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When mind and measurement diverge; the interplay between subjective cognitive complaints (SCCs), objective cognition, age, and depression in autistic adults

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ABSTRACT

While the increased incidence of dementia and subjective cognitive complaints (SCCs) suggests that autistic adults may face cognitive challenges at older age, the extent to which SCCs predict (future) cognitive functioning remains uncertain. This uncertainty is complicated by associations with variables like depression. The current study aims to unravel the interplay of age, depression, cognitive performance, and SCCs in autism. Using a large cross-sectional cohort of autistic (n=202) and non-autistic adults (n=247), we analyzed associations of SCCs with age, depression, and cognitive performance across three domains (visual memory, verbal memory, and fluency). Results showed a strong significant association between depression and SCCs in both autistic and non-autistic adults. Cognitive performance was not significantly associated with SCCs, except for a (modest) association between visual memory performance and SCCs in autistic adults only. Follow-up regression tree analysis indicated that depression and being autistic were considerably more predictive of SCCs than objective cognitive performance. Age nor sex was significantly associated with SCCs. These findings indicate that self-reported cognitive functioning does not equal cognitive performance, and should be interpreted with care, especially in individuals with high rates of depression. Longitudinal investigations are needed to understand SCCs' role in dementia and cognitive health in autism.

Lay abstract

Illustrated by an increased prevalence of dementia and self-reported cognitive difficulties, autistic adults may face challenges as they age. We were interested in understanding why autistic individuals report increased difficulties with their thinking compared to non-autistic adults. These reports are termed 'subjective cognitive complaints' (SCCs). Specifically, we aimed to understand how age, feelings of depression, and how well they perform on tests that measure their thinking skills (cognitive tests) all come together to shape SCCs in autism. Therefore, we looked at a large group of autistic adults (202 people) and a comparison group of non-autistic adults (247 people). We used two questionnaires to measure SCCs and depression symptoms, and cognitive tests to measure performance in visual memory, verbal memory, and verbal fluency. Across people (irrespective of being autistic) feelings of depression were the most clearly associated with SCC's. In contrast, SCC's and actual cognitive performance were not associated. There was one exception as in autistic adults only reporting SCC's was moderately associated with visual memory performance. In line with this, we also found that being autistic and experiencing depression symptoms were more important predictors of SCCs than performance on cognitive tests. This seems to suggest that self-reported cognitive challenges may not always match someone's thinking skills/cognitive performance. In conclusion, understanding how autistic adults

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experience thinking difficulties is complex. We show that it is important to consider factors like depression when interpreting reports of cognitive difficulties in autism. Additional research is needed to grasp the impact of SCCs on age-related cognitive performance in autistic adults.

1. Introduction

Subjective cognitive complaints (SCCs) are commonly associated with aging (Geerlings et al., 1999; Reid & MacLullich, 2006; Srisurapanont et al., 2015), as they are a core criterion for the diagnosis of mild cognitive impairment and dementia (Albert et al., 2011; McKhann et al., 2011). SCCs are also common in psychiatric classifications (Bortolato et al., 2014; Pierre et al., 2019), including autism (Davids et al., 2016; Joshi et al., 2016; Lever & Geurts, 2016a; van Heijst & Geurts, 2015). Concerningly, autism seems associated with an increased incidence of dementia and other forms of age-related disease (e.g., Hand et al., 2020; Vivanti et al., 2021), although the evidence is not entirely consistent (Schott et al., 2022). As SCCs are seen as precursors for age-related cognitive decline in non-autistic individuals (Jessen et al., 2014), they seem especially important to measure in autistic adults. It is easy to think that SCCs are a reflection of the same cognitive abilities that are measured on objective cognitive tests, often weak and inconsistent correlations between SCCs and objective performance are reported (Burmester et al., 2016; Groenman et al., 2022; Reid & MacLullich, 2006). Conversely, stronger and more consistent relations are reported between SCCs and depression and/or quality of life (Groenman et al., 2022; Hill, 2016). Given that SCCs are easily measured during clinical assessments, it is of the utmost importance to understand what constructs SCCs reflect. This study aims to unravel the effects of age, depression, and SCCs, and their interplay within autism.

Autistic individuals consistently report higher SCCs compared to norm groups or non-autistic individuals (Davids et al., 2016; Joshi et al., 2016; Lever & Geurts, 2016a; Torenvliet et al., 2022; van Heijst & Geurts, 2015). While generally weak and nonsignificant correlations are found between objectively measured cognition and SCCs (Groenman et al., 2022), one study in autism reported otherwise. Davids et al. (2016) showed small to moderate negative correlations between SCCs and performance on the Tower of London in older autistic adults, but not in non-autistic controls (Davids et al., 2016). This might suggest that those with autism are better at estimating their own cognitive performance. However, other studies looking into the relation between objective and subjective cognition did not find any significant correlations between objectively measured cognition and SCCs in autistic adults (Geurts et al., 2020; Lever & Geurts, 2016a). Given these inconsistent results an exploration of factors related to these effects in autism is necessary.

In other psychiatric and non-psychiatric cohorts depression has been linked to SCCs, with often stronger associations compared to objective measures of cognition (Brigola et al., 2015; Groenman et al., 2022; van Rijsbergen et al., 2019). In autism the association between SCCs and depression has been rarely investigated. Psychiatric comorbidity does occur frequently in autism (Lai et al., 2019; Lugnegård et al., 2011), with almost 80% of individuals having a lifetime diagnosis of one or more psychiatric disorders, and mood disorders being the most common comorbidity in autism (Lever & Geurts, 2016b). One study comparing individuals with high and low autistic traits observed that when controlling for current depression symptoms, the difference in SCCs between those with high and low autistic traits disappears (Stewart et al., 2022). This might suggest that differences in SCCs are best explained for example by differences in depression, and not objective cognition. While SCCs have been linked to lower quality of life in autism (van Heijst & Geurts, 2015), until now, it remains unclear whether SCCs are better explained by objective cognitive difficulties or depression.

The interplay between objective cognition, depression and SCCs may also be dependent on demographic variables like age and sex. Jonker et al. (2000) suggested that in non-autistic people SCCs were related to depression in younger samples, but increased SCCs reflected associations with objective memory performance in older samples. The autistic sample by Davids et al. (2016) was between 50 and 84 years, and thus relatively old. Therefore, the relation between SCCs and objective cognition found in this older sample could possibly be explained by age and sex. The wider age range (between 20 and 79 years) in the autistic sample studied by Lever and Geurts (2016a) could have clouded this association. However, the autistic sample studied by Geurts et al. (2020) had a similar age range to Davids et al. (2016) (between 60 and 85 years) but did not observe significant associations between SCCs and objective cognition. Additionally, in non-autistic people, female sex is associated with higher rates of depression (Malhi & Mann, 2018) and menopause is often associated with an increase in SCCs (Weber et al., 2014). This might suggest, that specifically in older age, sex differences might arise in the relation between SCCs, objective cognition, and depression. If and how sex influences the relation between SCCs and, depression, cognition, and autism will be explored in the current study.

This preregistered (https://aspredicted.org/GJA_IRB) study using a large sample (partly overlapping with Lever & Geurts, 2016a) aims to i) investigate whether SCCs are related to age, depression and measures of objective cognition in autistic and non-autistic individuals, ii) investigate potential interactions between age and depression or objective cognition, and iii) investigate the possibility of sex-specific effects in the aforementioned associations. We hypothesize an increase in the number of SCCs independent of group with older age and more depressive symptoms. Exploratively, we will investigate age-specific patterns of associations between depression symptoms and cognition, consistency of results using an alternative measure of SCCs, and use data-driven methods (i.e., regression trees) to detect possible subgroups SCCs.

2. Method

2.1. Participants

Participants, aged between 30 and 85, in this study were part of a multistage, overlapping longitudinal cohort study (Geurts et al., 2021). For the current study, data of the first measurement of participants at wave 1 (cohort 1) and wave 3 (cohort 2) are combined. Cohort 1 contains 118 autistic participants (autism), and 148 non-autistic comparisons (no-autism), Cohort 2 88 autistic participants, and 106 non-autistic comparisons. Exclusion criteria were the same for Cohort 1 and 2, being: 1) a history of neurological disorders (e.g., epilepsy, stroke, multiple sclerosis), schizophrenia or having experienced more than one psychosis, 2) IQ < 70 or MMSE < 26, 3) current alcohol or drugs dependency. For the autism group, two additional criteria were applied: 1) no registered diagnosis of autism according to the DSM-IV/5 criteria (American Psychiatric Association, 1994, 2013), 2) a score below the cut-off of both the Autism Diagnostic Observation Schedule(2) (ADOS [-2]; Bildt et al., 2013; Lord et al., 2012) and the autism spectrum quotient (AQ; Baron-Cohen et al., 2001) < 26. For the no-autism group, we had 4 additional criteria: 1) a history of autism or Attention-Deficit/Hyperactivity disorder (ADHD), 2) close family members with autism or ADHD, 3) AQ > 32, 4) ADHD-SR symptoms (Kooij et al., 2005) in childhood and/or adulthood ≥ 6.

2.2. Measures

Subjective Cognitive Complaints (SCCs) were measured using the Dutch version of the Cognitive Failures Questionnaire [CFQ; (Broadbent et al., 1982; Merckelbach et al., 1996)]. 25 items measure daily cognitive functioning on a four-point Likert scale. The CFQ has good psychometric properties (Bridger et al., 2013). In the current sample, Cronbach's α was .88 in the no-autism group and .91 in the autism group. Total score was used as a measure of SCCs and ranges between 0 and 100. Higher scores indicate more complaints.

Next to the CFQ, an in-house measure of self-indicated cognitive

performance was added at the end of the cognitive test battery in cohort 2. Participants indicated their performance on a visual analog scale (VAS) between 0 (very poor) and 10 (excellent).

Objective cognition was measured by 11 z-transformed outcome variables on seven cognitive domains – being verbal memory, visual memory, working memory, social cognition, processing speed, semantic, and phonemic fluency. Details of the measures are provided in our Supplementary Materials, S1, section S1. The number of outcome measures was reduced by performing exploratory factor analysis. Eigenvalues and parallel analysis revealed an optimal solution of three factors (see our supplementary R-Markdown (S2) for details). A promax rotation with a cut-off of 0.3 resulted in a verbal memory factor (direct recall, indirect recall, and recognition), a visual memory factor (direct recall, indirect recall, and recognition) and a fluency factor (semantic and phonemic). Measures of working memory, social cognition, and processing speed did not load on any of the factors and were removed from the analysis. Exact loadings and correlations of the final factor solution are provided in our R-Markdown (S2). Factor scores were directly extracted from the analysis solution, weighing the contribution of each measure by their factor loading.

Depression was measured using the depression subscale of Dutch version of the Symptom Checklist-90 [SCL-90; (Arrindell & Ettema, 2005))]. The 16 items are scored on a five-point Likert scale (1 to 5). Ratings on questions belonging to the depression subscale were summed to the depression subscale scoring, ranging from 16 to 80, with a higher score indicating more depressive symptoms.

2.3. Procedure

Ethical approval for this study was obtained from the local ethical review board at the University of Amsterdam (Wave 1 2011-PN-1952 and 2013-PN-2668, Wave 3 2018-BC-9285). Participants received a monetary reward of max. €30,- and travel compensation for their participation. Participants were asked to fill out the questionnaires independently prior to a visit to the university where cognitive testing took place.

2.4. Community involvement

Throughout our overall study on aging in autism (Geurts et al., 2021), we collaborated with a group of older/autistic adults (also referred to as the think tank). We met with the think tank at least three times a year to discuss recruitment strategies, information for participants, the interpretation of study results and other study-related matters. The members were paid for their contributions.

2.5. Analyses

All analyses were performed in RStudio (version 2022.07.2.576; RStudio Team, 2020). Reproducible code and outcomes of all analyses can be found in our R-Markdown (S2). Our pre-registered analyses plan (https://aspredicted.org/GJA_IRB) consisted of six steps. In step 1, five linear regressions were performed with SCCs (CFQ total score) as the outcome variable, and depression (SCL-90 depression), objective cognition (Factors 1, 2 and 3), and age as predictors. In step 2, group (autism / no-autism) and the interaction between the predictors and group were added to assess whether there is a group difference in the relation between SCCs and the predictor variables. Furthermore, we explored whether age^2 provides a better model fit. In step 3, dependent on the previous analyses, we compared beta's to assess the direction and size of the associations in higher in older vs younger age (<55 vs ≥ 55), and the possible differential effect of group (autism / no-autism). For these analyses, *p*-values below 0.01 were considered significant to reduce our false detection rate. In step 4, linear regression analysis was performed in the older group only, investigating sex and the interaction between group*sex with SCCs as the outcome.

In step 5, four linear regression analyses with our in-house rating of self-reported performance (VAS-post) as predictors, and objective cognition and SCCs as outcomes. In a separate step, group, and the interaction between group and subjectively rated performance (VAS-post) were added.

In step 6, we performed conditional tree analyses to investigate non-linear relationships between the proposed predictors and SCCs. SCCs as measured by the CFQ total score was our response variable, and the measures of objective cognition, depression, age, sex, and group were explored as covariates. These analyses were performed using the packages "*rpart*" (version 4.1.16, Therneau et al., 2013) and "*caret*" (version 6.0.94, Kuhn, 2008), following recent suggestions byRosenbush et al. (2021) (instead of "partykit", in our AsPredicted). To reduce the risk of overfitting, the data were randomly split into a train (0.8) and test (0.2) dataset for tuning the complexity parameter (cp). As the test dataset is relatively small, we repeated the splitting process 20 times to obtain an estimate of parameter and accuracy uncertainty (Rosenbusch et al., 2021). Across the 20 training datasets, eight different hyperparameters using 10-fold cross-validation were compared leading to 20 most stable and best fitting hyperparameters. Consecutively, these hyperparameters were used in the test datasets to obtain an estimate of accuracy (R^2, *r* (pred/true), RMSE, MAE) and accuracy uncertainty. Using the "*randomForest*" package (Breiman and Adele, 2021) version 4.7.1.1, we conduced random forest analyses to obtain an estimate of the most important predictors across 500 random regression trees indicated by the increase in % mean squared error when predictors are removed (% IncMSE).

3. Results

Out of 460 participants across both cohorts, eleven cases had missing values. As these were few (2.4%), we excluded these cases listwise – deviating from our AsPredicted. Demographic characteristics of the final sample (n=449) are provided in Table 1. Note that we did not ask participants about race/ethnicity and socioeconomic status, but the majority of the participants was White and had a high educational attainment (see Table 1). The autistic and non-autistic group had a fairly equal distribution of sex and education, and no significantly different age or IQ. As expected, autistic participants scored significantly higher than non-autistic participants on a self-reported measure of autistic traits, SCCs, and depression. The autistic group also scored significantly lower on Factor 1 (verbal memory) and Factor 3 (fluency), yet significantly higher on the Factor 2 (visual memory) compared to the non-autistic group.

A subsample of 187 participants (cohort 2) filled in the VAS-post measure of self-reported performance after all cognitive tasks. Compared to non-autistic participants, autistic participants rated themselves not significantly worse after completing the task battery. However, additional analyses on the VAS-pre measure showed that anticipated self-reported performance in the autistic group was worse compared to non-autistic group (Table 1). So, before starting the task battery autistic participants indicated lower self-reported expected performance, yet after finishing the task battery this difference disappeared.

3.1. Predicting SCCs by depression, cognitive factors, age, and sex

Outcomes of all hierarchical regression analyses are provided in Table 2 and visualized in Fig. 1. The first models, including a single predictor per model, showed a significant association between depression and SCCs, but not for any of the other predictors. In the second step, adding group and the interaction between the predictors and group showed improved model fit as compared to the first models indicating a significant addition to explaining the variance in SCCs. The interaction between Factor 2 (visual memory) and group showed a significant positive association with SCCs. In Fig. 1, panel 3 it can be seen that the

Table 1
Descriptive statistics of the autism and no-autism group.

	Autism (n=202)	No-autism (n=247)		
Sex (M/F/O, M%)	135/66/1, 66.8%	144/103/0, 58.3%	χ^2=4.93	
Education[a]	11/132/58	5/154/88	χ^2=5.44	
	Mean, SD (min-max)	Mean, SD (min-max)	t-val	d
Age (yrs.)	50.8, 15.0 (20-85)	50.6, 16.6 (20-85)	0.13	.01
IQ[b]	114.9, 16.3 (84-155)	113.3,16.6 (73-155)	1.01	.10
Autism traits[c]	34.4, 7.7 (8-49)	12.6, 5.6 (2-30)	**33.72****	**3.30**
SCCs[d]	46.2, 15.1 (10-84)	29.5, 10.4 (3-62)	**13.40****	**1.32**
Depression[e]	33.1, 12.5 (16-67)	20.4, 5.3 (16-45)	**13.54****	**1.38**
Factor 1 (verbal)[f]	-0.2, 1.3 (-3.6-2.6)	0.1, 1.1 (-3.6-3.5)	**-2.35***	**.23**
Factor 2 (visual)[g]	0.1, 1.0 (-4.2-2.4)	-0.1, 1.2 (-3.42-2.5)	**2.07***	**.19**
Factor 3 (fluency)[h]	-0.1, 1.1 (-2.8-4.0)	0.1, 1.1 (-2.6-3.0)	**-2.26***	**.22**
	Autism (n=86)	No-autism (n=101)		
	Mean, SD (min-max)	Mean, SD (min-max)	t-val	d
VAS-post[i]	6.5, 1.8 (2-10)	6.7, 1.9 (1-10)	-0.83	.12
VAS-pre[j]	6.7, 1.9 (1-10)	7.4, 1.8 (1-10)	**-2.40***	**.36**

Note. M, male; F, female; O, other; SD, standard deviation; d, Cohen's d; VAS, visual analog scale.

[a] Level of education was determined by the Verhage Coding System (Verhage, 1964), between slashes: junior secondary or practical education / senior secondary education or vocational college / university degree.

[b] IQ was estimated at baseline by using two subtests (matrix reasoning and vocabulary) of the Wechsler Intelligence Scale-III or IV (WAIS-III, WAIS-IV; Wechsler, 1997, 2003). As IQ was not used as an outcome measure, an estimate based on two subtests fulfilled our requirements.

[c] Autism traits were measured by the Autism Quotient (AQ; Baron-Cohen et al., 2001; Hoekstra et al., 2008).

[d] Subjective cognitive complaints (SCCs) were measured by the total score of the Cognitive Failures Questionnaire (CFQ; Broadbent et al., 1982).

[e] Depression was measured by the total score on the Symptom Checklist-90 depression subscale (SCL-90; Arrindell & Ettema, 2005)

[f] Factor 1 was constructed by direct recall, indirect recall, and recognition of the Rey Auditory Verbal Learning Task (RAVLT; Rey, 1941; Saan & Deelman, 1986).

[g] Factor 2 was constructed by direct recall, indirect recall, and recognition of the Wechsler Memory Scale-III, subscale visual reproduction (WMS-III; Wechsler, 1997b).

[h] Factor 3 was constructed by phonemic and semantic fluency of the Controlled Auditory Word Association Task and Groninger Intelligentie Test-2 respectively (COWAT; Schmand et al., 2008, GIT-2; Luteijn & Barelds, 2004).

[i] VAS-post indicates a rating of subjectively rated performance after completion the task battery (in-house development).

[j] VAS-pre indicates a rating of subjectively rated expected performance before starting the task battery (in-house development).

negative association between Factor 2 and SCCs is stronger for the autistic than for the non-autistic group. This is confirmed by follow-up analyses in both groups separately showing that the association between Factor 2 and SCCs was significant in the autism group, but not in the no-autism group (autism: t(202)=-2.34, p=.020, standardized beta=-.16; no-autism: t(247)=0.91, p=.991, standardized beta<.01). Fig. 1, panel 1 shows that depression scores were unevenly distributed between the groups . To see whether this biased our estimates of the association in either group (VIFs > 15), we performed separate follow-up analyses per group for depression too, in addition to our pre-registered analyses. This confirmed that both the autistic and non-autistic group showed a significant positive association SCCs and depression (autism: t(202)=6.45, p<.001, standardized beta=.42; no-autism: t(247)=5.50, p<.001, standardized beta=.33).

As Factor 2 (visual memory) and depression showed a significant association with SCCs, age-related differences were explored through separate regression analyses in the younger and older autism/no-autism group. This indicated that the association between SCCs and depression was significant in all groups (autism younger, autism older, no-autism younger, no-autism older; standardized beta's between .32-.45, p's<.001), yet that the association between Factor 2 (visual memory) and SCCs did not reach our threshold of p<.01 in any of the groups (standardized beta between -0.19-0.16, p's>.04, for details: see our R-Markdown, S2).

Biological sex was not significantly associated with SCCs in the older group (t(197)=1.31, p=.191, standardized beta=.18), nor was there a significant interaction between sex and group (t(197)=-1.71, p=.088, standardized beta=-.24).

3.2. Predicting SCCs by our in-house rating of self-reported performance

Outcomes of all hierarchical regression analyses with our in-house rating of self-reported performance after completing the task (VAS-post) as predictor are provided in Table 3. Self-reported performance was significantly negatively associated with SCCs. This indicates that participants' rating of their own performance after completing the battery of cognitive tests seems to correspond to their daily experienced SCCs, although the explained variance of the model is small (R^2=.02). Furthermore, self-reported performance was significantly associated with performance on visual memory tasks, although explained variance of this model is also modest (R^2=.04). None of the interactions between group and self-reported performance were significant, indicating that the associations that we observed did not differ significantly between the autistic and non-autistic group. As SCCs were unevenly distributed across groups (see S1, Fig. S1; VIFs>14), we re-analysed the associations between SCCs and self-reported performance for both groups separately in addition to our pre-registered analyses. This confirmed that the association between our in-house rating of self-reported performance and SCCs was similar across groups (autism: standardized beta=-.15, no-autism: standardized beta=-.14), although neither reached significance (p's>.147). Lastly, exploratory analyses (i.e., not pre-registered) were conducted using self-reported performance before starting the tasks (VAS-pre) as the predictor and SCCs, objective cognitive performance, and self-reported performance after completion of the tasks (VAS-post) as outcomes. SCCs and self-reported performance after the task significantly related to anticipated performance prior to the task (VAS-pre), yet none of the interactions with group were significant (see our R-Markdown, S2).

3.3. Predicting SCCs by regression trees

Running 20 partitioned samples (0.8 training/0.2 test) with a 10-fold cross-validation and 8 different hyperparameters in each run resulted in an average optimal complexity parameter of .026 (range=.012–049). The explanatory power of the regression trees (R^2 mean = .33, range=.11–48) and correlations between the predicted and observed scores were acceptable (r mean=.57, range=.33–70), given a test-retest reliability of 0.82 (Broadbent et al., 1982). RMSE ranged between 11.59 and 14.97 (average: 12.62), whereas MAE values ranged between 9.28 and 11.75 (mean=10.05). This indicates that there was noticeable variance across the partitioned samples and that most models performed unsatisfactory (~ 1 SD off; see Moriati 2007). Therefore, we conducted sensitivity analyses of all obtained complexity parameters in the total dataset.

Implementing the average complexity parameter (0.026) in the total dataset resulted in a tree with four splits, see Fig. 2. It can be seen that our sample with an average CFQ score of 37 (top blue box) was first splitted between the autism group (AUT) and no-autism group (NO AUT), which had an average CFQ score of 46 and 29 respectively. In the next step, both the autism and no-autism group are splitted based on

Table 2
Hierarchical regression models predicting SCCs (n=449).

Model	R^2	AIC	BIC	predictor	*t*-val	*p*-val	*B*	β
Single	0.33	3542	3554	Depression	**14.90**	**<.001**	**0.78**	**.58**
	<.01	3723	3735	Factor 1	-0.71	.479	-0.42	-.03
	<.01	3723	3736	Factor 2	-0.24	.807	-0.16	-.01
	<.01	3722	3735	Factor 3	-0.93	.353	-0.62	-.04
	<.01	3723	3735	Age	0.62	.534	0.03	.03
	<.01	3723	3736	Age^2	0.19	.851	<.01	.01
Int.	0.41	3493	3514	Depression	**7.36**	**<.001**	**0.58**	**.42**
				Group	**-3.51**	**<.001**	**-6.66**	**-.44**
				SCL-dep x Group	0.93	.353	0.07	.14
	0.30	3565	3586	Factor 1	0.71	.481	0.36	.03
				Group	**-13.87**	**<.001**	**-8.43**	**-.55**
				Factor 1 x Group	-0.31	.760	-0.15	-.01
	0.31	3558	3579	Factor 2	**-2.11**	**.035**	**-1.16**	**-.09**
				Group	**-14.14**	**<.001**	**-8.52**	**-.56**
				Factor 2 x Group	**2.23**	**.026**	**1.22**	**.09**
	0.30	3566	3586	Factor 3	0.36	.719	0.20	.01
				Group	**-13.82**	**<.001**	**-8.41**	**-.55**
				Factor 3 x Group	0.14	.888	0.08	.01
	0.30	3565	3586	Age	0.72	.470	0.03	.03
				Group	**-13.87**	**<.001**	**-8.38**	**-.55**
				Age x Group	-0.39	.697	-0.02	-.02
	0.30	3566	3586	Age^2	0.39	.698	0.00	.02
				Group	**-13.87**	**<.001**	**-8.39**	**-.55**
				Age^2 x Group	-0.20	.843	<.01	-.01

Note. Factor 1 reflected verbal memory, Factor 2 reflected visual memory and Factor 3 reflected verbal fluency. AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; B, unstandardized beta; β, standardized beta; Int., interaction.

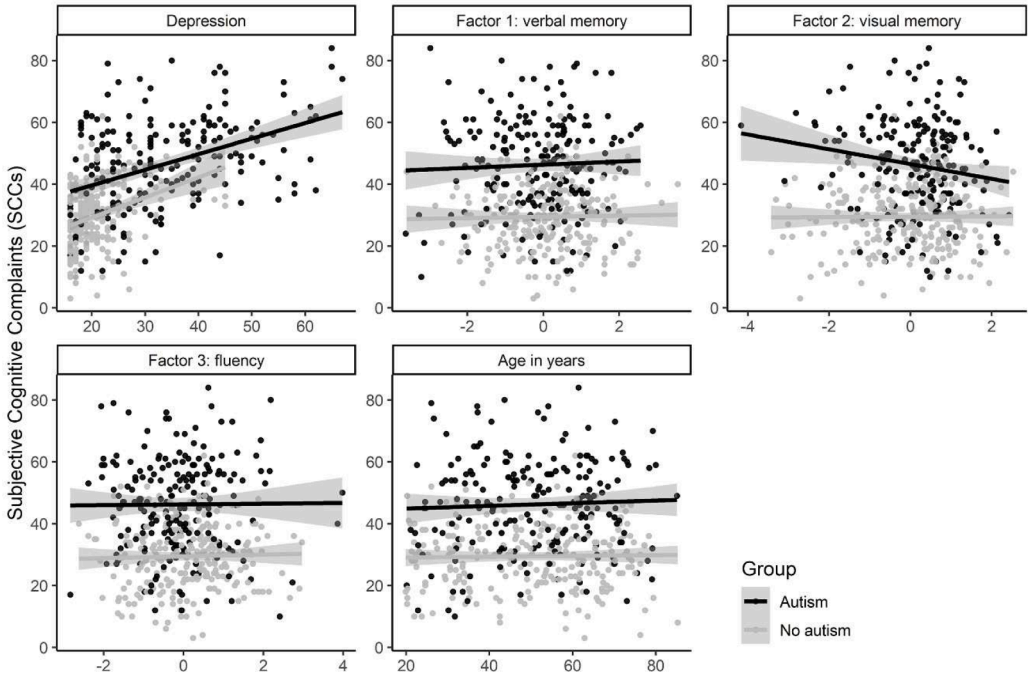

Fig. 1. Associations between SCCs and depression, objective cognitive functioning, and age split by group. Age was uncentered for visual purposes. X-axes are provided in each of the panel titles (e.g., depression for panel 1).

their level of depression symptoms (DEP). For the no-autism group this split was at a score of 18 on the SCL-90 depression subscale, resulting in an average CFQ score of 25 for those scoring below 18 and an average CFQ score of 32 for those scoring 18 or higher (bottom green boxes). For the autism group splits were at 41 and 18 on the SCL-90 depression subscale, resulting in an average CFQ score of 28 for those scoring below 18, an average CFQ score of 44 for those scoring between 18 and 40, and an average CFQ score of 56 for those scoring 41 or higher (bottom green boxes). Taken together, the regression tree indicates that only group and depression symptoms were significant predictors of SCCs.

Sensitivity analyses showed that trees remained stable for all values of all most likely complexity parameters, except for one (95%). When lowering the complexity parameter to the lowest value obtained from the 20 partitioned samples (0.013), the tree provided one additional split on Factor 2 (see S1, Fig. S2).

Additional random forest analyses indicated that group and

Table 3
Hierarchical regression models with our in-house rating of self-reported performance as predictor (n=187).

Outcome	R^2	AIC	BIC	predictor	*t*-val	*p*-val	B	β
SCCs	.02	1540	1549	VAS-post	**-2.12**	**.035**	**-1.24**	**-.15**
Factor 1	<.01	607	617	VAS-post	-0.44	.662	-0.02	-.03
Factor 2	.04	586	595	VAS-post	**2.81**	**.015**	**0.13**	**.20**
Factor 3	.01	553	563	VAS-post	1.50	.135	0.06	.11
SCCs	.33	1474	1490	VAS-post	**-2.04**	**.043**	**-1.00**	**-.12**
				Group	**-2.99**	**.013**	**-10.08**	**-.68**
				VAS-post x Group	0.58	.561	0.29	.13
Factor 1	.05	602	618	VAS-post	-0.41	.680	-0.02	-.03
				Group	**2.49**	**.014**	**0.82**	**.67**
				VAS-post x Group	-1.91	.058	-0.09	-.52
Factor 2	.07	584	600	VAS-post	**2.89**	**.004**	**0.13**	**.21**
				Group	-1.34	.181	-0.42	-.36
				VAS-post x Group	0.76	.446	0.03	.20
Factor 3	.03	555	571	VAS-post	1.39	.167	0.06	.10
				Group	0.37	.710	0.11	.10
				VAS-post x Group	0.07	.946	<.01	.02

Note. AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; B, unstandardized beta; β, standardized beta; VAS, visual analog scale.

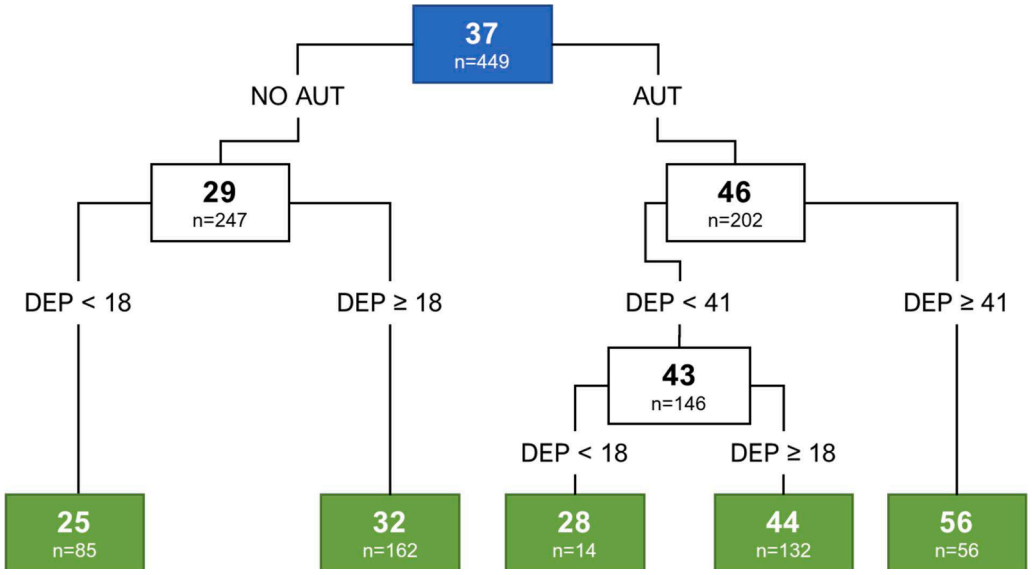

Fig. 2. Regression tree predicting SCCs. In each rectangle box, top rows indicate CFQ total scores, bottom row the number of individuals in each subgroup. DEP refers to depression scores on the subscale of the SCL-90.

depression were more important in predicting the outcome than any of the other predictors (% IncMSE Group = 71.3, depression=70.52; others: 6.9-0.0; see S1, Fig. S3).

4. Discussion

The current study aimed at gaining insight in SCCs in autistic adults, providing further knowledge on the use of SCCs in clinical practice and as a potential marker for age-related cognitive disorders such as dementia. Our results clearly indicate that depression symptoms are more important in explaining differences in rates of SCCs than objective measures of cognition in both autistic and non-autistic adults. Visual memory performance seems to align more closely with SCCs in autistic adults specifically, although the amount of variance explained by this factor was much smaller than by depression symptoms (<1% vs 33%). Unexpectedly, demographic factors like age and biological sex did not significantly explain differences in SCCs. Finally, subjective ratings of performance obtained directly after completion of the task battery were associated with SCCs and visual memory performance in both autistic and non-autistic adults.

These results illustrate the difficulties of using SCCs as a proxy for cognitive performance, and in autism specifically. That is, since both SCCs and depression symptoms are elevated and highly associated in autistic adults, they are hard to disentangle. Although the latter seems to be the case for non-autistic people too (Burmester et al., 2016), studies suggesting that elevated SCCs in autism are indicative of age-related disorders may be biased when ignoring group differences in depression symptoms (see also, Stewart et al., 2022). An alternative explanation is that both SCCs and depression symptoms indicate daily cognitive difficulties, as depression symptoms are known to enhance age-related cognitive decline (Ownby et al., 2006). Our results are not directly indicative of this explanation, as associations between SCCs and objective cognitive performance or age were modest at most. Hence, SCCs were not only related to depression symptoms, but they also seemed insufficiently related to objective cognitive performance or expected age-related decline (see also: Geurts et al., 2020; Lever & Geurts, 2016a, but for conflicting results see: Davids et al., 2016). Also, it could well be that the predictive value of depression symptoms to age-related cognitive decline is lower in autistic samples given their high prevalence. As we did not include cognitive functioning over time, we are cautious in

deriving such conclusions. Nonetheless, it seems vital to study the association between SCCs, depression, and age-related decline in more detail before assuming that such associations are similar to non-autistic adults. Our cross-sectional results seem to suggest that SCCs in autism may be an important clinical tool as a proxy for general functioning rather than as a proxy for cognitive functioning.

Our results might also indicate that the objective cognitive measures used in this study may not be reflective of daily cognitive difficulties in autism. Even though we increased their sensitivity by creating aggregated measures across three cognitive domains, objective cognitive functioning was not significantly associated to SCCs. Hence, it could be that low scores on the tasks were not indicative of daily cognitive difficulties (i.e., have low ecological validity). Moreover, the structured environment in which all tasks were performed, might not reflect the more volatile environment of daily life. However, it should be kept in mind that our cognitive measures do have merit, as they show sensitivity in picking up age-related decline in autistic- and non-autistic people (Torenvliet et al., 2023) as well as differences between autistic and non-autistic people (Table 1). Even so, it could be that more naturalistic tasks (for example, the Rivermead Behavioral Memory Test) show greater alignment with SCCs.

That being said, there may be one exception to the absent relation between SCCs and cognitive functioning. In visual memory only, the association between SCCs and objective performance was significant and larger for autistic people than in their non-autistic peers, similar to the findings in executive functioning of Davids et al. (2016). As no significant associations between SCCs and verbal fluency or verbal memory were observed, these results might suggest that SCCs are most sensitive in picking up autistic cognitive difficulties in visual memory specifically. Given that autistic people seem to show enhanced visual processing and stronger engagement in the neural visual systems (Mottron et al., 2006; Samson et al., 2012), autistic people may be more reliant on their visual system. Therefore, it is not unlikely that when difficulties in visual memory arise, these are most sensitive in reflecting daily cognitive difficulties in autistic people. However, it is important to note that these effects were modest, especially when compared to the effects of depression. Moreover, these results did not reach statistical significance in separate group analysis and were not detected as important predictors in data-driven models (regression trees) of SCCs. Nonetheless, our study highlights that the significance of cognitive domains when looking at SCCs, and particularly visual memory, may differ across autistic and non-autistic people.

Across both groups, measures of self-reported performance directly after completion of the task battery seemed to show more robust associations with objective cognitive functioning, albeit again only in visual memory. At the same time, associations with SCCs were also significant and similar across groups. Interestingly, autistic participants rated their expected performance before completing the task battery significantly worse than non-autistic participants, while afterwards this difference disappeared. As associations of self-reported performance (before or afterwards) with actual performance did not significantly differ across groups, it seems to be the case that autistic people are not necessarily better or worse at estimating their own performance, but the non-autistic group seems more optimistic in rating their own expected performance.

The current study shows that SCCs are related to depression cross-sectionally, however, the primary benefit of SCCs in clinical practice is that of prediction of cognitive decline over time. Large prospective studies indeed show that those with SCCs at baseline show greater deterioration in cognitive performance over time (Morrison & Oliver, 2023). While we cannot make inferences about the longitudinal relation between SCCs and cognitive decline in autism, we suspect that this relation will be complex. Autistic adults have trouble with several factors associated with SCCs and cognitive decline over time. For example, depression, which is more prevalent in those with autism, is associated with cognitive decline. Depression and SCCs have an independent, but also synergistic effect in predicting dementia (Wang et al., 2021). Many other factors that might differ in those with autism, such as sleep (Deserno et al., 2019; Stewart et al., 2020), sense of purpose (Pfund et al., 2022), lifestyle factors, and social engagement (Dominguez et al., 2021), also appear to play a role in the longitudinal relation between SCCs and cognitive decline (Costa et al., 2022; Pearson et al., 2023). To disentangle this likely complex relation in autism, longitudinal studies that tap into both subjective and objective cognitive difficulties are warranted.

Strengths of the current study are the rigorous exploration of the relation between SCCs, objective cognitive performance, and depression, the large sample size and extensive battery of cognitive tasks. While the current study presents several strengths, some limitations should be kept in mind. All of our participants had an IQ above 70 and we excluded those with neurological disorders. Given what is known on cognitive reserve (e.g., Cabeza et al., 2018), the current sample might disregard those most vulnerable to cognitive decline. Moreover, the sample was largely white, higher educated, and diagnosed at relatively late age, limiting the generalizability of our findings to this population. Lastly, while we used a rigorous test battery of cognitive tasks, and multiple measures of SCCs, for our depression outcome we relied on a subscale of the SCL-90. Even though this is a valid instrument, and research in other populations also stress the importance of depression in relation to SCCs (e.g., Groenman et al., 2022; Smith et al., 2022), future studies are recommended to use additional measures of depression to increase the reliability of their results. Additionally, since both SCCs and depression symptoms were measured using questionnaires in our study, it is possible that their associations were influenced by shared method variance. Conversely, the association between SCCs and objective cognitive performance may have been weakened due to divergent method variance. To address both of these limitations, using clinical tools such as a (semi)-structured interview and/or hetero-anamnestic information for assessing depression symptoms might improve the reliability of our depression measure and promote more methodologically consistent comparisons among SCCs, depression, and objective cognitive performance.

In conclusion, our findings emphasize the differences between self-reported cognitive functioning and objective cognitive performance. This does not mean that SCCs are not of value in clinical practice, as they are strongly related to depression, and might represent those activities that those with depression struggle with in daily life. Clinicians are recommended to be careful in interpreting SCCs as equivalent to objective cognitive functioning and should also consider general functioning (or depression) when people present with SCCs in their practice.

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CRediT authorship contribution statement

Carolien Torenvliet: Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Annabeth P. Groenman:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Joost A. Agelink van Rentergem:** Writing – review & editing. **Tulsi A. Radhoe:** Writing – review & editing, Project administration. **Hilde M. Geurts:** Conceptualization, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

None of the authors have competing interests relevant to the work to report.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2024.115759.

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