Autistic traits and visual processing: Effect of target and contextual features on visual disembedding

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Abstract

Individuals with autism spectrum disorder (ASD) have been shown to possess better visual disembedding abilities than neurotypical controls as indicated by their superior performance on visual search tasks like the Embedded Figures Test. Previous research also suggests that this visual processing advantage may exist in individuals with high levels of autistic traits from the general population as well, albeit to a lesser extent. However, not all studies have found an association between sub-clinical autistic traits and visual search performance, so it remains unclear if this visual processing advantage seen in clinical ASD populations does indeed extend into the general population. In addition, it is yet to be examined how different stimulus and context features affect a target’s embeddedness and whether there are differences between individuals high and low on autistic-like traits, respectively, in how much embeddedness hinders their disembedding abilities. Therefore, the current study investigated the association between autistic-like traits and visual disembedding. The Autism-Spectrum Quotient (AQ) was used to assess autistic-like traits of 163 university students. Participants completed the Leuven-Embedded Figures Test (L-EFT), a visual search task that systematically manipulates different stimulus features, including target complexity and embedding context. A low and a high AQ group were created using the lower and upper 15% of AQ scores, respectively. No significant differences between the groups were found in overall performance on the L-EFT or in the degree to which the groups were hindered in their performance by stronger embeddedness. The results suggest that the superior disembedding abilities found in clinical ASD individuals do not extend into the general population.

Keywords: Embedded figures, L-EFT, Autism-Spectrum Quotient, Disembedding, Visual processing, Autistic-like traits
Introduction

Autism spectrum disorder (ASD) is a pervasive neurodevelopmental disorder characterized by impaired social and communication skills, narrow interests, and repetitive behaviors. The DSM-5 (American Psychiatric Association, 2013), unlike its predecessor the DSM-IV (American Psychiatric Association, 2000), considers autism to be a continuous condition ranging from milder to more severe forms, as expressed by the term “spectrum disorder”. In addition, with the publication of the DSM-5 in 2013, atypical sensory experiences, such as hyper- and hyporesponsiveness to sensory stimuli, were added as additional diagnostic criteria (American Psychiatric Association, 2013). These symptoms do not occur merely as a consequence of limited social interactions, but rather appear early in development and are predictive of the social and communicative abnormalities seen later in life (Robertson & Baron-Cohen, 2017).

One area of sensory processing that shows alterations in ASD is visual processing. Individuals differ in which type of information of a visual scene they rely on to guide their cognition. Some people see parts of a whole more easily and are able to mentally separate stimuli from background information. This cognitive style is called field-independent. On the other end of this spectrum are individuals with a field-dependent cognitive style. For them, it is more difficult to disentangle individual pieces of information from the background; they tend to see the whole of something rather than its parts (Witkin & Goodenough, 1977). Individuals with autism tend to be field-independent. One study included male children from England between the ages of 8 and 12, of which 11 had been diagnosed with ASD prior to the study and 13 were neurotypical. The authors found that the group with ASD showed a more field-independent processing style than their neurotypical counterparts. However, the study also included a Singaporean sample, where this difference was not found (Koh & Milne, 2012).
Another way to conceptualize this difference in visual processing is by distinguishing global versus local processing styles. These concepts are related to those of field-dependence and field-independence and are sometimes used interchangeably. Local processing is similar to field-independence. It refers to the tendency of seeing the constituent parts of something, instead of and at the expense of the whole itself; or as it is often described “seeing the trees but not the forest”. Global processing, on the other hand, is similar to field-dependence and refers to the process of grouping individual pieces of a visual scene together to form a meaningful whole. Individuals with ASD tend to have reduced global processing abilities. This was shown, for instance, in a study that compared 290 twins, between 8 and 31 years old, of which 64 had been diagnosed with ASD. The authors found that ASD diagnosis predicted lower performance on a global processing task (Neufeld et al., 2020). On the other hand, individuals with ASD have sometimes been shown to have enhanced local processing abilities. One study, for example, compared 3-year-old children with and without ASD on how many star- and X-shapes they could find in a colorful image. The authors found that the ASD group performed significantly better than the control groups on this task and inferred superior local processing skills. However, other measures of local processing used in this study yielded no significant differences (Nilsson Jobs et al., 2018). A recent meta-analysis concluded that, rather than being generally unable to use global processing strategies, individuals with ASD merely find this more difficult, when local elements are present in a visual scene (Van Der Hallen et al., 2015).

Global/local processing and field-dependence/field-independence can be assessed with different tests. One of the most frequently used tests is the Embedded Figures Test (EFT). During this test, participants are shown a card depicting a geometrical shape made up of lines. They are then required to discover this shape in an embedding context on a different card and trace its outline to demonstrate that they have found the shape. There are 12 trials in total and performance is usually judged both in terms of error rate as well as average response time.
Discovering the simple shape is difficult because it blends in with the background and appears as being embedded into it; it is perceived as a Gestalt, i.e. a meaningful whole. Mentally inhibiting formation of this Gestalt is easier for people who have a local/field-independent processing style (Witkin, 1971).

Many studies have shown that individuals with ASD tend to perform better on the EFT than the general population. The first to discover this were Shah and Frith (1983). They used a version of the EFT designed for children and found that autistic children gave more accurate responses than neurotypical controls and mildly mentally disabled controls. Another study, although unable to replicate the higher accuracy rates, showed that autistic adults finished the task in a shorter time than controls (Jolliffe & Baron-Cohen, 1997). More recently, this was shown again in a study comparing thirteen 12- to 15-year-old males diagnosed with ASD to age-matched controls on their performance on the EFT. The autistic children gave faster and more accurate answers (Brosnan et al., 2012). However, not all studies have been able to find these differences in EFT performance. One study used two relatively large samples, one containing 45, the other 62 children with ASD, and compared their performance on the EFT to that of matched controls. No significant differences were found, neither in accuracy nor in response time (RT), even when accuracy was included as a covariate in the RT analyses (White & Saldaña, 2011). A meta-analysis compared results from 35 studies about autists’ performance on the EFT. Despite large heterogeneity in the results they analyzed, they did find a small, but significant effect indicating that individuals with ASD performed better than controls on the EFT (Muth et al., 2014). However, another recent meta-analysis investigating local versus global visual processing in ASD did not find this difference in performance, neither in accuracy, nor in RT, between ASD and neurotypical individuals (Van Der Hallen et al., 2015). The latter meta-analysis included 19 samples, the majority of which were also included in Muth et al., and employed stricter inclusion criteria, which may be the reason for these discrepant findings. Overall, the argument that individuals diagnosed with ASD
outperform individuals from the general population on the EFT still seems to hold, although, as shown by these meta-analyses, conclusiveness cannot be said to have been reached.

Since the publication of the DSM-5 (American Psychiatric Association, 2013), ASD is considered a spectrum disorder including conditions of varying degrees of symptom severity. In addition, some of the symptoms appear to continue into the neurotypical population (Ruzich et al., 2015). One way to assess autistic traits in the general population, is to administer the Autism-Spectrum Quotient (AQ). The AQ is a self-report questionnaire that can be used to measure sub-clinical traits of autism. It assesses five subdomains, namely social skills, attention switching, attention to detail, communication, and imagination. People high on autistic traits generally show low levels of social skills, have problems with attention switching, pay relatively more attention to details, have low levels of communication skills, and have a poor imagination (Baron-Cohen et al., 2001). The AQ has been shown to reliably distinguish between individuals who warrant a diagnosis of ASD and those who do not (Woodbury-Smith et al., 2005).

Since individuals with a clinical diagnosis of ASD typically perform better on the EFT than their neurotypical peers (e.g. Brosnan et al., 2012; Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983), it is imaginable that this superior performance can also be found in people with high, but subclinical, levels of autistic traits. This was indeed found in a few studies conducted on the topic. One study compared the EFT performance of students selected for their high scores on the AQ with those selected for their low AQ scores. The high scorers gave faster and more correct answers (Grinter et al., 2009). These results were replicated and extended by Russell-Smith et al. (2012); they showed that it is specifically high scores on the social skills subscale of the AQ that are related to superior EFT performance (Russell-Smith et al., 2012). Cribb et al. (2016) meta-analyzed 12 studies that compared EFT performance to AQ score and concluded that the high AQ-scorers superiority on the EFT was consistently found, as long as participants were split into two groups: those scoring low on the AQ and
those scoring high on the AQ (i.e. having lower/higher levels of sub-clinical autistic traits, respectively). No such difference was found, if AQ scores were assessed as a continuous variable. This is possibly due to the fact that, by including more participants from the middle of the AQ score range, fewer participants with extreme (low or high) AQ scores are included. This, in turn, results in less variance in autistic traits and makes finding an effect more difficult. In addition, it has been shown that the more extreme the groups that are being compared are in terms of AQ scores, the more power the study design will have (Cribb et al., 2016).

Recently, an altered version of the EFT, the Leuven-Embedded Figures Test (L-EFT, de-Wit et al., 2017) was developed in order to identify what exactly causes a figure to be embedded. This allows for interpretations that go beyond a mere distinction between local and global processing styles, and rather shows how different stimulus features affect disembedding abilities. To achieve this, different features of the target shape (symmetry, closure, number of target lines) were systematically manipulated. In addition, the embedding context was manipulated by varying the number of lines continued into the background. This was believed to affect embeddedness because lines tend to be perceived to continue into their original direction, which can make them appear as being part of a longer line and therefore harder to detect in a visual scene. The authors found that more accurate answers were given if the embedded shapes were symmetric, if they consisted of more lines, and if fewer lines continued into the background. These three manipulations also led to shorter RTs. The manipulation of closure showed a discrepancy between accuracy and RT. While participants gave answers more quickly in trials with closed figures, open figures yielded more correct responses. The latter finding was only significant when a time limit was introduced to the task (de-Wit et al., 2017). A second study was not able to replicate the finding that openness and symmetry affected accuracy (Van der Hallen et al., 2018). More research using the L-EFT seems to be necessary.
Building on earlier research showing superior performance in individuals with ASD on the original EFT (e.g. Brosnan et al., 2012; Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983), the L-EFT was used in a study comparing disembedding abilities of autistic children, between the ages of 8 and 15 years, with that of age-matched neurotypical controls. The results showed that the children diagnosed with ASD consistently performed more accurately than the control group. Furthermore, as was already shown by de-Wit et al. (2017), the more lines continued into the background the lower the accuracy was. However, although children with ASD were also negatively affected in their performance by more continued lines, the effect was smaller than it was for neurotypical controls, suggesting that stronger embeddedness caused less of a hindrance for the ASD group (Van der Hallen et al., 2018).

Due to its novelty, the L-EFT has never been used in a non-clinical population sample in combination with the AQ. It remains to be seen if individuals with high sub-clinical levels of autistic traits will show superior performance on the L-EFT in the same way that studies have found it to be the case on the traditional EFT (Grinter et al., 2009; Russell-Smith et al., 2012). If a similar visual processing advantage exists, albeit to a lesser degree, in the general population, it will be another argument in favor of viewing ASD, and specifically the visual processing aspect of it, as a dimensional, rather than a categorical construct.

The aim of the current study was to explore whether individuals with high AQ scores differ in their performance on the L-EFT from individuals with low AQ scores and whether a correlation exists between L-EFT performance and AQ score. Both tests were independently administered to a group of first-year students. A low and a high AQ group were created using the lower and upper 15% of AQ scores, as this has been shown to be the most powerful study design (Cribb et al., 2016). The majority of research findings outlined above revealed a positive correlation between ASD or high levels of autistic traits and performance on different versions of the EFT. Therefore, it is expected that participants with high AQ scores will perform better on the L-EFT compared to those with low AQ scores. Performance will be
judged both by accuracy and response time (RT) with high accuracy and low RT indicating good performance. Hence, it is expected that participants with higher accuracy rates will have shorter RTs. Furthermore, based on the results by van der Hallen et al. (2018), it is hypothesized that AQ score will moderate how much embedding context, as indicated by number of lines continued into the background, will be a hindrance for correct perception. It is expected that more complex embedding contexts, i.e. increased embeddedness, will lead to a decrease in accuracy for both groups, however, this decrease is expected to be smaller for the high AQ group. Finally, de-Wit et al. (2017) showed that figures consisting of fewer target lines, i.e. less complex targets, were recognized later and less accurately and were therefore believed to be perceived as more embedded by participants. Assuming that this finding will be replicated, it is hypothesized that the high AQ group will show a smaller decrease in accuracy than the low AQ group as targets get more complex.

Method

Participants

A total of 163 psychology students of Tilburg University participated in this study. Eight participants were excluded due to missing data. The mean age of the final sample of 155 participants (132 female, 22 male) was 19.34 (SD = 2.5). The participants were naïve to the research question and purpose of the study. The experiment was conducted in accordance with the ethical standards of the Declaration of Helsinki, as well as approved by the Ethics Review Board of the School of Social and Behavioral Sciences of Tilburg University (EC-2016.48). Written informed consent from participants was obtained prior to the experiment. All participants were awarded a total of 1 course credit in hours in exchange for their participation. Due to the COVID-19 pandemic and the resulting social distancing measures,
this study was conducted entirely online. Participants used their own computers or laptops at their home.

**ASD trait assessment**

ASD traits were assessed using an online version of the Autism-Spectrum Quotient (AQ) in Qualtrics. The AQ is a self-report questionnaire that measures autistic-like traits. It consists of five subscales, each consisting of ten statements: social skills (e.g. “I find it hard to make new friends”), attention switching (“I prefer to do things the same way over and over again”), attention to detail (“I often notice small sounds when others do not”), communication (“When I talk on the phone, I’m not sure when it’s my turn to speak”), and imagination (“When I’m reading a story, I find it difficult to work out the characters’ intentions”). High levels of autistic-like traits are inferred from low social skills, problems with attention switching, strong attention to detail, poor communication skills, and a relative lack of imagination. Subjects answer on a 4-point Likert-scale, including the answer options “definitely agree”, “slightly agree”, “slightly disagree” and “definitely disagree”. Half of the items are formulated in a way that someone scoring high on autistic traits would disagree with the statement, whereas the other half are formulated to elicit agreement in someone high on autistic traits. Every statement is scored with either 0 or 1 and hence, scores on each subscale range from 0 to 10 and overall scores range from 0 to 50, with 50 representing the most autistic-like traits. A score of 32 is generally used as the cut-off score to distinguish subclinical levels of autistic traits from a potential clinical diagnosis of ASD (Baron-Cohen et al., 2001). Participants completed the AQ and the L-EFT separately and were unaware of the fact that both parts belonged to the same study.

**L-EFT**

An online version of the recently developed L-EFT (de-Wit et al., 2017) was administered using the OSWeb extension of OpenSesame (Mathôt et al., 2012).

**Stimulus materials**
Stimuli were presented on a white background in the center of a computer screen. The stimuli consisted of 16 simple black line drawings (target shapes) that differed in three aspects. Firstly, the line drawings could be either symmetrical or asymmetrical around their vertical axis. Secondly, the target shapes were either closed or open. Lastly, the drawings consisted of either three, four, six, or eight lines (target complexity). Each target shape was embedded in four different contexts that varied in how many of the target’s lines continued into the background. The number of continued lines was 0,1,2, or 3 (for drawings consisting of three target lines), 0,1,2, or 4 (for drawings consisting of four target lines), 0,2,4, or 6 (for drawings consisting of six target lines), or 0,4,6, or 8 (for drawings consisting of eight target lines). The target shape in the embedding context was never rotated or scaled and never embedded more than once in a single context. Some embedding contexts contained additional lines across the target shape. The different conditions, i.e. 16 different target shapes and four embedding contexts, resulted in 64 unique trials. An overview of the variables and conditions is presented in Table 1. In each trial two additional contexts with the same number of lines as the embedding context that contained the target were presented that did not contain the target shape in any form. These acted as distractors. Neither the target shapes, nor the contexts contained curved lines and could not be perceived as 3-dimensional. An example of a target shape, embedding context containing the target, and two distractor contexts is shown in Figure 1. The complete stimulus set is publicly available (https://dx.doi.org/10.6084/m9.figshare.3807885, https://dx.doi.org/10.6084/m9.figshare.3807894).
Table 1 Overview of variables and conditions

<table>
<thead>
<tr>
<th>Target lines</th>
<th>Number of lines continued into the background for each embedding context</th>
<th>Closure</th>
<th>Symmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0,1,2, or 3</td>
<td>Open/Closed</td>
<td>Symmetrical/Asymmetrical</td>
</tr>
<tr>
<td>4</td>
<td>0,1,2, or 4</td>
<td>Open/Closed</td>
<td>Symmetrical/Asymmetrical</td>
</tr>
<tr>
<td>6</td>
<td>0,2,4, or 6</td>
<td>Open/Closed</td>
<td>Symmetrical/Asymmetrical</td>
</tr>
<tr>
<td>8</td>
<td>0,4,6, or 8</td>
<td>Open/Closed</td>
<td>Symmetrical/Asymmetrical</td>
</tr>
</tbody>
</table>

Procedure

All 64 conditions were presented to each participant in randomized order. Every trial was shown just once. Once the experiment started, participants were shown one of the target shapes at the top of the screen and three context drawings at fixed positions at the bottom: the correct embedding context and two distractors. The location of the correct embedding context was randomized across trials. The embedding contexts were numbered 1, 2, and 3 from left to right and participants pressed either 1, 2, or 3 on their keyboard depending on the location of the correct embedding context. They were instructed to respond as accurately and as quickly as possible, but no time limit was imposed. After they had pressed one of the keys, the experiment resumed; no feedback was provided about whether they had responded correctly or incorrectly. Completion of the L-EFT took approximately 10 minutes.
Figure 1 Example of a target shape with two distractor contexts (1 and 2) and the correct context containing the target shape (3).

Statistical analyses

Statistical analyses were carried out using IBM SPSS Statistics 25. Analyses were focused on two of the four variables that had initially been manipulated, namely number of target lines (target complexity) and number of lines continued into the background (embedding context). Both variables had four levels, which resulted in 16 unique trials with four repetitions. Correlations were calculated between AQ score and accuracy, as well as between AQ score and average RT. Furthermore, repeated measures analyses of variance (ANOVA) were performed on both the accuracy data, as well as the RT data, with target complexity and embedding context as within-subject factors, and AQ group (low, high) as between-subjects factor. In case the sphericity assumption was violated, a Greenhouse-Geisser correction was applied, in which case ε-values, corrected p-values and uncorrected degrees of freedom are reported. In the case of significant interaction effects, post hoc analyses using Bonferroni-corrected paired samples t-tests were conducted.
Results

L-EFT

Descriptive statistics of participants’ overall performance on the L-EFT are presented in Table 1. On average participants took 4.77 seconds to identify the embedding context that contained the target shape ($SD = 2.02$) and performed accurately in 89.64% of the trials ($SD = 5.93$). No participants made any “fast errors”, i.e. inaccurate trials in which they answered within 1.5 seconds and no participants performed below the chance level of 33%. These data show that participants were able to adhere to the instructions and perform the task correctly.

Table 1 Descriptive statistics of overall performance on the L-EFT

<table>
<thead>
<tr>
<th></th>
<th>Average accuracy (SD)</th>
<th>Average response time (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full sample (N = 155)</td>
<td>89.64% (6.23)</td>
<td>4.77s (2.02)</td>
</tr>
<tr>
<td>High AQ (n = 24)</td>
<td>90.23% (6.17)</td>
<td>4.03s (1.53)</td>
</tr>
<tr>
<td>Low AQ (n = 24)</td>
<td>88.47% (5.58)</td>
<td>4.03s (1.53)</td>
</tr>
</tbody>
</table>

Autism spectrum quotient

The mean AQ score of the included sample was 15.9 ($SD = 6.1$). This is in line with scores found in earlier studies assessing AQ in the general population (Ruzich et al., 2015). As can be seen in Figure 2, the AQ scores were approximately normally distributed. Low and high AQ groups were defined using the lower and upper 15% of AQ scores as cut-offs, respectively, as it has been shown that using these percentiles results in the highest power to detect a relationship between autistic traits and disembedding abilities (Cribb et al., 2016). Descriptive statistics of the AQ for the entire sample and two subgroups are presented in Table 2. In the current sample, the low AQ group included scores of 10 or below and initially consisted of 30 participants, whereas the high AQ group included scores of 23 or above and consisted of 24 participants. In order to ensure equal group sizes for subsequent repeated measures ANOVA, six participants from the low AQ group were randomly selected and
excluded from subsequent statistical analyses, resulting in a total of 24 participants in the low and high AQ group, respectively.

**Table 2** Descriptive Statistics Autism Spectrum Quotient

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full sample (N = 155)</td>
<td>15.9 (6.1)</td>
<td>3-31</td>
</tr>
<tr>
<td>High AQ (n = 24)</td>
<td>26.2 (2.7)</td>
<td>23-31</td>
</tr>
<tr>
<td>Low AQ (n = 24)</td>
<td>8.0 (2.0)</td>
<td>3-10</td>
</tr>
</tbody>
</table>

**Figure 2** Distribution of AQ scores in the included sample (N = 155). The lower and upper 15% are highlighted in dark.

**Autistic traits and L-EFT performance**

There was no correlation between AQ score and average RT $r(153) = .14, p = .07$ and no correlation between AQ score and average accuracy $r(153) = .13, p = .12$. Using independent-samples t-tests, a marginally significant difference in RT was found between the low and the high AQ group $t(40.014) = -2.04, p = .048$. The difference in accuracy between
the low and high AQ group was not significant $t(46) = -1.04, p = .31$. In order to examine whether target complexity and embedding context differently affected L-EFT performance in the low and high AQ group, several repeated measures ANOVAs were conducted.

**Speed-accuracy trade-off**

A strong correlation was found between accuracy and RT, $r(153) = .56, p < .001$. Therefore, statistical analyses were performed both on accuracy and RT for accurate trials.

**Accuracy**

A repeated measures ANOVA on the accuracy data was conducted with target complexity (indexed by the number of target lines; 3,4,6,8) and embedding context (1,2,3,4) as within-subject factors, and AQ group (low, high) as between-subjects factor. Significant main effects of embedding context ($F(3, 138) = 62.802, p < .001, \eta^2_p = .58, \epsilon = .61$), and target complexity $F(3,138)=3.51, p < .05, \eta^2_p = .07$ on accuracy were found. As embedding contexts got more complex, the accuracy rate decreased, as would be expected from a successful manipulation of this feature. In the case of target complexity, accuracy was highest for trials with three target lines, however, it was lower for four target lines than for six or eight target lines.

There was no significant main effect of AQ score on accuracy $F(1,46) = 1.07, p = .31$, indicating that the low AQ group and the high AQ group performed similarly in terms of accuracy across trials. Neither the interaction between embedding context and AQ group $F(3, 138) = 0.91, p = .40$, nor that between target complexity and AQ group $F(3, 138) = 62.80, p=.84$ reached significance, suggesting that the low AQ group and the high AQ group were affected in a similar way by differences in embedding context and differences in number of target lines. These effects are visually displayed in Figures 3 and 4.
Figure 3 Effect of embedding context on accuracy for low AQ and high AQ; error bars represent +/- one standard error of the mean.

Figure 4 Effect of target complexity on accuracy for low AQ and high AQ; error bars represent +/- one standard error of the mean.

The three-way interaction between target complexity, embedding context, and AQ group was not significant $F(9, 414) = .83, p = .56$. 

A significant interaction effect was found between embedding context and target lines $F(9, 414) = 12.98, p < .001, \eta^2_p = .22, \varepsilon = .70$. This shows that the embedding context affected accuracy differently depending on the number of target lines and vice versa. Post-hoc analyses, using Bonferroni-corrected pairwise comparisons, were conducted to compare the effect of embedding context on accuracy at each level of target lines. In the case of three target lines, a significant difference was only found between embedding context 1 and 2 ($p < .05$) and between embedding context 1 and 4 ($p < .05$). In the case of four target lines, the only nonsignificant difference was between embedding context 2 and 3 ($p = 1.00$). In the case of six target lines, embedding contexts 1 and 2 were not significantly different ($p = .58$), neither were embedding contexts 3 and 4 ($p = .91$). Finally, in the case of eight target lines, the only embedding contexts that were not significantly different were 1 and 2 ($p = .06$) and 2 and 3 ($p = .17$).

**Response time**

A repeated measures ANOVA on the RT data was conducted with target complexity (indexed by the number of target lines; 3,4,6,8) and embedding context (1,2,3,4) as within-subject factors, and AQ group (low, high) as between-subjects factor. There was a significant main effect of embedding context on RT $F(3, 138) = 79.68, p < .001, \eta^2_p = .63, \varepsilon = .53$ indicating that, as expected, RTs were increased for more complex embedding contexts. A significant main effect was also found for target complexity $F(3, 138) = 36.90, p < .001, \eta^2_p = .45, \varepsilon = .50$. Response times were longer when targets consisted of more lines.

The main effect of AQ group just failed to reach significance $F(1,46) = 3.75, p = .06$, indicating that the low AQ group and high AQ group performed similarly in terms of overall RT across trials. In addition, no significant interaction effect between embedding context and AQ group on RT was found $F(3, 138) = 1.40, p = .25$. This suggests that embedding context did not affect RT differently for the high and the low AQ group. This is visually displayed in Figure 5. There was also no significant interaction between target complexity and AQ score.
$F(3, 138) = 1.92, p = .16$. Hence, the effect that the number of target lines had on RT was the same for the high and the low AQ group. This is shown in Figure 6.

**Figure 5** Effect of embedding context on RT for low AQ and high AQ; error bars represent +/- one standard error of the mean

**Figure 6** Effect of target complexity on RT for low AQ and high AQ; error bars represent +/- one standard error of the mean
The three-way interaction between target complexity, embedding context, and AQ group was also not significant $F(9, 414) = .72, p = .55$.

A significant interaction effect was found between embedding context and target lines ($F(9, 414) = 10.558, p < .001, \eta^2_p = .19, \epsilon = .36$), indicating that the effect that the embedding context had on the RT depended on the number of target lines and vice versa. Post-hoc analyses, using Bonferroni-corrected pairwise comparisons, were conducted to compare the effect of embedding context on RT at each level of target lines. In the case of three target lines, all embedding contexts significantly differed from one another. In the case of four target lines, the only nonsignificant difference was between embedding context 2 and 3 ($p = .64$). In the case of six target lines, only embedding context 1 and 2 were not significantly different ($p = .10$). Finally, in the case of eight target lines, only embedding context 3 and 4 did not differ significantly ($p = .10$).

**Discussion**

The current study investigated the association between autistic traits and visual disembedding abilities in the general population. First year university students scoring high on the AQ were compared to those scoring low on the AQ on their performance on the recently-developed L-EFT, which systematically manipulates different stimulus features believed to affect the degree of embeddedness. It was examined whether complexity and stronger embeddedness of the target stimulus hindered L-EFT performance of individuals with high AQ scores less than that of individuals with low AQ scores. Performance on the L-EFT was measured both in terms of accuracy and RT.

Previous studies have shown that those with more autistic-like traits, as indicated by higher AQ scores, tend to give more correct responses on the EFT (Grinter et al., 2009; Russell-Smith et al., 2012). Therefore, it was expected that participants who scored high on the AQ would answer more accurately on the L-EFT as well. However, the results revealed
that accuracy did not depend on the AQ score of the subjects and equally many correct answers were given by individuals with low and high levels of sub-clinical autistic traits. Furthermore, if targets contained more lines that continued into the background (i.e. the embedding context was more complex), they were harder to disembed, as shown by the fact that fewer participants answered correctly on those trials. However, opposite to what was expected, this stronger embeddedness caused just as much of a hindrance to the high AQ group as it did to the low AQ group. As can be seen in Figure 3, plotting the data, however, suggests that participants with higher AQ scores did tend to have higher accuracy rates than low AQ scorers as the targets became more embedded, i.e. in the trials with more complex embedding contexts. Even though this effect was not significant in the current sample, it is conceivable that by including more participants in the sample, a significant difference would have emerged. This would replicate the findings from Van der Hallen et al. (2018), who found that children with ASD performed better overall and in the three most complex embedding contexts. However, the effects they found, although significant, were small. Therefore, it is likely that potentially existing group differences would be even smaller in a non-clinical population, which would indeed require a larger sample size in order to detect them. In addition, the study by Van der Hallen et al. (2018) looked at L-EFT performance in autistic children. It has been shown that symptoms of autism tend to abate between childhood and adolescence/adulthood (Seltzer et al., 2003). This might lead to even smaller group differences in adulthood, which in turn might be another reason why no significant differences were found in the current study, which used adult participants. Lastly, contrary to what was expected, participants with high AQ scores were affected in their accuracy rates by changes in target complexity in a similar way as participants with low AQ scores were. However, despite not reaching significance, the high AQ group tended to perform slightly better in trials with more complex targets, suggesting that they might have been less hindered by this increase in target complexity. If differences do indeed exist, however, they are likely
to be very small, as can be seen in Figure 4. Noteworthy, the effect that target complexity had on participants’ performance in this study was different from that found by de-Wit et al. (2017). They found that more complex targets made a shape easier to detect. In the current study, no clear pattern in terms of accuracy and target complexity emerged. For example, accuracy rates were highest for targets consisting of three lines, i.e. the least complex targets. Targets consisting of four lines, not six or eight, on the other hand, yielded the lowest accuracy rates. De-Wit et al. (2017) hypothesized that a more complex target, i.e. a target which consists of more lines, can more easily be detected, because it is a more “unique appearance” within the embedding context and therefore easier to locate. However, the current study shows that this is not necessarily the case. Future research should investigate further whether simple (consisting of few lines) or complex (consisting of many lines) targets are more easily detectable, i.e. perceived as less embedded and whether this manipulation makes a difference in performance of autistic versus neurotypical individuals.

Overall, the current study provides evidence that individuals with more autistic-like traits do not show superior disembedding abilities compared to those with low levels of autistic-like traits, although the results do point in the direction that they might perform slightly better on the L-EFT.

It was also expected that the higher participants’ AQ score was, the lower their RT would be since being able to not only detect a target correctly, but also in a short amount of time may be considered an indicator of a good performance. The results that were found, however, were not in line with this expectation. No clear difference was found between the high and the low AQ group in the time they took to give correct answers on the L-EFT. The test of this group difference just barely failed to reach significance, which may be because the sample size was too small. As can be seen in Figure 5 and Figure 6, it seems that, if a difference does indeed exist between the two groups in terms of RT, it would more likely be in the opposite direction of what was expected; people scoring high on the AQ seem to take
more, rather than less time, to give correct answers. In addition, this study looked at whether there are any differences in how strongly increasingly complex embedding contexts (i.e. lines continuing into the background) affect the RTs of the low and high AQ group. All participants took longer to detect targets of which more lines continued into the background (i.e. targets embedded in more complex embedding contexts), but, contrary to what had been expected, this prolonged RT was present in the high AQ group just as much as it was in the low AQ group. This suggests that both groups were hindered by stronger embeddedness, due to more complex embedding contexts, to a similar extent. Lastly, it was found that all participants took longer to respond in trials with more complex targets (made up of more lines). This was equally the case for the low and the high AQ group, although as suggested by Figure 6, while the high AQ group took longer than the low AQ group at all levels of target complexity, the difference in RT seems to get slightly larger as targets became more complex.

These results are generally in accord with what was discovered by Van der Hallen et al. (2018) in their comparison of children with ASD and neurotypical controls. When looking at overall performance on the L-EFT they, too, did not find a difference in RT, but in the trials with more complex embedding contexts (i.e. more lines continued into the background) subjects with ASD showed longer RTs. In addition, they investigated performance on two related embedded figures tasks, the meaningful-embedded figures test (M-EFT) and the three-dimensional embedded figures test (D-EFT) and found that the group with ASD took longer to give correct answers on these tasks as well. However, the current results contrast with earlier studies (e.g. Grinter et al., 2009; Russell-Smith et al., 2012), using the original EFT, which have found individuals with high subclinical levels of autistic traits to give correct responses more quickly. Shorter RTs on the EFT have also been reported in clinical ASD populations (Brosnan et al., 2012; Jolliffe & Baron-Cohen, 1997), although not every study has been able to replicate this result (White & Saldaña, 2011).
Although there was no significant difference in performance on the L-EFT (both in terms of accuracy and RT) between the high and low AQ group, in the current study, the results do point into a certain direction. Having a higher score on the AQ might be associated with giving more accurate responses on the L-EFT but taking more time to give them. Because of the longer RTs, it may be speculated that participants from the high AQ group were more conscientious during the task, expressed by a high level of diligence and desire to perform well. Some prior research has found a correlation between conscientiousness and the attention-to-detail subscale of the AQ (Austin, 2005; Schweinberger et al., 2020). However, other studies have found that full-scale AQ was negatively correlated with conscientiousness (Wakabayashi et al., 2006) or not correlated to conscientiousness (Ingersoll et al., 2011).

Whether a correlation between autistic traits and conscientiousness exists in the general population and whether it could explain the current findings that individuals with high AQ scores take longer to respond on the L-EFT remains to be examined in future research.

Taken together, the current study provides additional evidence for the view that individuals with more autistic-like traits do not have the ability to disembed shapes faster than neurotypical controls and, if anything, may even need more time to do so.

It is possible that the results of the current study would have reached significance if a larger sample size had been used. However, when comparing the current study to earlier studies comparing EFT performance of high and low AQ scorers (see Cribb et al., 2016 for a meta-analysis), which did find significant differences between the two groups, it can be seen that group sizes were generally similar to that included in this study. Furthermore, it may be speculated that the high percentage of female participants affected the results of the current study. It has been shown that males in the general population show higher levels of autistic-like traits, as indicated by higher scores on the AQ (Ruzich et al., 2015). By including fewer male than female participants the range of included AQ scores may have been restricted and the high and low AQ group may have been too similar to each other. However, as was the
case with sample size, the current sample did not differ from those included in earlier studies in its gender distribution; in the majority of studies more participants were female and significant differences could still be found. In addition, the mean AQ scores of the low and the high groups, respectively, were similar to those found in earlier studies (e.g. Almeida et al., 2010, 2013; Russell-Smith et al., 2010).

Perhaps a more plausible explanation for the current findings is that, on average, participants gave close to 90% correct answers on the L-EFT, which suggests that the task was not very difficult for most participants. This might be due to the fact that all participants were university students and therefore can be assumed to have above-average levels of intelligence, although this was not specifically assessed. Prior research has shown that performance on different types of embedded figures tests often positively correlates with measures of general intelligence, i.e. individuals of higher intelligence tend to perform better on the EFT (see McKenna, 1984 for an overview). This might explain why the average accuracy rate was so high and why no significant differences were found between the two groups.

If truly no difference exists between low and high AQ scorers in their performance on the L-EFT, this would have implications for the understanding of ASD as a continuous condition and its assumed extension into the general population. Prior research suggests that superior visual processing skills may be correlated with symptom severity in clinical ASD populations. One study found that superior nonverbal skills, including visual processing, are associated with more severe social deficits in populations of individuals with clinically diagnosed ASD (Joseph et al., 2002). More specifically, it has also been found that higher levels of social symptoms are associated with better performance on visual search tasks (Joseph et al., 2009). These results suggest a continuity of visual processing abilities within clinical populations. In addition, it has been shown that autistic-like traits do extend into the general population (Ruzich et al., 2015). However, in light of the current study, it is
conceivable that some of the disorder’s features, including superior visual processing or more specifically superior disembedding abilities, might be categorical rather than dimensional and only exist on a continuum within clinical populations. More research is needed to clarify which symptoms of ASD continue into the general population.

A few limitations of the current study should be mentioned. Due to the COVID-19 pandemic and the associated social distancing measures, it was not possible to let participants take part in the study in a controlled environment. Instead, online versions of the L-EFT and the AQ were administered and participants were instructed to use their own computers. Realistically the differences in testing environments should not be too dramatic. Still, it cannot be ruled out entirely that differences in hardware (e.g. monitor size) between participants might have affected the test results. In addition, some participants might have been less able to focus than others in their own home environment. This might also explain the fact that RTs in the current study were on average about twice as long as those reported in the original study using the L-EFT by de-Wit et al. (2017). A strength of the current study is the use of the new L-EFT, instead of the original EFT, which allowed for not only testing of participants’ overall performance, but also assessing the degree to which they were affected by different stimulus manipulations. In addition, this has brought to light that more research is needed to identify precisely how target complexity affects embeddedness and detectability of a shape. Furthermore, future research could assess performance on the L-EFT in a clinical ASD sample of participants with different levels of symptoms severity. Since individuals with more severe symptoms, specifically social symptoms (Joseph et al., 2002, 2009), may have even better visual processing abilities than those with less severe symptoms, it would be interesting to see if those individuals would be less affected by target complexity and embedding context. This would help in understanding which aspects of superior visual disembedding abilities exist on a continuum in ASD and which are categorical.
Conclusion

The current study did not find a difference in performance on the L-EFT, neither in terms of accuracy nor response time, between individuals with high and low levels of sub-clinical autistic traits. This suggests that, contrary to what has been found in some prior studies, the superior disembedding abilities found in clinical ASD populations might not extend into the general population, but instead, might be a categorical feature of ASD.
References


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