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Psychometric characteristics of the AQ-Adolescent in autistic and non-autistic adolescents

Marieke de Vries [a,b,*,1], Sander Begeer [c,2], Hilde M. Geurts [b,d,e,3]

[a] *Development and Education of Youth in Diverse Societies (DEEDS), Faculty of Social Sciences, Utrecht University, the Netherlands*
[b] *School of Psychology, University of Nottingham Malaysia, Malaysia*
[c] *Faculty of Behavioral and Movement Sciences, Section Clinical Developmental Psychology, VU University, Amsterdam, the Netherlands*
[d] *Dutch Autism & ADHD Research Center, section Brain & Cognition, Department of Psychology, University of Amsterdam, the Netherlands*
[e] *Leo Kannerhuis, Youz, Parnassiagroup, the Netherlands*

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ABSTRACT

The Autism Spectrum Quotient (AQ) measures autistic traits in children and adults. The adolescent version of the AQ is understudied. We analyzed the factor structure, informant- and sex differences, and clinical utility of the AQ adolescent in 1) parent reports from adolescents in the general population (GenPop; AQ50; $N = 465$), parent reports from autistic adolescents (Netherlands Autism Register, NAR; AQ28 [Hoekstra et al., 2011]; $N = 284$), and parent- and self-reports of autistic and non-autistic adolescents (MATCH; AQ50; $N = 84$). The tested AQ-Adult factor models (Hoekstra et al., 2011; Murray, Allison et al., 2017; Murray, McKenzie et al., 2017; Russell-Smith et al., 2011), showed an acceptable fit in the GenPop sample, and the bi-factor AQ28-Hoekstra (Murray et al., 2011) fitted the NAR sample acceptably. On the AQ28-Hoekstra, autistic adolescents scored *lower* whereas non-autistic adolescents scored *higher* than their parents (MATCH), and males scored higher than females on several factors (GenPop, NAR). Moreover, this factor model appeared invariant among autistic and non-autistic groups. Two cut-off scores were evaluated with ROC analyses for parent reports. Given the informant differences, these cannot be applied to self-reports. In conclusion, the AQ28-Hoekstra reliably measures autistic traits in adolescents with and without autism. Combining parent and self-report seems most informative.

Autism Spectrum Conditions, henceforward referred to as autism, are characterized by difficulties in social behavior and communication and special interests and/or repetitive behavior (American Psychiatric Association, 2013a). The worldwide prevalence of autism is estimated at one in 59–100 people (Baio et al., 2018; X. Sun et al., 2019), although numbers may vary depending on the used methods (Hansen et al., 2015). The term *spectrum,* as used in the DSM-5 (American Psychiatric Association, 2013b), reflects that autism is not a dichotomous condition, and there are individual differences in autistic traits between autistic individuals. Moreover, people without an autism diagnosis might also exhibit a certain level of autistic traits (Baron-Cohen et al., 2001). With the current study, we aim to analyse the psychometric qualities of a widely used measure of autistic traits in adolescents, the Autism-Spectrum

* Correspondence to: University of Nottingham Malaysia, Jalan Broga, 43500 Semenyih, Selangor, Malaysia.
E-mail address: m.devries7@uu.nl (M. de Vries).
[1] ORCID: https://orcid.org/0000-0003-2845-8956.
[2] ORCID: https://orcid.org/0000-0002-0572-6893.
[3] ORCID: https://orcid.org/0000-0002-4824-9660.

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Quotient Adolescent (AQ-Adol; Baron-Cohen et al., 2006), in adolescents with and without an autism diagnosis.

The original 50-item Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001) was developed to measure autistic traits in adults without an intellectual disability. The original self-report questionnaire is rated on a 4-point Likert Scale, but scored binary (definitely agree, slightly agree =1, slightly disagree, definitely disagree =0). A score above the cut-off of 32 suggests clinically significant autistic traits and is an implication for further assessment (Baron-Cohen et al., 2001). Although not developed to be a diagnostic instrument, the AQ is sometimes used for screening (NICE, 2012), despite the relatively low specificity and low negative predictive value (Ashwood et al., 2016). Nevertheless, for scientific research, the AQ is considered to be a good descriptive measure of autistic traits in adults with average intelligence (Ruzich et al., 2015; Wheelwright et al., 2010). Moreover, the AQ has been translated into many languages, is freely available, often used, and is hence an important instrument to study more thoroughly.

The AQ50 has been adapted for various age groups and respondents, such as the parent-report AQ-Adolescent (Baron-Cohen et al., 2006) and AQ-Child (Auyeung et al., 2008). Moreover, shorter versions, with a subset of the original items, have been developed with 28 items (Hoekstra et al., 2011), and 10 items for adults (Allison et al., 2012), adolescents (parent-report AQ10-Adol) and children (parent-report AQ10-Child; Baron-Cohen, 2019). The current study focuses on the AQ-Adol. The AQ50-Adol is identical to the original AQ50, with a lower suggested cut-off score of 30 (Baron-Cohen et al., 2006). Given the lack of psychometric studies on the AQ-Adol, the relevant factor model findings from the AQ-Adult and AQ-Child versions are evaluated.

The original AQ50 had five subscales with 10 items each; Social Skills, Attention Switching, Attention to Detail, Communication, and Imagination (Baron-Cohen et al., 2001). Although partly confirmed in the child version (Auyeung et al., 2008), the subscales have not been consistently replicated (Kloosterman et al., 2011). Several studies have sought to find better-fitting and more reliable factor models. Three factor models fitted better than the original; a 43-item 4-factor-model (Stewart & Austin, 2009), a 26-item 3-factor (Austin, 2005), and a hierarchical model (Hoekstra et al., 2008). However, a direct comparison did not show an adequate fit for these models, and an alternative 28-item 5-factor-model was proposed (Kloosterman et al., 2011). Although promising, the participant sample included mainly female psychology students (Kloosterman et al., 2011). Sex (Grove et al., 2017) and group (van Rentergem et al., 2019) might have influenced the findings.

Several other factor models of the AQ have since been proposed. A shorter hierarchical factor model seems equally reliable to the original AQ50 (Hoekstra et al., 2011), and might be a better measure of autistic traits than the AQ50 by excluding dysfunctional items (van Rentergem et al., 2019). Moreover, a direct comparison of AQ factor studies showed that a 28-item 3-factor-model (Russell-Smith et al., 2011) had the best psychometric properties (English et al., 2020). The AQ50-Adult hence has two promising factor models; a 28-item hierarchical factor model (Hoekstra et al., 2011) and a 28-item 3-factor-model (Russell-Smith et al., 2011) which we will refer to as AQ28-Hoekstra and AQ28-Russell-Smith henceforward. Despite the same number of items in the models, 10 items differ between the models. Finally, Murray, Allison et al. (2017) and Murray, McKenzie et al. (2017) proposed an alternative bi-factor model (i.e., a model with a general factor influencing all or most items, and specific factors influencing subsets of items) for the AQ28-Hoekstra, showing a better fit than the original AQ28-Hoekstra.

The AQ-Child has been studied much less extensively than the AQ-Adult. Three studies produced two promising factor models; a 35-item 4-factor-model (Gomez et al., 2019), and a 30-item 5-factor-model (F. Sun et al., 2019). The third, a 47-item 4-factor-model (Auyeung et al., 2008) was later not confirmed (Gomez et al., 2019). There are hence two promising AQ-Child models, a 35-item 4-factor-model (Gomez et al., 2019), and a 30-item 5-factor-model (F. Sun et al., 2019).

An important difference between the original AQ50 and the AQ-Adol and AQ-Child is that the latter two are parent-reported (Baron-Cohen et al., 2006). Parents tend to interact with and observe their children extensively and might have better insight into their child's behavior than children can report themselves. Young children might not be able to read, understand, interpret, and reflect on AQ items. Adolescents, however, can rate their own behavior and might have *more* insight into their own preferences and feelings (Hobson, 2006). Moreover, parents might become less involved in their child's life once reaching adolescence. It is debatable whether parent- or self-report is preferable for adolescents. Both might give independent, insightful information.

Parent- and self-reported autistic traits seem to differ, though findings are inconsistent. Parent reports of autistic children (Wakabayashi et al., 2006) and parent reports of autistic adults (Leung et al., 2019; Poon et al., 2019) report more autistic traits, and less empathy (Baron-Cohen & Wheelwright, 2004) than their child's self-report. However, such effects are not seen in the AQ parent reports of non-autistic children (Johnson et al., 2009) or parent reports of non-autistic adults (Poon et al., 2019). Surprisingly, the AQ50 parent- and self-report was significantly correlated in non-autistic children (Johnson et al., 2009) and autistic adults (Poon et al., 2019), but not in autistic children (Johnson et al., 2009). Finally, the AQ50-Adult parent report showed a higher sensitivity and specificity than the AQ50-Adult self-report (Poon et al., 2019), similar to other autism trait questionnaires (Lerner et al., 2012; Pearl et al., 2016). With respect to adolescents, parents rate the social skills of their adolescent autistic child lower than the child's self-report (Lerner et al., 2012). However, to our knowledge, the AQ-Adol parent- and self-report were not directly compared yet. If there are differences between informants, cut-off scores should be different for parent- and self-report.

Autism is thought to be more common in men than in women, with a male-female ratio of 4.2:1, with higher proportions of males among samples with a higher IQ (Loomes et al., 2017). There is a trend of males scoring higher than females on the AQ in adults (Austin, 2005; Hoekstra et al., 2011; Ruzich et al., 2015; Stewart & Austin, 2009; Wheelwright et al., 2006) and children (F. Sun et al., 2019) in the general population, but see (Poon et al., 2019). However, these sex differences might only occur on certain subscales (Austin, 2005; Lau et al., 2013; Stewart & Austin, 2009). In autistic samples, the picture is slightly more complicated. There seem to be no general sex differences (Ruzich et al., 2015), but certain traits are more prominent in males and other traits more prominent in females. For example, autistic girls show less profound early childhood restricted and repetitive behavior than autistic boys, but social interaction and communication difficulties appear to be comparable (Tillmann et al., 2018). This is reflected in AQ studies; autistic males score higher on the number/patterns factor, and autistic females score higher on the social behavior factor (Grove et al., 2017; F.

Sun et al., 2019). Finally, some AQ-*items* show Differential Item Functioning in males and females on the AQ50 (van Rentergem et al., 2019), and AQ10 (Murray, Allison et al., 2017; Murray, McKenzie et al., 2017). It is thus essential to explore sex differences in the AQ-Adol. Besides the original publication (Baron-Cohen et al., 2006), the psychometric properties of the AQ-Adol have, as far as we know, not been studied. It is essential to explore the AQ utility in adolescents. Adolescence is a critical developmental period, and autism may be diagnosed during this time. Self-reports become an important source of information. Findings from adult and child samples may not be applicable to adolescents.

In this study, we investigated whether the AQ is a valid instrument to measure autistic traits in adolescence. Specifically, we examined the factor structure, reliability, informant- and sex differences, and clinical utility of the AQ adolescent in three different samples. (1) The fit of the aforementioned most promising adult-based (Hoekstra et al., 2011; Murray, Allison et al., 2017; Murray, McKenzie et al., 2017; Russell-Smith et al., 2011), and child-based (Gomez et al., 2019; F. Sun et al., 2019) models (see Table 3) and the reliability were tested in a general population sample (GenPop; $N = 465$; AQ50-Adol parent report). The fit of the AQ28-Hoekstra-Adol parent report was tested in a broad autism sample (NAR $N = 284$). Measurement invariance of the best-fitting model was tested in the GenPop and NAR samples. (2) The influence of the informant (self- versus parent; inter-rater-reliability) was studied in a matched autistic and control sample (MATCH; $N = 84$; AQ50-Adol parent and self-report). (3) Possible sex differences were studied in all three samples. (4) Finally, the clinical utility of the best-fitting model is described, by exploring cut-off scores in the GenPop and NAR samples, and comparing autistic and non-autistic groups in the MATCH sample.

Table 1
Demographic variables for the general population, NAR and MATCH samples.

	Group								
	GenPop		NAR-Autism			MATCH-TD		MATCH-Autism	
Measure	$N = 465$	%	$N = 284$		%	$N = 41$	%	$N = 42$	%
AQ version	AQ50-Adol parent-report		Hierarchical AQ28-Adol parent-report			AQ50-Adol parent- & self-report			
Child									
Age in years M (SD)	14.0 (1.2)		14.3 (0.9)			14.2 (1.3)		14.2 (1.3)	
Range	12.0–16.0		9.4–16.4			11.8–16.8		11.8–16.8	
Sex (Female/Male)	231/234	49.7/50.3	54/230		19/81	22/19	53.7/46.3	17/25	40/60
Education level									
Primary	37	8.0	2		1	5	12.2	6	14.0
Secondary	394	84.7	102		36	36	87.8	4	12.3
Higher education	2	0.4	1		0	0	0	0	0
Special education	28	6.1	154		54	0	0	29	69.8
Other/missing	4	0.9	25		9	0	0	3	2.3
Parent reported disabilities									
Learning disabilities	65	14.0	31		13.2	2	4.9	12	27.9
Physical problems	33[a]	7.1	13[b]		41.8	1	2.4	9[c]	20.9
Autism	38	8.2	284		100	0	0	42	100
ADHD	54	11.6	78		27.3	0	0	7	18.6
Mood disorder	8	1.7	9		2.3	0	0	6	14.0
Anxiety	4	0.9	21		6.4	1	2.4	11	25.6
Mental retardation	5	1.1	1		1.3	0	0	0	0
Other	19	4.1	49		22.8	3	7.3	14	37.2
None	298	64.1	140[d]		45.0	36	86.4	11[8]	25.6
Medication	70	15.1	149[e]		48.6	1	2.4	20	48.8
Parent/caregiver									
Sex Female/Male/Other, unknown	280/185/0	60/40/0	259/25/0		91/9/0	36/4/1	88/10/2	36/1/5	86/2/12
Highest completed Education			Mother	Father					
High[f]	132	28.8	145	128	51/45	NA		NA	
Middle[g]	236	50.8	109	115	38/41	NA		NA	
Low[h]	94	20.2	30	30	11/11	NA		NA	
Unknown, no education	3	0.6	0	11	0 /4	NA		NA	
Employment									
Paid employment	373	80.2	181	246	64/87	NA		NA	
No paid job/retired/unknown	92	19.8	103	38	36/13	NA		NA	

Note ADHD Attention Deficit Hyperactivity Disorder GenPop General Population Sample MATCH Matched Sample NAR Netherlands Autism Registry Sample TD Typically Developing.

[a] Chronical.
[b] Current.
[c] Neurological conditions or physical handicap.
[d] No reported disorders apart from autism.
[e] Autism related medication.
[f] Higher vocational education, university.
[g] Middle vocational education, higher secondary education, pre-university education.
[h] Primary education, lower vocational education, lower or middle general secondary education.

1. Methods

1.1. Participants

In total, 833 participants were recruited through three main sources; one general population (GenPop) sample (parent-report, N = 465), one autistic sample (parent-report, Netherlands Autism Register; NAR, N = 284), and one matched sample (MATCH) of autistic and non-autistic adolescents (parent and self-report, N = 84). Approval to combine the data was gained from the Science & Engineering Research Ethics Committee (SEREC) from the University of Nottingham Malaysia (MDV200718). For demographic information, see Table 1.

1.1.1. General population sample (GenPop)

The GenPop sample was recruited through market research company Kantar TNS (Kantar, 2016), as part of an overlapping project to gather normative data for several Dutch questionnaires. For the overlapping project, a total sample of 2192 families of children between the age of 7–18 years (based on an expected response rate of about 50 %) was invited to fill in online questionnaires. The current sample was selected based on the child's age and sex and is representative of the Dutch population based on the responding parent's age, location (urban/rural), Social Economical Status (SES; education, current occupation), and household size. Although we did not have information about formal autism diagnoses in this sample, 8.2 % of the parents reported that their child had (suspected) autism. The AQ50-Adol was sent to the parents of children of twelve to fifteen years old (N = 751) and was filled in by 465 parents. The Medical Ethics Committee from the Academic Medical Center Amsterdam (METC) approved the study (ethics application number 15.0347).

1.1.2. Netherlands autism register sample (NAR)

AQ28-Hoekstra-Adol parent reports (N = 284) were collected through the NAR, a database that collects information on an annual basis from individuals with an autism diagnosis according to the DSM-IV or DSM-5. Detailed information about the diagnosis (where, when and by whom they were diagnosed) is given by the participants, and in part of the cases official diagnostic proof was obtained (see https://www.nederlandsautismeregister.nl/english/). Several questionnaires are filled in by autistic adults and children (or their parents) yearly on a voluntary basis. Participants receive personal feedback, and the data are used for scientific research. The *Vaste Commissie Wetenschap en Ethiek van de Faculteit der Gedrags- en Bewegingswetenschappen* (VCWE), Vrije Universiteit Amsterdam approved the NAR data collection (VCWE-2020–041).

1.1.3. Matched samples with and without autism (MATCH)

The matched samples data was collected as part of an overarching study focusing on executive functioning in autistic adolescents. Forty-six adolescents with an autism diagnosis according to DSM-IV (American Psychiatric Association, 2000) were recruited through the Dutch association of Autism website and mental health organizations. A comparison group of 42 non-autistic adolescents was recruited through advertisements and the researchers' social network. Incomplete data (n = 7), and data from one autistic participant who did not meet the criteria for an autism diagnosis on two autism screeners; the Developmental, Dimensional and Diagnostic interview (Slappendel et al., 2016), and a score of 57 on the Social Responsiveness Scale (Constantino et al., 2003; Roeyers et al., 2011) were removed. Finally, 42 autistic adolescents and their parents, and 41 non-autistic adolescents and their parents were included. The study was approved by the institutional research ethics committees (2013-PN-2861 and 2015-BC-4576).

1.2. Materials

The AQ-Adol parent-report is a proxy version of the Dutch adult AQ (Baron-Cohen et al., 2001, 2006), to be filled in by parents/caregivers. The original AQ50 (Hoekstra et al., 2008) and AQ28-Hoekstra were also studied in Dutch samples. Items were filled in on a 4-point Likert scale to improve the range of reliable measurement (Murray et al., 2016). Half of the items are scored reversely. A higher score on the AQ indicates more autistic traits. In the GenPop sample, all parents filled in the AQ50-Adol parent-report. In the NAR sample, all parents filled in the AQ28-Hoekstra-Adol parent-report. In the MATCH sample, parents filled in the AQ50-Adol parent-report, and adolescents filled in the AQ50-Adol self-report (i.e., this version is identical to the original adult AQ50).

1.3. Statistical analyses

1.3.1. Factor structure and reliability

With confirmative factor analyses (CFA) with SPSS AMOS (Arbuckle, 2017) we tested which oblique factor structure from the five most relevant factor structure studies (Gomez et al., 2019; Hoekstra et al., 2011; Murray, Allison et al., 2017; Murray, McKenzie et al., 20177; Russell-Smith et al., 2011; F. Sun et al., 2019), would fit on the AQ-Adol in the GenPop sample (n = 465, parent-report). For an overview of the factors and items of each model see Table 3. Weighted Least Square Mean and Variance estimators were used, including the following fit indices; χ^2 (smaller is generally better, though χ^2 values tend to be inflated in large sample sizes), Ratio (preferably 1 < 2), Root Mean Square Error of Approximation (RMSEA; fair fit < 0.08, good fit <.06), Standardized Root Mean Square Residual (SRMR; fair fit < 0.08, good fit <.06) (Hu & Bentler, 1999), Comparative Fit Index (CFI; fair fit > 0.90, good fit >.0.95), Akaike Information Criterion (AIC; lower indicating a better fit), and Goodness of Fit Index (GFI; fair fit >.90, good fit >.95). In the NAR sample (n = 284, parent report), we compared the 28-item factor-model (Hoekstra et al., 2011), the bi-factor AQ28-Hoekstra model (Murray et al., 2017), and a one-factor-model. Internal consistency was evaluated with Mcdonald's Omega (see Table 3) (Kalkbrenner, 2021).

To test whether the AQ-Adol measures the same construct in autistic and non-autistic adolescents metric invariance (i.e. factor loadings are equal across autistic and non-autistic groups), and scalar invariance (i.e., factor loadings and intercepts are equal across autistic and non-autistic groups) were tested with SPSS AMOS for the best fitting model (the bi-factor AQ28-Hoekstra) in the GenPop and NAR samples. No metric invariance was assumed with a difference of $> -.010$ in CFI, a difference of $> .015$ in RMSEA, and a change of $> .030$ in SRMR. No scalar or residual measurement invariance was assumed with a difference of $\geq -.010$ in CFI, a difference of $> .015$ in RMSEA and a difference of $> .010$ in SRMR. (Chen, 2007).

1.3.2. *Parent vs self-report*

In the MATCH sample parent and self-report AQ28-Hoekstra derived from the AQ50 were compared with paired sample t-tests, and the correlation between informants was tested with Pearson's correlation.

1.3.3. *Sex*

Firstly, we compared total AQ-scores between sexes with *t*-tests for each sample. Secondly, we compared the AQ28-Hoekstra Factor Model Sum Scores, in line with its use in clinical practice, in the GenPop and NAR samples between sexes (MANOVA).

1.3.4. *Clinical utility hierarchical/bi-factor AQ28-Hoekstra*

We explored the clinical utility and the cut-off scores (65 and 70) of the AQ28-Hoekstra. Firstly, with a Receiver Operating Characteristics (ROC) analysis, the discriminatory power and cut-off score were evaluated in the GenPop excluding parent-reported autism ('typically developing' GenPop-TD; $n = 427$) and the NAR-autism sample. Secondly, parent and self-report AQ28-Hoekstra scores derived from the AQ50, between adolescents with and without an autism diagnosis were compared in the MATCH sample.

2. Results

There were no statistical outliers in the AQ data (Median +/- 1.5 Interquartile range). Although the AQ were normally distributed in the MATCH sample, in the GenPop sample and in the NAR sample the data were not normally distributed. Fig. 2 illustrates that, as expected, AQ28-Hoekstra scores were skewed towards the higher scores in the autistic samples and skewed towards the lower scores in the non-autistic samples.

2.1. *Factor structure and reliability*

The two 28-item factor-models (Hoekstra et al., 2011; Russell-Smith et al., 2011) showed similar acceptable fit indices, and better fit indices than the 30-item factor-model (F. Sun et al., 2019), and the 35-item model (Gomez et al., 2019) (See Table 2).

All fit indices showed a better fit of the 28-item factor-model than the one-factor-model (See Table 2).

In the 28-item factor-model (Hoekstra et al., 2011) the factor Social Behavior, and the Total score showed a good internal consistency (GenPop and NAR). The subfactors Social Skills and Imagination, and the factor Numbers/Patterns showed an acceptable to good internal consistency (GenPop/NAR), whereas the subfactors Routine and Switching showed a Questionable (GenPop) to Poor/Unacceptable (NAR) internal consistency. The factors of the AQ28-Russel-Smith showed acceptable to good internal consistency (GenPop). In the 30-item factor-model (F. Sun et al., 2019) the factors Socialness, and the Total score had a good internal consistency, the factors Social Communicative Competence and Patterns an Acceptable internal consistency. The factor Imagination had questionable, and Attention Switching Poor internal consistency. In the 35-item factor-model (Gomez et al., 2019), the Imagination factor had an unacceptable internal consistency, and the other factors an Acceptable to Good internal consistency (See Table 3).

The AQ28-Hoekstra fitted acceptably on the non-autistic and autistic samples. However, the bi-factor version of this model showed a better fit (see Table 2), suggesting that a general factor should be considered when interpreting the AQ28-Hoekstra. The following analyses will hence primarily focus on the bi-factor and AQ28-Hoekstra. The factor loadings of the bi-factor/AQ28-Hoekstra in the GenPop and NAR samples can be found in supplementary Tables S2A and S2B. Visual inspection of the current factor loadings and the factor loadings reported by Murray, Allison et al. (2017) and Murray, McKenzie et al. (2017) shows a rather similar pattern, though it is notable that in the current NAR sample, four items (20, 36, 42, 45) of the Imagination subscale had a negative factor loading. In Murray et al.'s study, these items also had relatively low factor loadings (.24,.13,.18, and.13 respectively).

Of the bi-factor AQ28-Hoekstra (Murray et al., 2017), we tested the measurement invariance (see supplementary table S1 for an overview of the fit indices). In the metric invariance model, RMSEA (.041) and SRMR (.077) showed a good fit, but CFI (.848) did not. In the scalar invariance model, RMSEA (.046) showed a good fit, but the SRMR (.081) and CFI (.798) did not. In the residual invariance model, RMSEA (.047) and SRMR (.079) showed a good fit, but CFI (.779) did not. For metric, scalar, and residual invariance, the CFI drop exceeded the cutoff (−0.013, −0.050, −0.019 respectively). However, the differences in RMSEA (0.001, 0.005, 0.001 respectively) and SRMR (0.009, 0.004, −0.002 respectively) were within the recommended cutoff. These findings tentatively indicate measurement invariance among autistic and non-autistic groups.

2.1.1. *Parent vs self-report*

Parent-reports of non-autistic adolescents ('typically developing' MATCH-TD $M = 43.8$, $SD = 6.8$) were significantly *lower* than the self-reports ($M = 48.9$, $SD = 7.3$) $t\,(40) = -3.82$, $p < .001$, and parent- and self-reports were not significantly correlated $r = .29$, $p =$

Table 2
Fit statistics of five factor models in the GenPop sample (n = 465), and three factor models in the NAR-Autism sample (n = 284).

Statistics	Model fit in GenPop (*n* = 465)					Model fit in NAR-Autism (*n* = 284)		
	Hoekstra et al. (2011)[a]	Russell-Smith et al. (2011)[a]	Murray, McKenzie et al. (2017)[a]	F. Sun et al. (2019)[b]	Gomez et al. (2019)[b]	Hoekstra et al. (2011)[a]	Murray, McKenzie et al. (2017)[a]	1-factor model
N items	28	28	28	30	35	28	28	28
Df	343	345	322	391	550	345	322	341
$\chi 2$	926.958	928.350	**843.072**	1028.869	1386.706	667.110	**581.332**	758.005
Ratio	2.703	2.691	2.618	2.631	2.521	**1.934**	**1.805**	2.223
RMSEA	**.061**	**.060**	**.059**	**.059**	**.057**	**.057**	**.053**	**.066**
SRMR	**.070**	**.068**	**.060**	**.072**	**.075**	**.072**	**.068**	**.079**
CFI	.851	.870	.867	.851	.839	.809	.846	.753
AIC	1052.958	1050.350	**1011.072**	1176.869	1546.706	789.110	**749.332**	888.005
GFI	.865	.863	.877	.861	.835	.852	.871	.829

Note AIC Akaike Information Criterion CFI Comparative Fit Index GenPop General Population GFI Goodness of Fit Index RMSEA Root mean square error of approximation SRMR Standardised Root Mean Square Residual In bold are the fit indices that are considered acceptable/good. See Table 3 for an overview of the items.
[a] Most promising adult models.
[b] Most promising child models.

Table 3
Item allocation in the factor models from Russell-Smith et al. (2011) (AQ50), F. Sun et al. (2019) (AQ50-C), Hoekstra et al. (2011) (AQ28), and Murray, McKenzie et al. (2017) and McDonald's Omega in our GenPop (n = 465) and NAR-Autism (n = 284) samples.

Factors	Items	N items	McDonald's Omega	
			GenPop (*n* = 465)	NAR-Autism (*n* = 284)
Hoekstra et al. (2011), Murray, McKenzie et al. (2017)				
1. Social Behavior		23	.870**	.811**
Social Skills	1, 11, 13, 15, 22, 44, 47	7	.825**	.739*
Routine	2, 25, 34, 46	4	.628	.564
Switching	4, 10, 32, 37	4	.694*	.493
Imagination	3, 8, 14, 20, 36, 42, 45, 50	8	.721*	.717*
2. Numbers/Patterns	6, 9, 19, 23, 41	5	.746*	.769*
Total	All items	28	.861**	.797*
Russell-Smith et al. (2011)				
1. Social Skills	1, 10, 11, 13, 15, 17, 22, 26, 34, 38, 44, 46, 47	13	.877**	
2. Details/Patterns	5, 6, 9, 12, 19, 23, 41	7	.768*	
3. Communication/Mindreading	20, 27, 31, 35, 36, 39, 45, 48	8	.797*	
Total	All items	28	.878**	
F. Sun et al. (2019)				
1. Socialness	11, 17, 38, 44, 47	5	.824**	
2. Social Communicative Competence	7, 20, 21, 22, 26, 33, 35, 39, 45	9	.741*	
3. Imagination	14, 31, 36, 40, 50	5	.601	
4. Patterns	6, 9, 12, 13, 19, 23, 41	7	.766*	
5. Attention Switching	2, 4, 5, 16	4	.594	
Total	All items	30	.856**	
Gomez et al. (2019)				
1. Mind-Reading	4, 7, 10, 16, 18, 27, 31, 32, 33, 35, 36, 37, 39, 45, 48	15	.852**	
2. Social Skills	1, 11, 13, 15, 17, 34, 38, 44, 47	9	.850**	
3. Attention to Detail	6, 9, 12, 19, 23, 41	6	.769*	
4. Imagination	3, 8, 20, 21, 50	5	.487	
Total		35	.875**	

Note AQ50 50-item Adult Autism Spectrum Quotient AQ50-C 50-item Child Autism Spectrum Quotient AQ28 28-item Adult Autism Spectrum Quotient GenPop General Population sample NAR Netherlands Autism Registry autistic sample.
McDonald's Omega interpretation (Kalkbrenner, 2021).
*Acceptable reliability.80 ≥ . 65.
** Strong reliability > .80.

.068. MATCH-autism parent-reports ($M = 78.6$, $SD = 9.9$) were significantly *higher* than the self-reports ($M = 67.5$, $SD = 12.1$) $t\,(39) = 8.15$ $p < .001$, and parent- and self-reports were significantly correlated $r = .71$ $p < .001$. The parent-self report correlations were significantly different between the autistic and non-autistic groups *Fisher's Z* $= -2.532$ $p = 0.006$. Hence, parents of non-autistic adolescents interpret their child to have fewer autistic traits than the self-report, and there is a low agreement between parents and their child. In contrast, parents of autistic adolescents rate the autistic traits as more severe than the autistic adolescents themselves, but relatively high-scoring adolescents also had relatively high-scoring parents (See Fig. 1).[4]

2.1.2. Sex

Males scored higher than females in the GenPop sample (total AQ50) $t(463) = 3.9$, $p<.001$, and in the NAR sample (total AQ28-Hoekstra) $t(282) = 2.1$, $p = .040$. In the MATCH samples (AQ50; parent, self, autistic, and non-autistic) there were no significant sex differences $ps > .306$.

In the GenPop sample males scored higher than females on the subfactors Switching $p<.001$, and Imagination $p<.001$, the Factors Social Behavior $p < .001$, and Numbers/ patterns $p = .014$, and the Total score $p < .001$. In the NAR sample, males scored higher than females on the subfactor Imagination $p = .020$, the Factor Numbers/Patterns $p = .005$, and the Total score $p = .040$ (See Table 4).

2.1.3. Clinical utility AQ28-Hoekstra

The test accuracy of the ROC was excellent; the area under the curve (AOC) = .949, $SE = 0.008$, 95 % $CI = .934 - .965$ $p < .001$. A cut-off score of 65 would have a sensitivity of.923 and a specificity of.815, while a cut-off score of 70 would have a sensitivity of.856 and a specificity of.904 (see Fig. 2 for a visualization of the scoring of all samples within each score band) (GenPop and NAR).

On all factors parent- and self-report, adolescents with an autism diagnosis scored higher than adolescents without an autism diagnosis $ps < .001$ (MATCH).

3. Discussion

This study aimed to explore the psychometric properties of the AQ-Adol. Factor structure, reliability, inter-rater-reliability, sex differences and clinical utility were explored in non-autistic adolescents (parent-report) and autistic adolescents (parent- and self-report). Of the tested AQ-Adult based and AQ-Child based factor-models, the AQ-Adult-based models showed a better fit. The 28-item adult factor-models (Hoekstra et al., 2011; Russell-Smith et al., 2011) fitted the data best in the general population sample. The 28-item hierarchical factor-model (Hoekstra et al., 2011) also fitted better on the NAR sample compared to a one factor-model. Most factors were reliable for both 28-item factor-models. Males scored higher than females (GenPop and NAR) and autistic adolescents scored higher than non-autistic adolescents (MATCH), both on parent- and self-reports. Parent reports of autistic adolescents were higher, while parent reports of non-autistic adolescents were lower on the AQ28-Hoekstra-Adol than the self-reports. For parent reports, a cut-off score of 65 would have 92.3 % true positives but 18.5 % false positives, while a cut-off score of 70 would have 85.6 % true positives and 9.6 % false positives.

3.1. Factor structure

Surprisingly, two mutually different (only 18 items overlap) 28-factor AQ-Adult based factor-models (Hoekstra et al., 2011; Russell-Smith et al., 2011) showed a good fit on our adolescent data. Although the fit indices for the tested models did not show undisputable differences, the two 28-item models did show a somewhat better fit than the other models, and the bi-factor AQ28-Hoekstra (Murray et al., 2017) was confirmed in two different samples. Given the clinical utility advantages of using a shorter questionnaire, the AQ28-Hoekstra seems the most suitable questionnaire for adolescents. Both AQ28 models (Hoekstra et al., 2011; Russell-Smith et al., 2011) have also been confirmed in other studies (English et al., 2020; van Rentergem et al., 2019). These models are, partly, based on student samples (English et al., 2020; Hoekstra et al., 2011; Russell-Smith et al., 2011), which might explain the better fit than the child-based models. Adolescent behavior might link better to young adults than children. On the other hand, these previous models are based on self-report, while the current findings are based on parent report, which is similar to the AQ-Child. However, the AQ-Child literature is relatively limited and hence the previous factor structures had not been confirmed in other studies yet (Auyeung et al., 2008; Gomez et al., 2019).

Although for both 28-item factor-models most factors were reliable, the Hoekstra et al. (2011) Routine and Switching subfactors were less reliable. This seems to align with previous reports that the Switching and Routine subfactors would be better reflected by the Total score (Murray et al., 2017). Both 28-item factor-models seem a good fit, seem reliable, and show a clear difference between adolescents with and without autism. Based on the invariance analyses results, the bi-factor 28 item model (Hoekstra et al., 2011; Murray, Allison et al., 2017; Murray, McKenzie et al., 2017) seems to function similarly in a non-autistic sample and an autistic sample. This suggests that for the adolescent population, using a 28-item version of the AQ might be suitable, given the sound psychometric properties. This has the obvious clinical advantage that it saves time for parents and clinicians.

3.2. Parent- versus self-report

Parent reports of autistic adolescents were higher than the adolescents' self-reported autistic traits, in line with child (Wakabayashi et al., 2006) and adult (Leung et al., 2019; Poon et al., 2019) findings. In line with results from autistic adults (Lever & Geurts, 2018;

[4] The pattern was identical for the AQ50

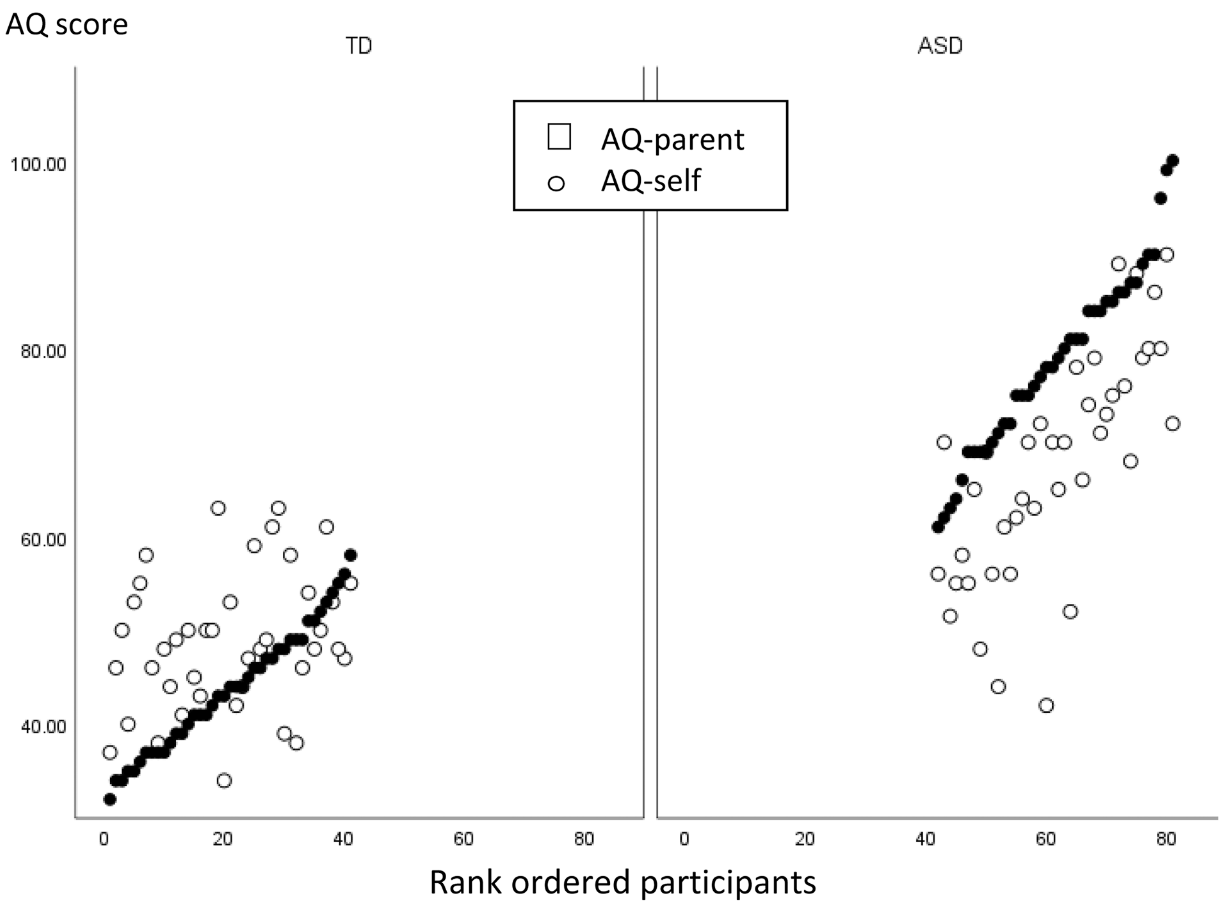

Fig. 1. The relation between Parent- and Self-report on the AQ28 (Hoekstra et al., 2011) in the Matched sample Typically Developing. *(TD N = 41), and Autism Spectrum Disorder (Autism N = 40) adolescents.*

Table 4

Sex differences in sum scores of the AQ28-Hoekstra in the GenPop, and NAR-Autism (MANOVA).

GenPop	Males $N = 234$	Females $N = 231$			
	M (SD)	*M (SD)*	*F (1,463)*	*p*	η_p^2
1. Social Behavior					
Social Skills	14.8 (4.6)	14.0 (4.2)	3.3	.068	.01
Routine	9.1 (2.8)	8.7 (2.4)	3.2	.075	.01
Switching	9.6 (2.6)	8.7 (2.4)	13.7	.000	.03
Imagination	18.1 (4.1)	16.6 (3.8)	17.3	.000	.04
Total Social Behavior	51.6 (11.0)	48.1 (9.7)	13.7	.000	.03
2. Numbers/Patterns	8.7 (3.1)	8.1 (2.9)	6.1	.014	.01
Total	60.4 (12.3)	56.1 (10.4)	16.2	.000	.03
NAR-Autism	Males $N = 230$	Females $N = 54$			
	M (SD)	*M (SD)*	*F (1,282)*		η_p^2
1. Social Behavior					
Social Skills	21.1 (3.8)	20.2 (3.6)	2.3	.128	.01
Routine	12.4 (2.3)	12.9 (2.0)	2.0	.156	.01
Switching	13.3 (2.0)	13.4 (2.1)	.3	.606	.00
Imagination	24.0 (4.0)	22.6 (4.5)	5.5	.020	.02
Total Social Behavior	61.9 (7.6)	60.8 (7.5)	1.0	.323	.00
2. Numbers/Patterns	10.9 (3.6)	9.4 (3.2)	7.9	.005	.03
Total	81.7 (10.3)	78.5 (9.7)	4.3	.040	.02

Note GenPop General Population sample NAR-Autism Netherlands Autism Registry Autistic sample.

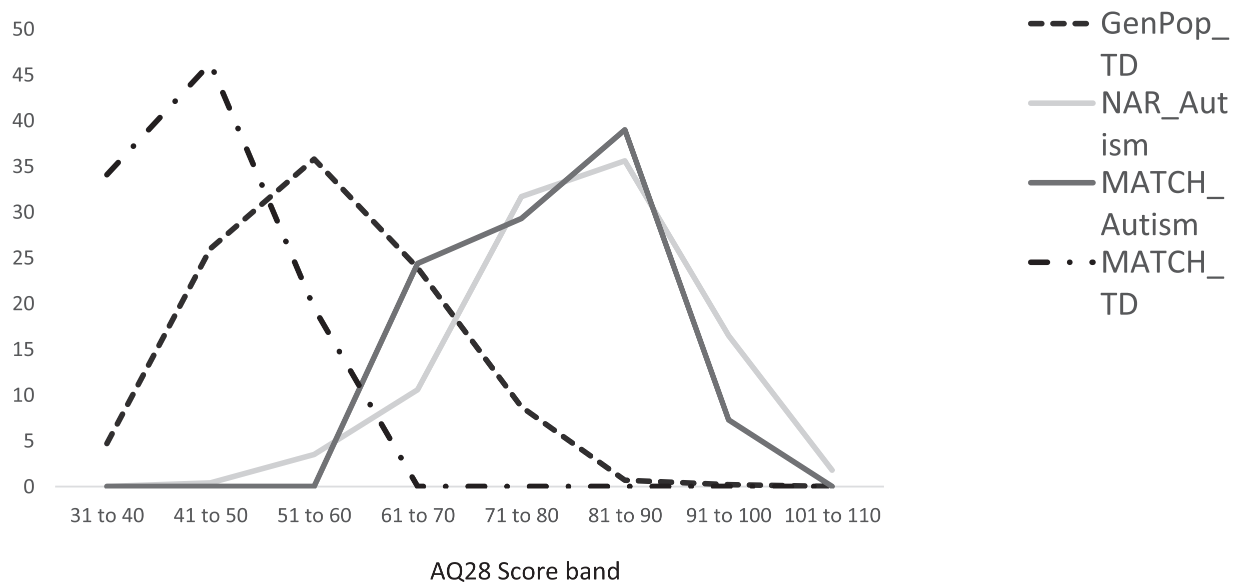

Fig. 2. Percentages of scores on the AQ-28 Parent report in the General Population sample (without parent-reported autism), Netherlands Autism Registry sample, and Matched sample, *Note* TD typically developing.

Poon et al., 2019), but contrasting with results from autistic children (Johnson et al., 2009), the parent and self-report were correlated in autistic adolescents. Parents interpreting autistic traits as more 'severe', might result from parents comparing their child's behavior with non-autistic peers, while the adolescents themselves might not do so. Previous research hypothesized that the relatively low parent-child agreement on autistic traits in childhood (Hobson, 2006) results from limited self-awareness in young children. The current findings suggest that in adolescence, agreement between parents and their child improves, and that parent- and self-report are related and measure the same construct. Moreover, both parent and self-report show differences between autistic and non-autistic adolescents. This suggests that both the parent- and self-report measure autistic traits, but that lower cut-off scores for the parent-report than self-report are indicated.

Compared to self-report, parents of non-autistic adolescents interpret their child to have fewer autistic traits. Previous studies in non-autistic children (Johnson et al., 2009) and non-autistic adults (Poon et al., 2019) did not report such differences, or opposite results, i.e., higher proxy- than self-report scores in non-autistic adults (Lever & Geurts, 2018). Moreover, whereas our results showed no significant relation between parent- and self-reports, significant parent-self-report correlations were reported in non-autistic children (Johnson et al., 2009) and adults (Lever & Geurts, 2018). This could be partly explained by a floor effect in the MATCH-TD data: both parents and adolescents scored relatively low, and the spread was narrow.

The parent and self-report correlated in the autistic population, but the different interpretation of severity/intensity of autistic traits between parents and self-report might indicate that parents are overly concerned about the difficulties their autistic adolescent child encounters, or that the autistic adolescent is relatively unaware of their own autistic traits. Although the AQ adolescent was originally not developed for self-report, the current findings suggest that the self-report could give important insights in the autistic traits the adolescent subjectively experiences. Both informants might give distinct and important information about the *perceived* challenges, which is essential for treatment purposes.

3.3. Sex

In line with studies in adults (Austin, 2005; Hoekstra et al., 2011; Ruzich et al., 2015; Stewart & Austin, 2009; Wheelwright et al., 2006) and children (F. Sun et al., 2019), but see (Poon et al., 2019), our findings show that in the general population, adolescent males score higher than females on the AQ50-Adol, on the total score and most factors, though not in Social Skills and Routine. In autistic adolescents, sex differences were only found on the Imagination subfactor, the Numbers/Patterns factor and the total score. This is partly in line with previous studies showing higher Numbers/Patterns scores in autistic males, though these studies did not report total AQ sex-differences (Grove et al., 2017; F. Sun et al., 2019). Although our findings should be interpreted with caution given the higher number of males than females, our findings substantiate the earlier notion that the AQ might be less sensitive to specific female autistic traits, and that research into a gender-specific AQ factor structure might be informative (F. Sun et al., 2019).

3.4. Clinical Utility

In line with Hoekstra et al. (2011) our findings suggest that using the AQ28-Hoekstra cut-off of 65 might be considered for screening in a clinical setting, with 18.5 % false positives, and 7.7 % false negatives in Parent-reports. The choice for (a higher) cut-off score might have to be adapted to the screening goal. Although we could not analyze cut-off scores for self-reports, the overall higher self-reports among autistic adolescents suggest that higher cut-off scores are needed.

3.5. Caveats

The current study is one of the first studies to explore the psychometric properties of the AQ-Adol in a large sample of adolescents with and without autism. The GenPop sample is representative of the general population (sex, SES), whereas previous studies often included student samples. Moreover, the inclusion of samples from different resources allowed cross-validation. However, the inclusion of different samples came with some challenges; 1) The total number of participants is high, but the numbers in the separate samples are relatively low. Moreover, not all samples filled in the same AQ version (AQ50, AQ28-Hoekstra). The analysis approach had to be adapted to the sample size and the available measures in each sample. 2) the MATCH sample was originally not gathered for the current project and was relatively small. The inter-rater reliability analyses should hence be interpreted with caution, and the sample size was too small to study the factor structure of the self-report AQ-Adol. 3) We did not have IQ information of all samples. Although not restricting the IQ range makes the data more broadly generalizable, we could not test possible IQ effects. 4) We did not have formal autism diagnostic information from the GenPop sample, but a relatively high percentage of the parents reported that their child had autism (8.2 %). Out of the 38 parent-reported autism cases, 28 scored above the cut-of (30 binary scoring) on the AQ-Adol (Baron-Cohen et al., 2006). This number is higher than would be expected based on the official prevalence number of autism in the Netherlands (2.8 % in 2014; van Herten et al., 2014). However, the official numbers are based on children aged 4–12 years, and the number of diagnoses increases with age. In our sample with older children, a higher percentage of autistic adolescents might be expected. Importantly, we did not explicitly ask about “official diagnoses”, hence the number merely reflects the parents’ evaluation of (possible) autism (traits). Moreover, parents of autistic children might be more prone to participate in the survey (Fombonne, 2018). 5) The AQ28-Russell-Smith fitted well in the GenPop sample, but this could not be tested in an autistic sample. This is important to study in future research. 6) Finally, although outside the scope of the current study, future studies could explore possible differential item functioning between sexes.

4. Implications

The AQ28-Hoekstra-Adol is a reliable questionnaire to measure autistic traits in adolescents with and without autism. Autistic adolescents score higher on the AQ28-Hoekstra than those without autism, and males score higher than females. Using both the parent and self-report seems the optimal choice in this age group, as both give distinct relevant information.

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Community involvement

Although no autistic community members were involved in the current project, the Dutch Association for Autism (NVA) and other autism community stakeholders are involved in the Netherlands Autism Register’s annual survey.

Ethics

General Population Sample: The Medical Ethics Committee from the Academic Medical Center Amsterdam (METC) approved the study (ethics application number 15.0347).

Netherlands Autism Register: The Vaste Commissie Wetenschap en Ethiek van de Faculteit der Gedrags- en Bewegingswetenschappen (VCWE), Vrije Universiteit Amsterdam approved the NAR data collection (VCWE-2020–041).

Matched Sample: The study was approved by the institutional research ethics committees (2013-PN-2861 and 2015-BC-4576).

Approval to combine the data was gained from the Science & Engineering Research Ethics Committee of the University of Nottingham Malaysia (ethics application number MDV200718).

CRediT authorship contribution statement

Marieke de Vries: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Sander Begeer:** Conceptualization, Methodology, Writing – review & editing. **Hilde M. Geurts:** Conceptualization, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.rasd.2023.102201.

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