face stimuli), rather than a corresponding face-specific figure closure process (i.e., filling in the gaps for face-specific stimuli), appears to tap more substantially and directly nonverbal communication difficulties reported by those higher in trait-autism. Consequently, this study provides some support for the weak central coherence theory for processing of non-face objects. Finally, the short-form Mooney Face Test used in this study is reliable and valid and can be administered online efficiently.

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Data Availability The datasets generated and analysed during the current study are available in the OSF repository; <https://osf.io/a5ybx/>.

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose. The authors also have no competing interests to declare that are relevant to the content of this article.

Informed consent Informed consent was obtained from all individual participants included in the study.

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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References

- Aljaafreh, A., Abadleh, A., Alja'afreh, S. S., Alawasa, K., Almajali, E., & Faris, H. (2022). Edge deep learning and computer vision-based physical distance and face mask detection system using Jetson Xavier NX. *Emerging Science Journal*, 7, 70–80. <https://doi.org/10.28991/esj-2023-sper-05>
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Publishing.
- Ashwin, C., Baron-Cohen, S., Wheelwright, S., O'Riordan, M., & Bullmore, E. T. (2007). Differential activation of the amygdala and the 'social brain' during fearful face-processing in Asperger Syndrome. *Neuropsychologia*, 45(1), 2–14.
- Awang, Z., Afthanorhan, A., & Asri, M. A. M. (2015). Parametric and non parametric approach in structural equation modeling (SEM): The application of bootstrapping. *Modern Applied Science*, 9(9), 58.
- Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism-Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High-Functioning Autism, Males and Females, Scientists and Mathematicians. *Journal of Autism and Developmental Disorders*, 31(1), 5–17. <https://doi.org/10.1023/A:1005653411471>
- Bishara, A. J., & Hittner, J. B. (2012). Testing the significance of a correlation with nonnormal data: comparison of Pearson, Spearman, transformation, and resampling approaches. *Psychological Methods*, 17(3), 399–417. <https://doi.org/10.1037/a0028087>
- Booth, R. D. L., & Happé, F. G. E. (2018). Evidence of reduced global processing in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 48(4), 1397–1408. <https://doi.org/10.1007/s10803-016-2724-6>
- Bothe, E., Palermo, R., Rhodes, G., Burton, N., & Jeffery, L. (2019). Expression recognition difficulty is associated with social but not attention-to-detail autistic traits and reflects both alexithymia and perceptual difficulty. *Journal of Autism and Developmental Disorders*, 49(11), 4559–4571. <https://doi.org/10.1007/s10803-019-04158-y>
- Bralten, J. J., van Hulzen, K. J. K. J., Martens, M. B. M. B., Galesloot, T. E. T. E., Arias Vasquez, A. A., Kiemeneij, L. A. L. A., Buitelaar, J. K. J. K., Muntjewerff, J. W. J. W., Franke, B. B., & Poelmans, G. G. (2018). Autism spectrum disorders and autistic traits share genetics and biology. *Molecular Psychiatry*, 23(5), 1205–1212. <https://doi.org/10.1038/mp.2017.98>
- Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge University Press.
- Chalmers, R. P. (2012). mirt: A multidimensional item response theory package for the R environment. *Journal of Statistical Software*, 48(6), 1–29. <https://doi.org/10.18637/jss.v048.i06>
- Decramer, T., Premereur, E., Zhu, Q., Van Paesschen, W., van Loon, J., Vanduffel, W., Taubert, J., Janssen, P., & Theys, T. (2021). Single-unit recordings reveal the selectivity of a human face area. *The Journal of Neuroscience*, 41(45), 9340–9349. <https://doi.org/10.1523/jneurosci.0349-21.2021>
- Deruelle, C., Rondan, C., Gepner, B., & Tardif, C. (2004). Spatial frequency and face processing in children with autism and Asperger syndrome. *Journal of Autism and Developmental Disorders*, 34(2), 199–210. <https://doi.org/10.1023/B:JADD.0000022610.09668.4c>
- Duchaine, B., & Nakayama, K. (2006). The Cambridge Face Memory Test: Results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. *Neuropsychologia*, 44(4), 576–585. <https://doi.org/10.1016/j.neuropsychologia.2005.07.001>
- Dworzynski, K., Happé, F., Bolton, P., & Ronald, A. (2009). Relationship between symptom domains in autism spectrum disorders: A population based twin study. *Journal of Autism and Developmental Disorders*, 39(8), 1197–1210. <https://doi.org/10.1007/s10803-009-0736-1>
- Ekstrom, R. B., French, J. W., Harman, H. H., & Dermen, D. (1976). *Kit of factor-referenced cognitive tests*. ETS Research and Development.
- Foreman, N. (1991). Correlates of performance on the Gollin and Mooney tests of visual closure. *The Journal of General Psychology*, 118(1), 13–20. <https://doi.org/10.1080/00221309.1991.9711129>
- Germine, L. T., Duchaine, B., & Nakayama, K. (2011). Where cognitive development and aging meet: Face learning ability peaks after age 30. *Cognition*, 118(2), 201–210. <https://doi.org/10.1016/j.cognition.2010.11.002>
- Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences*, 102, 74–78. <https://doi.org/10.1016/j.paid.2016.06.069>
- Hall, J. A., Horgan, T. G., & Murphy, N. A. (2019). Nonverbal communication. *Annual Review of Psychology*, 70(1), 271–294. <https://doi.org/10.1146/annurev-psych-010418-103145>
- Halliday, D. W. R., MacDonald, S. W. S., Sherf, S. K., & Tanaka, J. W. (2014). A reciprocal model of face recognition and autistic

- traits: Evidence from an individual differences perspective. *PLOS One*, 9(5), e94013. <https://doi.org/10.1371/journal.pone.0094013>
- Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Review*, 20(3), 290–322. <https://doi.org/10.1007/s11065-010-9138-6>
- Hoaglin, D. C., & Iglewicz, B. (1987). Fine-tuning some resistant rules for outlier labeling. *Journal of the American Statistical Association*, 82(400), 1147–1149. <https://doi.org/10.1080/01621459.1987.10478551>
- Jolliffe, T., & Baron-Cohen, S. (2001). A test of central coherence theory: Can adults with high-functioning autism or Asperger syndrome integrate fragments of an object? *Cognitive Neuropsychiatry*, 6(3), 193–216. <https://doi.org/10.1080/13546800042000124>
- Kanwisher, N., & Yovel, G. (2006). The fusiform face area: A cortical region specialized for the perception of faces. *Philosophical Transactions of the Royal Society B*, 361(1476), 2109–2128. <https://doi.org/10.1098/rstb.2006.1934>
- Kelley, K. (2007). Confidence intervals for standardized effect sizes: Theory, application, and implementation. *Journal of Statistical Software*, 20(8). <https://doi.org/10.18637/jss.v020.i08>
- Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry*, 59(9), 809–816.
- Lewis, M. B., & Ellis, H. D. (2003). How we detect a face: A survey of psychological evidence. *International Journal of Imaging Systems and Technology*, 13(1), 3–7. <https://doi.org/10.1002/ima.10040>
- McGrew, K. S. (2009). CHC theory and the human cognitive abilities project: Standing on the shoulders of the giants of psychometric intelligence research. *Intelligence*, 37(1), 1–10. <https://doi.org/10.1016/j.intell.2008.08.004>
- Meade, A. W., & Craig, S. B. (2012). Identifying careless responses in survey data. *Psychological Methods*, 17(3), 437–455. <https://doi.org/10.1037/a0028085>
- Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy, and Law*, 7(1), 3. <https://doi.org/10.1037/1076-8971.7.1.3>
- Minio-Paluello, I., Porciello, G., Pascual-Leone, A., & Baron-Cohen, S. (2020). Face individual identity recognition: A potential endophenotype in autism. *Molecular Autism*, 11(1), 1–81. <https://doi.org/10.1186/s13229-020-00371-0>
- Monk, R., Whitehouse, A. J. O., & Waddington, H. (2022). The use of language in autism research. *Trends in Neurosciences*, 45(11), 791–793. <https://doi.org/10.1016/j.tins.2022.08.009>
- Mooney, C. M. (1957). Age in the development of closure ability in children. *Canadian Journal of Psychology/revue Canadienne de Psychologie*, 11(4), 219–226. <https://doi.org/10.1037/h0083717>
- Morrison, K. E., Pinkham, A. E., Kelsven, S., Ludwig, K., Penn, D. L., & Sasson, N. J. (2019). Psychometric evaluation of social cognitive measures for adults with autism. *Autism Research*, 12(5), 766–778.
- Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, 36(1), 27–43. <https://doi.org/10.1007/s10803-005-0040-7>
- Newton, J. H., & McGrew, K. S. (2010). Introduction to the special issue: Current research in Cattell–Horn–Carroll–based assessment. *Psychology in the Schools*, 47(7), 621–634. <https://doi.org/10.1002/pits.20495>
- Pemberton, C. (1952). The closure factors related to other cognitive processes. *Psychometrika*, 17(3), 267–288.
- R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. <https://www.R-project.org/>. Accessed 2 Aug 2021
- Robertson, D. J., Jenkins, R., & Burton, M. A. (2017). Face detection dissociates from face identification. *Visual Cognition*, 25(7–8), 740–748. <https://doi.org/10.1080/13506285.2017.1327465>
- Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, 48(2), 1–36. Retrieved from <http://www.jstatsoft.org/v48/i02/>. Accessed 2 Aug 2021
- Russell-Smith, S. N., Maybery, M. T., & Bayliss, D. M. (2011). Relationships between autistic-like and schizotypy traits: An analysis using the Autism Spectrum Quotient and Oxford-Liverpool Inventory of Feelings and Experiences. *Personality and Individual Differences*, 51(2), 128–132. <https://doi.org/10.1016/j.paid.2011.03.027>
- Russell-Smith, S. N., Maybery, M. T., Bayliss, D. M., & Sng, A. A. H. (2012). Support for a link between the local processing bias and social deficits in autism: An investigation of embedded figures test performance in non-clinical individuals. *Journal of Autism and Developmental Disorders*, 42(11), 2420–2430. <https://doi.org/10.1007/s10803-012-1506-z>
- Sholl, M. J., & Egeth, H. E. (1982). Cognitive correlates of map-reading ability. *Intelligence (Norwood)*, 6(2), 215–230. [https://doi.org/10.1016/0160-2896\(82\)90015-0](https://doi.org/10.1016/0160-2896(82)90015-0)
- Sun, L., Grützner, C., Bölte, S., Wibrall, M., Tozman, T., Schlitt, S., Poustka, F., Singer, W., Freitag, C. M., & Uhlhaas, P. J. (2012). Impaired gamma-band activity during perceptual organization in adults with autism spectrum disorders: Evidence for dysfunctional network activity in frontal-posterior cortices. *The Journal of Neuroscience*, 32(28), 9563–9573. <https://doi.org/10.1523/jneurosci.1073-12.2012>
- The Jamovi Project. (2021). *Jamovi*. (Version 2.2) [computer software]. Retrieved from <https://www.jamovi.org>. Accessed 29 Jul 2021
- Verhallen, R. J., & Mollon, J. D. (2016). A new Mooney test. *Behavior Research Methods*, 48(4), 1546–1559. <https://doi.org/10.3758/s13428-015-0666-0>
- Verhallen, R. J., Bosten, J. M., Goodbourn, P. T., Lawrance-Owen, A. J., Bargary, G., & Mollon, J. D. (2017). General and specific factors in the processing of faces. *Vision Research*, 141, 217–227. <https://doi.org/10.1016/j.visres.2016.12.014>
- Vivek, P., Surendra, N., Singh, S. M., & Donovan, D. T. (2017). *Parallel analysis engine to aid in determining number of factors to retain using R [computer software]*. Retrieved from <https://analytics.gonzaga.edu/paralleleengine/>. Accessed 21 April 2022
- Von Karolyi, C., Winner, E., Gray, W., & Sherman, G. F. (2003). Dyslexia linked to talent: Global visual-spatial ability. *Brain and Language*, 85(3), 427–431. [https://doi.org/10.1016/S0093-934X\(03\)00052-X](https://doi.org/10.1016/S0093-934X(03)00052-X)
- Walker, D. L., Palermo, R., Callis, Z., & Gignac, G. E. (2023). The association between intelligence and face processing abilities: A conceptual and meta-analytic review. *Intelligence*, 96, 101718. <https://doi.org/10.1016/j.intell.2022.101718>
- Walker, D. L., Palermo, R., & Gignac, G. E. (2022). A structural equation model of face processing abilities, cognitive abilities and trait-autism. [Manuscript in Preparation]. School of Psychological Science, the University Of Western Australia.
- Walter, E., Dassonville, P., & Bochsler, T. M. (2009). A specific autistic trait that modulates visuospatial illusion susceptibility. *Journal of Autism and Developmental Disorders*, 39(2), 339–349. <https://doi.org/10.1007/s10803-008-0630-2>
- Wasserstein, J., Barr, W. B., Zappulla, R., & Rock, D. (2004). Facial closure: Interrelationship with facial discrimination, other closure tests, and subjective contour illusions. *Neuropsychologia*, 42(2), 158–163. <https://doi.org/10.1016/j.neuropsychologia.2003.07.003>
- Wechsler, D. (2008). *Wechsler adult intelligence scale* (4th ed.). Pearson.

- Wilmer, J. B. (2017). Individual differences in face recognition: A decade of discovery. *Current Directions in Psychological Science*, 26(3), 225–230. <https://doi.org/10.1177/0963721417710693>
- Wilmer, J. B., Germine, L. T., & Nakayama, K. (2014). Face recognition: a model specific ability. *Frontiers in Human Neuroscience*, 8. <https://doi.org/10.3389/fnhum.2014.00769>
- Zhang, G., Jiang, G.-., Hattori, M., & Trichtinger, L. (2019). *EFAutilities: Utility Functions for Exploratory Factor Analysis*. R package version 2.0.0. Available online at: <https://CRAN.R-project.org/package=EFAutilities>. Accessed 21 April 2022

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