

Genetic and Environmental Contributions to the Inverse Association Between Specific Autistic Traits and Experience Seeking in Adults

Ángel Romero-Martínez,¹ Luís Moya-Albiol,¹ Anna A. E. Vinkhuyzen,² and Tinca J. C. Polderman^{3*}

¹Department of Psychobiology, University of Valencia, Valencia, Spain

²Queensland Brain Institute, University of Queensland, St. Lucia, QLD, Australia

³Department of Complex Trait Genetics, Center for Neurogenomics and Cognitive Research (CNCR), Neuroscience Campus Amsterdam (NCA), VU University Amsterdam, Amsterdam, The Netherlands

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Autistic traits are characterized by social and communication problems, restricted, repetitive and stereotyped patterns of behavior, interests and activities. The relation between autistic traits and personality characteristics is largely unknown. This study focused on the relation between five specific autistic traits measured with the abridged version of the Autism Spectrum Quotient (“social problems,” “preference for routine,” “attentional switching difficulties,” “imagination impairments,” “fascination for numbers and patterns”) and Experience Seeking (ES) in a general population sample of adults, and subsequently investigated the genetic and environmental etiology between these traits. Self-reported data on autistic traits and ES were collected in a population sample ($n = 559$) of unrelated individuals, and in a population based family sample of twins and siblings ($n = 560$). Phenotypic, genetic and environmental associations between traits were examined in a bivariate model, accounting for sex and age differences. Phenotypically, ES correlated significantly with “preference for routine” and “imagination impairments” in both samples but was unrelated to the other autistic traits. Genetic analyses in the family sample revealed that the association between ES and “preference for routine” and “imagination impairments” could largely be explained by a shared genetic factor (89% and 70%, respectively). Our analyses demonstrated at a phenotypic and genetic level an inverse relationship between ES and specific autistic traits in adults. ES is associated with risk taking behavior such as substance abuse, antisocial behavior and financial problems. Future research could investigate whether autistic traits, in particular strong routine preference and impaired imagination skills, serve as protective factors for such risky behaviors. © 2015 Wiley Periodicals, Inc.

Key words: autism; sensation seeking; personality; substance abuse

INTRODUCTION

Autism spectrum disorders (ASDs) are lifelong neurodevelopmental disorders that are highly heritable [Polderman et al., 2015].

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Social, communication and functioning impairments are generally considered hallmarks of ASDs [American Psychiatric Association, 2013]. Additionally, important characteristics of ASD are stereotypic and repetitive behaviors such as motor mannerisms, preoccupation with nonfunctional objects or parts of objects, interest in patterns and extreme rigidity, and a lack of interest in novelty [Soderstrom et al., 2002; South et al., 2005; Gomot et al., 2006]. In line with this, ASD affected people tend to follow strict (self-made) rules and a rigid norm-abiding style, maintain limited social contact, and show little interest in typical social activities and new experiences [Boucher, 1977; South et al., 2005; Santosh and Mijovic, 2006; Ramos et al., 2013]. Characteristics of ASD are not limited to clinical ASD. Instead, autistic traits show a continuous

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*Correspondence to:

Tinca J. C. Polderman, Department of Complex Trait Genetics, Center for Neurogenomics and Cognitive Research (CNCR), Neuroscience Campus Amsterdam, De Boelelaan 1085, 1081 HV, Amsterdam, The Netherlands.

E-mail: tinca.polderman@vu.nl

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distribution when assessed in population samples [Baron-Cohen et al., 2001; Constantino and Todd, 2003].

A contrasting trait, in particular compared to the stereotype and repetitive behaviors of ASD, is the personality trait Experience Seeking (ES). In general, ES persons prefer a non-conforming lifestyle, have a strong need for novel, varied, and stimulating experiences, and like to make new friends. Moreover, they show a willingness to take physical and social risks for the sake of novel experiences such as substance abuse and antisocial behaviors [Zuckerman, 1979; Miles et al., 2001]. Consequently, ES behavior is associated with psychopathological outcomes such as drug or gambling addiction [Crawford et al., 2003]. As the characteristics of ES seem the opposite of typical autistic traits one could hypothesize that individuals that have a high preference for routine and a reduced interest in new experiences, such as meeting new people, score low on ES measures and tend to show less risky novelty seeking behaviors. Indeed, this was demonstrated in a clinical study where adolescents with Asperger syndrome (Note that Asperger syndrome in the current DSM-5 is not a separate disorder but instead is included in the broader term "Autism Spectrum Disorders") were compared to healthy controls using self-reported measures of sensation seeking traits, personality factors such as introversion and inhibition, and drug use. The participants with Asperger showed significantly lower scores on sensation seeking traits (a trait strongly related to ES) and drug use, and higher scores on inhibition [Ramos et al., 2013]. Interestingly, similar patterns were observed in a general population sample of young adults. Kanne et al. [2009] assessed autistic trait scores in a sample of young undergraduate students where they tested for differences in personality traits in lower and higher scoring individuals. The group that scored low on autistic traits scored significantly higher on sensation seeking compared to the high scoring group. Based on the above mentioned studies one could hypothesize that having a certain degree of autistic traits serves as a protective factor regarding risk taking behavior as implied in ES.

The inverse relationship between autistic traits and ES might have a shared biological basis. Significantly higher levels of dopamine have been associated with ES behavior in humans as well as rodents, in particular when expecting an upcoming reward (see for a review Norbury and Husain, 2015). Additional support for these observations comes from a meta-analysis that reported evidence for an association between novelty seeking and the dopamine D4 receptor (DRD4) gene [Munafo et al., 2008]. Several studies reported disturbed dopamine functions [Makkonen et al., 2011], and dopamine related genes [Neale et al., 2012; Hamilton et al., 2013] also to be associated with ASD, with in particular the SLC6A3 gene to be important.

We aim to broaden our knowledge on the association between autistic traits and ES with a study design that includes four novel aspects. Firstly, as autistic traits are not limited to the period of childhood and adolescence, but tend to persist into adulthood [Billstedt et al., 2007], and also personality traits such as ES are only fully developed in adulthood [Carver and Scheier, 2007], we focus on adults instead of adolescents. Secondly, we focus on the general population to explore the full distribution of ES, and autistic traits. This will provide insight in the association between both traits in the general population, increases statistical power to detect asso-

ciations, and will complement the outcomes of studies in clinical samples, that specifically report on the extreme end of this distribution. Thirdly, to get more insight in the association between the broader spectrum of ASD traits and ES we used in our analyses a measure that distinguishes five specific autistic traits: (a) impairments in social skills, b) attention switching, c) imagination, d) fascination for patterns, and e) routine preferences). Lastly, as both autistic traits and ES [Polderman et al., 2015] are substantially heritable, and some potentially shared genetic mechanisms have been suggested, we investigated the contribution of genetic and environmental factors to the association between the particular autistic traits and ES in a twin family sample.

MATERIALS AND METHODS

Subjects

This study used two independent population samples that volunteered in the Netherlands Study of Cognition, Environment and Genes (NESCOG). One sample consisted of genetically unrelated participants who were recruited through media advertisement or through the Science Live Program of the NEMO Science Center in Amsterdam (www.sciencelive.nl). This sample consisted of 559 participants (34% men) with a mean age of 41.53 (SD 11.37) years old (Sample 1). The second sample (Sample 2) was a family sample consisting of 560 twins and siblings (41% men). There were 81 monozygotic (MZ) and 67 dizygotic (DZ) twin pairs, 89 incomplete twin pairs (28 MZ and 61 DZ), one triplet and 321 full siblings from 256 families. Mean age of the participants was 46.60 (SD 12.38) years at the time of assessment. Zygosity of same-sex twins was determined using DNA polymorphisms (127 pairs) or, if information on DNA markers was not available, using questions about physical similarity and confusion of the twins by family members and strangers (see Polderman et al. [2013], for details of both NESCOG samples).

All participants completed a behavioral questionnaire about life events, environmental factors and behavioral conditions, including items on ES and autistic traits. The study was performed with understanding and written consent of each participant, and was approved by the Central Committee on Research Involving Human Subjects of the VU/VUmc Amsterdam, The Netherlands.

Measures

Autistic traits. Autistic traits were measured with the abridged version of the Autism-Spectrum Quotient (AQ-Short), which is validated in Dutch and UK populations [Hoekstra et al., 2011]. It is a self-administered questionnaire composed of 28 items that quantifies autistic traits in normative populations. Items were rated on a four-point Likert scale, with answer categories "1 = definitely agree," "2 = slightly agree," "3 = slightly disagree," and "4 = definitely disagree." The AQ-Short assesses five different autistic traits: social skills (AQ-Short Social, 7 items), routine preference (AQ-Short Routine, 4 items), attention switching problems (AQ-Short Switch, 4 items), imagination deficits (AQ-Short Imagination, 8 items), and fascination for numbers and patterns (AQ-Short Numbers, 5 items). The scoring is reversed for applica-

ble items in such a way that a high score on the AQ-Short reflects more autistic problems. When assessed in the general population the AQ shows a normal distribution of trait scores [Baron-Cohen et al., 2001].

Experience seeking. The Experience Seeking (ES) scale is one of the four subscales of the Sensation Seeking Scale. The ES scale refers to desired experiences through wanderlust, exhibitionism, use of marijuana and hallucinatory drugs, association with non-conformist friends, and liking of modern and arousing arts and music. It contains 14 items ranked on a five-point Likert scale ranging from 1 (definitely disagree) to 5 (definitely agree). Sum scores calculated across all items were used as unit of analysis in this study. All items were scored such that a higher score indicates a higher degree of ES behavior. The reliability and validity of the ES has extensively been tested [Zuckerman, 1971; Zuckerman, 1979; Feij and van Zuilen, 1984], also for the Dutch translation [Feij et al., 1997].

Reliability

Table I shows Cronbach's alphas for the different measures in Sample 1 and 2. We also obtained test-retest correlations for all measures from a small independent population sample of parent-offspring pairs (Sample 3). Sixty participants completed the behavioral questionnaire twice in two months. These data were used to examine the test-retest reliability of the measures. Written consent was obtained from each participant.

Statistical Analyses

All the analyses were conducted in Mx statistical software that is designed to apply structural equation models to family data. Mx provides parameter estimates by maximizing the raw data likelihood [Neale et al., 2006]. For Sample 1 and 2, estimates of the means, variances, phenotypic correlations, as well as the effects of sex and age on the means, were obtained from a bivariate (with one AQ-Short scale and ES) saturated model which is free from assumptions regarding genetic and environmental variant components for the traits under study. Sex and age were included as covariate in subsequent genetic analyses when they had a significant effect on the means.

In Sample 2 the saturated model was also used to test for differences between zygosity groups in means and variances, as well as for differences between DZ twin correlations and regular sibling correlations of autistic traits and ES. All tests were performed using hierarchical likelihood ratio (χ^2) tests. The χ^2 statistic is obtained by using a χ^2 test of -2 LL difference with degrees of freedom corresponding to the difference in the degrees of freedom between two models (reference model and the log-likelihood of a submodel with certain constraints). To account for multiple testing, type-I error rate was set at 0.01.

Twin Model

The AQ-Short and ES scores of MZ and DZ twins and non-twin siblings (i.e., Sample 2) were used to divide the observed variance of AQ-Short traits and ES, and also the covariance between traits, into latent genetic and environmental variance components (A, C, D, and E). "A" represents additive genetic effects of alleles summed over all genetic loci (additive genetic effects). "C" represents shared environmental influences that render offspring of the same family more alike (shared environmental factors). "D" represents nonadditive genetic effects within loci (genetic dominance). "E" represents all environmental influences that result in differences between members of a family, including measurement error (nonshared environmental factors).

MZ twins are genetically identical, thus, they share all their additive genetic effects. However, DZ twins and normal siblings share, on average, half of their segregating genes and therefore, on average, half of their additive genetic effects, and a quarter of their dominant genetic effects. All twins and siblings in this sample grew up in the same family and thus share their family environment.

Genetic Models

We tested whether additive genetic, dominant genetic, shared and non-shared environmental factors contributed significantly to the total variance of ASD traits and ES, and to their covariance. In the bivariate saturated models, cross trait-cross twin correlations (CTCT) were used to indicate to what extent different trait dimensions are influenced by the same set of genetic or environmental factors. If MZ CTCT correlations are higher than DZ CTCT

TABLE I. Reliability of AQ-Short Scales and ES Scale

Measures	N items	Cronbach's alpha		Test-retest correlation
		Sample 1	Sample 2	Sample 3
AQ-Short total	28	0.80	0.77	0.83
AQ-Short social	7	0.78	0.71	0.80
AQ-Short routine	4	0.62	0.52	0.65
AQ-Short switch	4	0.62	0.54	0.66
AQ-Short imagination	8	0.69	0.68	0.75
AQ-Short numbers	5	0.76	0.70	0.88
Experience seeking [ES]	14	0.75	0.74	0.86

As expected [Cortina, 1993], lower alpha's were observed for scales with the fewer items.

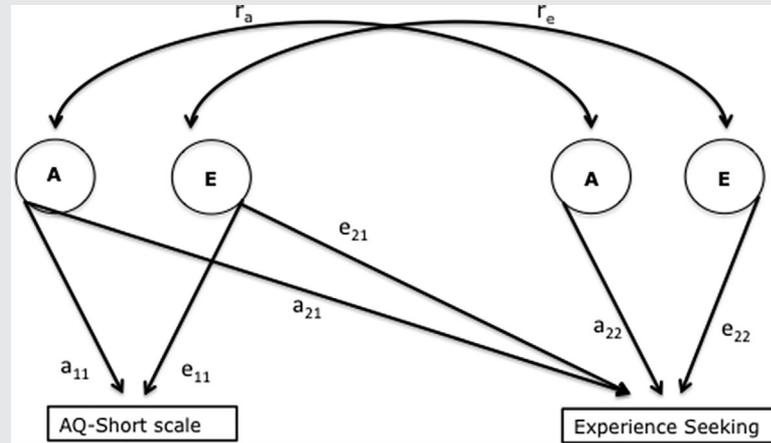


FIG. 1. Example of AE bivariate, genetic model of the AQ-Short scale, and experience seeking (ES) for one individual.

r_a = genetic correlation; r_e = unique environmental correlation; A = latent additive genetic factor; E = latent unique environmental factor.

$$\text{Heritability AQ-Short scale} = \frac{a_{11}^2}{a_{11}^2 + e_{11}^2}$$

$$\text{Heritability experience seeking} = \frac{a_{21}^2 + a_{22}^2}{a_{21}^2 + a_{22}^2 + e_{21}^2 + e_{22}^2}$$

$$\text{Genetic correlation} = \frac{a_{11} \times a_{21}}{\sqrt{a_{11}^2 + e_{11}^2} \times \sqrt{a_{21}^2 + a_{22}^2}}$$

correlations genetic influences are expected to play a role in the covariation between traits.

A bivariate genetic model was used to test the significant contribution of A, D, C, or E to the variance of ES and each AQ-Short scale, and to the covariation between ES and the AQ-Short scales. The genetic or environmental variance explained is usually reported in a standardized form, as a proportion, by dividing this part of the variance by the total phenotypic variance. The proportion of variance that is explained by genetic effects is called the heritability estimate (i.e., heritability is calculated as genetic variance divided by the total phenotypic variance). A genetic correlation between two traits indicates to what extent identical genetic factors play a role in both traits, and the environmental correlation can be interpreted in a similar vein. Figure 1 shows an example of the bivariate model for one AQ-Short scale and ES.

Male and female data were combined as with the current sample size the power to detect sex differences in the variance and covariance components was low [Polderman et al., 2006].

RESULTS

Descriptives

Two males were removed from Sample 2 because their scores were >3 standard deviations from the mean for the AQ-Short. Table II shows descriptive statistics for ASD traits and ES for both samples, significant sex and age effects on the means, and phenotypic correlations between ES and the AQ-Short scales. The means and SD of both groups were quite similar for the majority of the AQ-Short scales and ES. In Sample 1, ES significantly correlated with the AQ-Short Total, AQ-Short Routine and AQ-Short Imagi-

TABLE II. Estimated Means, Standard Deviations (SD), and Significant Sex and Age Effects for the AQ-Short Scales and Experience Seeking (ES) Scale

Measures	Sample 1 (n = 559)			Sample 2 (n = 558)		
	Mean (SD)	β sex/ β age	Correlation with ES	Mean (SD)	β sex/ β age	Correlation with ES
AQ-Short total	55.67 ± 9.55	-2.86/0.09	-0.17*	53.40 ± 8.46	-2.37/0.09	-0.18*
AQ-Short social	12.65 ± 3.82	-/0.03	-0.10	12.38 ± 3.26	-/—	-0.02
AQ-Short routine	8.05 ± 2.26	-/—	-0.28*	7.95 ± 2.09	-/—	-0.24*
AQ-Short switch	9.26 ± 2.37	-0.59/—	0.03	7.44 ± 2.07	-/0.03	0.03
AQ-Short imagination	13.97 ± 3.63	-/0.06	-0.31*	14.14 ± 3.64	-/0.06	-0.35*
AQ-Short numbers	11.67 ± 3.61	-1.79/—	0.12	9.57 ± 3.13	-1.38/0.03	0.07
Experience seeking (ES)	41.36 ± 8.64	-2.52/—	—	36.52 ± 8.28	-3.04/—	—

* $P < 0.01$.

TABLE III. Left: Monozygotic (MZ) and Dizygotic (DZ) Twin-Sibling Correlations in Sample 2; Right: The Contribution of Additive Genetic (A), Common (C) and Unique Environmental (E) Variance to the total variance of each AQ-Short Scale and the Experience Seeking (ES) Scale

Measures	Twin correlations		CTCT correlations			Full model			Reduced model		
	MZ	DZ/twin-sib	MZ	DZ/twin-sib	A	D	E	A	E		
AQ-Short total	0.54 [0.40-0.65]	0.19 [0.07-0.32]	-0.11 [-0.23-0.01]	-0.07 [-0.16-0.02]	23 [0-61]	31 [0-64]	46 [35-60]	51 [37-63]	49 [37-63]		
AQ-Short social	0.35 [0.13-0.52]	0.09 [-0.04-0.22]	-0.22 [-0.33-0.10]	-0.08 [-0.16-0.00]	03 [0-27]	37 [6-53]	61 [46-79]	28 [11-44]	72 [56-89]		
AQ-Short routine	0.42 [0.25-0.57]	0.02 [-0.06-0.13]	-0.24 [-0.35-0.11]	-0.13 [-0.22-0.04]	15 [0-48]	35 [0-58]	51 [38-66]	42 [27-56]	58 [44-73]		
AQ-Short switch	0.47 [0.28-0.60]	0.18 [0.07-0.29]	—	—	51 [5-70]	10 [0-59]	39 [29-53]	59 [47-71]	41 [29-53]		
AQ-Short imagination	0.50 [0.34-0.62]	0.14 [0.04-0.26]	—	—	—	—	—	—	—		
AQ-Short numbers	0.36 [0.17-0.52]	0.17 [0.06-0.29]	—	—	—	—	—	—	—		
Experience seeking (ES)	0.60 [0.45-0.71]	0.27 [0.16-0.38]	—	—	—	—	—	—	—		

95% confidence intervals in brackets.

nation with $r = -0.17$, $r = -0.28$, and $r = -0.31$, respectively (all $P < 0.01$), but not with the other AQ-Short scales. The similar significant pattern of negative correlations was observed in Sample 2, with $r = -0.18$, $r = -0.24$, and $r = -0.35$ (all $P < 0.001$) for the AQ-Short total, AQ-Short Routine and AQ-Short Imagination respectively, and with again no significant correlations with other AQ-Short scales.

Genetic Results

The twin correlations are presented in Table III. We performed bivariate genetic analyses for those AQ-Short scales that correlated significantly with ES in Sample 2 (i.e., AQ-Short Total, AQ-Short Routine, and AQ-Short Imagination). MZ CTCT correlations were generally higher than DZ CTCT correlations, suggesting that genetic influences partly explained the phenotypic correlations between autistic traits and the ES scale. Nevertheless, as MZ CTCT correlations were lower than the within-person phenotypic correlations, non-shared environmental influences also explain part of the relationship between those autistic traits and ES.

Table IV shows the fit statistics of the bivariate genetic models. For all three AQ-Short scales an AE model was the most parsimonious best fitting model. The phenotypic association between ES and AQ-Short Total, AQ-Short Routine and AQ-Short Imagination could largely be explained by a shared genetic factor (66%, 89%, and 70%, respectively), and the genetic correlations were substantial, in particular for AQ-Short Routine and AQ-Short Imagination (-0.52 and -0.49 , respectively).

DISCUSSION

This is the first study to examine the (genetic) relationship between specific autistic traits and ES in adults. We found an inverse phenotypic relationship between the autistics traits “preference for routine” and “imagination impairments” with ES in two independent samples. With one of the samples being a twin family sample, we could also show that these inverse relationships were largely explained by genetic factors.

ES is associated with novelty seeking, and risk taking behavior such as drug abuse, alcohol problems, and antisocial behavior while autistic traits, in contrast, are associated with a lack of interest in novelty, change or drug use, and with high levels of inhibition [Kanne et al., 2009; Ramos et al., 2013]. Our study was conducted in the general population and focused on specific dimensions of autistic traits to obtain more insight in the nature of the relation between autistic traits and ES. Only “preference for routine” and “imagination impairments” were associated with ES while “attentional switching difficulties,” “social problems,” and “fascination for numbers and patterns” showed no correlation with ES. Although one could argue that ‘preference for routine’ and ES are both sides of the same coin, the 14 ES items were largely non-overlapping with the four items of AQ-Short routine scale. The majority of ES items included subjects like drug use, preference for yoga, or experimental music, or artistic friends, having unusual feelings, or mystic experiences, or writing poems, and were as such quite different from the four AQ-Short routine items that were about doing the same things over and over again, or being

TABLE IV. Model-Fitting Results of Bivariate Genetic Models in Sample 2 for the AQ-Short Total, AQ-Short Routine and AQ-Short Imagination With the Experience Seeking (ES) Scale

ES with:	-2 LL	χ^2	df	P	Genetic correlation with ES/% of r_p explained by genetic factors	Unique environmental correlation with ES/% of r_p explained by unique environmental factors
AQ-short total						
Saturated	7681.774	2.561	1	0.11		
ADE	7684.335	1.825	3	0.61	-0.22 [-0.42 to -0.01]/66%	-0.14 [-0.31 to 0.05]/34%
AE	7686.160	3.905	1	0.05		
No genetic overlap	7690.066	2.189	1	0.14		
No unique environmental overlap	7688.350					
AQ-short routine						
Saturated	6139.487					
ADE	6145.942	6.455	3	0.09		
AE	6151.184	5.242	3	0.16	-0.52 [-0.83 to -0.23]/89%	-0.05 [-0.23 to 0.14]/11%
No genetic overlap	6162.305	11.121	1	<0.00		
No unique environmental overlap	6151.433	0.249	1	0.618		
AQ-short imagination						
Saturated	6714.681					
ADE	6718.745	5.742	2	0.13		
AE	6723.422	4.678	3	0.20	-0.49 [-0.70 to -0.27]/70%	-0.21 [-0.38 to -0.04]/30%
No genetic overlap	6739.299	15.877	1	<0.00		
No unique environmental overlap	6728.873	5.451	1	0.02		

95% confidence intervals in brackets. r_p = phenotypic correlation.

disturbed by routine changes, or new situations. One could speculate that people with a strong preference for routine have an extreme resistance to change and may therefore be less likely to seek out high-sensation behaviors like drug use, or listening to new experimental music. Other latent factors that may underlie this association could relate to anxiety for new or unexpected situations, or a strong need for controlling the course of specific events.

The imagination scale that was associated with ES reflects items such as “Trying to imagine something, I find it easy to create a picture in my mind,” “I find it difficult to imagine what it would be like to be someone else” and “I find it easy to work out what someone is thinking or feeling.” To test whether this association could be explained by the routine preference scale we reran the correlation analyses while controlling for routine. The correlation between ES and the imagination scale dropped from -0.36 to -0.25 but was still significant. A clinical study by Lind and Bowler [2010] demonstrated that clinically diagnosed individuals with ASD exhibit impairments in episodic future thinking, scene construction and self-projection. One could hypothesize that due to this kind of impairments people who score high on the imagination scale do not seek new experiences simply because they cannot imagine how a certain experience would be like. Another explanation for this specific association could be that individuals who have less imagination skills will show less affinity with writing a poem or experience mystic feelings. Additionally, they could be less interested in socially interacting with artistic people, who will likely have high imagination skills.

Genetic analyses in the twin sample revealed that the association between ES and “preference for routine” and “imagination impairments” could be explained by shared genetic influences (89% and 70%, respectively) while unique environmental variation only accounted for 11–30% of the phenotypic correlations. The inverse relationship between the two autistic traits and ES implies that a higher presence of these autistic traits and a lower tendency to show ES behavior is largely influenced by the same genetic factors. Genetic factors that are shared between both traits might be involved in dopamine functions, so genetic mechanisms involved in dopaminergic pathways, such as the SLC6A3 gene, might be interesting to explore [Hamilton et al., 2013; Neale et al., 2012; Norbury and Husain, 2015].

This study has several limitations. First, we assessed ASD traits and ES based on self-reports only. Although this approach is common in epidemiological research, multiple ASD and ES measurements would reinforce the validity of our findings. Second, the twin-sibling sample used for the genetic analyses was relatively small, decreasing the statistical power to estimate variance components. This was illustrated by the rather wide confidence intervals for these estimates. Our genetic results should therefore be interpreted with caution and replication in an independent twin sample is warranted. However, twin data collections of, in particular, autistic traits are as yet scarce. The statistical power to investigate sex differences in the etiology of autistic traits and ES, and in the covariance between traits, was also low. However, a recent study in a larger adult twin sample found no evidence that sex moderates the variance decomposition of autistic traits [Polderman et al., 2014]. Still, for ES some sex differences have been reported [Koopmans et al., 1995].

Third, the internal consistency of some of the ASD dimensions was relatively low, in particular for AQ-Short Routine and Switch. This was presumably due to the low number of items or heterogeneity among these scale items. Low alphas for ASD dimensions have been reported before [Ronald et al., 2006; Hoekstra et al., 2011], and future studies should aim to optimize the collection of autistic dimensions in the (adult) general population.

An important strength of our study is that we obtain similar phenotypic findings (i.e., the associations between ES and specific AQ-Short scales) in two relatively large, independent population samples. In addition, we focused on specific autistic traits, in contrast to an overall measure, to obtain more insight in specific patterns of the association between autistic traits and ES. Moreover, we could analyze the etiology of these associations in a genetically informative twin-sibling design.

To conclude, we demonstrated the existence of an inverse relationship between ES and the specific autistic traits “routine preference” and “impaired imagination skills” in adults. We also showed that the relation was largely explained by shared genetic factors indicating shared biological mechanisms underlying ES and these autistic traits. As ES is associated with risk taking behavior such as drug abuse, alcohol problems, antisocial behavior and financial problems, future research could investigate whether autistic traits, in particular strong routine preference and impaired imagination skills, serve as protective factors for such risky behaviors.

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