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Received: 24 December 2021 | Accepted: 1 August 2022
DOI: 10.1002/aur.2790

RESEARCH ARTICLE

The psychometric properties of the Greek version of the Social Communication Questionnaire

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Abstract

There is a scarcity of diagnostic assessments and screening tools for autism spectrum disorders (ASD) in Greek. In this study, we examined the psychometric properties of the recently developed Greek version of the Social Communication Questionnaire (SCQ). We used parental responses for 311 children (mean age: 7.54 years old, $SD = 1.92$), 122 with a diagnosis of ASD (93 boys, 29 girls) and 189 neurotypical children (104 boys, 85 girls), with 167 responses referring to the Lifetime and 144 to the Current form of the SCQ. Both forms presented adequate construct validity based on the four-factor model, while in both forms, autistic children presented higher SCQ total and subscale scores (four factors) than typical children. The forms had excellent internal reliability. An item-response-theory analysis suggested that over 80% of test items fitted adequately a Rasch model, while a preliminary analysis of gender biases suggested that a small number of items (Lifetime: five; Current: six out of 39) were differentially sensitive to autistic symptomatology in boys and girls. A receiver-operating-characteristic analysis showed excellent diagnostic performance based on the SCQ total score (Lifetime: area-under-the-curve/AUC = 0.937, Current: AUC = 0.963), and acceptable to excellent discrimination for the four subscales (AUCs between 0.737 and 0.955). Our preliminary results suggest that the Greek SCQ presents satisfactory psychometric properties and can be used for differentiating children with ASD from typical children in initial assessments within clinical and research settings.

Lay Summary

Autism spectrum disorder (ASD or autism) is a lifelong neurodevelopmental condition with a prevalence of ~1.5%–2% and characterized by difficulties in social interaction and communication and repetitive and restricted behaviors. There is increasing concern that research in ASD has focused on a small number of languages and cultural settings and that this bias challenges the identification and diagnosis of the condition in other languages and cultures, which are underrepresented in autism research. One such language is Greek (spoken by ~13.5 million), for which there is a scarcity of standardized instruments for the diagnosis of autism. This study examines the psychometric properties of the recently published Greek version of the Social Communication Questionnaire (SCQ), a widely used screening tool for ASD. We conduct an in-depth psychometric analysis of the Greek SCQ, including both forms in which the instrument is available (Lifetime and Current). This analysis shows that the Greek SCQ can be used for differentiating children with ASD from typical children in initial assessments within clinical and research settings. The findings of this study have implications for clinicians, special educators and researchers working with Greek-speaking individuals with ASD and, more broadly, for cross-cultural autism research.

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KEYWORDS
autism, autism spectrum disorder, cultural adaptation, Greek, psychometrics, screening tools, Social Communication Questionnaire, validation

INTRODUCTION

Autism is a lifelong neurodevelopmental condition which presents a heterogeneous cognitive profile, characterized by difficulties in social interaction and verbal and non-verbal communication, repetitive, inflexible behaviors and restricted activities, as well as a range of sensory symptoms and sensory atypicalities (DSM-5; American Psychiatric Association, 2013). Receiving an early diagnosis enables autistic[1] people and their families to gain timely access to support, services, and interventions (Mansell & Morris, 2004). However, as the diagnosis of autism requires multiple examinations to take place, it can be a lengthy and exacting process (Crane et al., 2016).

The first stages of the autism diagnostic process can be assisted by screening tools, such as the Social Communication Questionnaire (SCQ) (Rutter, Bailey, et al., 2003), the Social Responsiveness Scale (SRS-2; Constantino & Gruber, 2012), the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001), the Autism Behavior Checklist (ABC; Krug et al., 2008) or the Modified Checklist for Autism in Toddlers (M-CHAT; Robins et al., 2001) and the Developmental Checklist-Early Screen (DBD-ES; Gray & Tonge, 2005) for early developmental stages. By virtue of their ease of use and their short administration time, screening tools are useful for detecting autistic symptomatology at levels that warrant further investigation. Screening instruments are also useful in research settings and enable researchers to corroborate autism diagnoses and obtain measures of autistic symptomatology for intra-individual comparisons (Corsello et al., 2007).

Many screening tools for ASD have been initially developed for English and were subsequently translated into other languages. However, this process is often not inclusive of less prominent languages and cultures (de Leeuw et al., 2020). With respect to Greek, currently spoken by around 13.5 million people (Ethnologue; Eberhard et al., 2021), there is an increasing concern about the lack of tools supporting accurate diagnosis and early intervention in individuals with autism and related disorders (for example, see Zarokanellou et al., 2017; Poppi et al., 2019; Papanikolaou et al., 2009). In an early investigation, Papanikolaou et al. (2009) studied the interrelationship between the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000), the Autism Diagnostic Interview-Revised (ADI-R; Rutter, Le Couteur et al., 2003) and DSM-IV (American Psychiatric Association, 2000) clinical diagnosis, in a small sample of children and adolescents with a possible pervasive developmental disorder (in terms of DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, APA, 2000; and the ICD-10, International Classification of Diseases 10th Revision, World Health Organization, 1993). They found that ADI-R and ADOS-G show good diagnostic validity for pervasive developmental disorders. More recently, Zarokanellou et al. (2017) performed a pilot study investigating the psychometric properties of a translation of the SCQ into Greek. Their preliminary findings indicated that the Greek version of SCQ they employed was both valid and reliable. These researchers, nevertheless, pointed out that the cutoff for the subject's level of functioning should be adapted for Greek populations.

Despite the above-mentioned studies, there are, to the best of our knowledge, no standardized screening instruments for autism available in Greek. This lack of standardized screening tools challenges the identification, diagnosis, and understanding of autism in child populations in Greece and Cyprus.

This study aims to address this gap in the diagnosis and the study of ASD in Greek-speaking populations and provide a standardized, valid, and reliable instrument for clinicians, educators, and researchers. Specifically, we examined the psychometric properties of the recently published official Greek translation of the SCQ (Karaminis et al., 2019). The SCQ, which distils the gold-standard ADI-R (Rutter, Le Couteur et al., 2003) into 40 yes/no questions (Berument et al., 1999), is completed by the parent or primary carers in less than 10 min. The SCQ is currently available in 17 published translations. Earlier studies often recommend a cutoff threshold of 15 for the SCQ total score for differentiating school-aged autistic and neurotypical children with high sensitivity and specificity (e.g., English: Berument et al., 1999; Arabic: Aldosari et al., 2019; Chinese: Gau et al., 2011; simplified Chinese: Liu et al., 2022; German: Bölte et al., 2008; Portuguese: Sato et al., 2009; Turkish: Avcil et al., 2015; Öner et al., 2012), although the optimal threshold may depend on age or diagnostic categorization (Corsello et al., 2007).

In our examination of the psychometric properties of the instrument, we included both forms in which the instrument is available, namely the Lifetime and the Current form. SCQ Lifetime takes into account an individual's current behaviors, as well as behaviors presented at the age of four; SCQ Current focuses on behaviors presented during the last 3 months. The great majority of validation studies for SCQ have so far focused on the Lifetime version (see also Wei et al., 2015).

[1]We use 'identify-first' language ('autistic person') rather than person-first language ('person with autism') because it is the preferred term of autistic activists (e.g., Sinclair, 1999) and many autistic people and their families (Kenny et al., 2016) and is less associated with stigma (Gernsbacher, 2017).

METHODS

Participants

A total of 311 children (197 boys, 114 girls), with a mean age of 7.54 ($SD = 1.92$; range 4; 3–11; 4) and their primary carers participated in the study. Of the 311 children, 122 had a clinical diagnosis of ASD or Asperger's syndrome, based on the ICD-10 and DSM-IV classifications. Autistic children were recruited through speech and language centers and professionals, who provided information on the diagnostic status of children and their diagnostic label. The children were allocated to two samples, A ($N = 167$) or B ($N = 144$), assessed with the Lifetime or the Current version of the SCQ, correspondingly. Data for sample A were collected in the period March–September 2016, and data for sample B were collected between March and September 2017. The demographics of samples A and B, presented by subgroups of autistic and typical children within each sample, alongside statistical comparisons (gender: chi-squared tests; age: one-way ANOVAs- non-parametric Kruskal-Wallis as the assumption of normality was not met), are shown in Table 1.

The participants came from various areas in Greece, including Thessaloniki, Athens, Imathia, Kalamata, Ioannina, Corfu, and Crete. Participants were recruited through community contacts and social media platforms, as well as from four Speech and Language Therapy Centers (for the recruitment of autistic children). Data were collected using paper copies, 19 parents provided responses through an online platform. All participants provided informed written consent at the onset of the study, according to the research procedures that applying to the Aristotle University of Thessaloniki, Greece.

Materials

Social Communication Questionnaire

The SCQ (Rutter, Bailey et al., 2003; Rutter, Bailey et al., 2003) consists of 40 yes/no questions or items. The first SCQ question is not scored The remaining 39 items are scored with 0 or 1, yielding a total SCQ score between 0 and 39. A total of 15 items are scored positively (a YES response contributes 1 to the total score and a NO contributes 0), and 24 items are scored negatively (YES = 0; NO = 1). The 39 SCQ items correspond to one of four subscales or factors, namely social interaction (factor 1–20 items: 17, 19, 21–23, 26–40), communication (Factor 2–6 items: 2, 9, 15, 20, 24–25), abnormal language (factor 3–6 items: 3–7) and repetitive, repetitive and stereotypical behaviors (Factor 4–7 items: 8, 10–14, 16, 18). Furthermore, from the 39 SCQ items, 37 can be mapped to three ADI-R subdomains, namely, social interaction, communication, and repetitive/stereotyped behavioral patterns.

Greek version of the SCQ

The Greek version of the SCQ was developed as follows. First, the Lifetime and the Current version of the SCQ were translated into Greek by two experienced researchers in the field of language acquisition and communication disorders. Alongside translation, certain items were culturally adapted. For example, rhymes from the English culture in item 34 (spontaneous joining in social games) were replaced with Greek rhymes. Additional language corrections were applied to the initial translation by an experienced linguist and the editors of the Greek edition. Subsequently, an experienced clinical psychologist developed a back-translation, which was reviewed to revise the initial translation. Next, we liaised with the publishers (WPS and Glafki) to complete two further rounds of back-translation and revision, which led to the final Greek SCQ Lifetime and Current forms.

Statistical analyses

All data were entered in a spreadsheet, and we conducted two parallel analyses for the data from the SCQ Lifetime and the Current version. Analyses were performed with R (R Core Team, 2021) and the statistical software package JAMOVI (The jamovi Project, 2021).

Construct validity

We first examined construct validity, which refers to the extent to which measurements correspond to an underlying theoretical model. This type of validity was examined in two ways.

First, we conducted a confirmatory factor analysis (CFA) of the SCQ in samples A and B to evaluate the fit of the four-factor structure used in the original SCQ (Berument et al., 1999), as well as in recent cross-cultural adaptations (e.g., Arabic: Aldosari et al., 2019; simplified Chinese: Liu et al., 2022). We also evaluated the fit of a two-factor structure corresponding to the DSM-5 and consisting of an S-domain (social communication and interaction; factors 1, 2, and 3) and the R-domain (factor 4) (see Liu et al., 2022); as well as the fit of a unidimensional model (SCQ total without any factors).

We used the R packages lavaan (Rosseel, 2012) and semTools (Jorgensen et al., 2021) with a nonlinear minimization subject to box constraints (NLMINB) optimization method and a diagonally-weighted least squares (DWLS) estimator. Missing values (effectively, data from a total of 25 non-verbal autistic children who did not give responses to items SCQ2-SCQ7) were excluded in this analysis. To assess model fit, we considered the following indices: root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), Chi-square, and standardized root mean

TABLE 1 Participants demographics

Sample A - SCQ Lifetime			
Measure	**Typical (NT-L)**	**ASD (ASD-L)**	**Comparison**
N	96	71	n/a
Gender (boys:girls)	55:41	53:18	χ^2 (2, $N = 167$) = 5.38, $p = 0.02$
Age			
M (*SD*)	7.59 (1.45)	7.82 (1.99)	χ^2 (2, $N = 167$) =0.79, $p = 0.37$, $\varepsilon^2 = 0.005$
Range	4.99–10.6	4.16–12.3	
Total score			
M (*SD*)	6.79 (4.87)	20.75 (7.38)	χ^2 (2, $N = 167$) = 93.3, $p < 0.001$, $\varepsilon^2 = 0.562$
Range	0–27	3–36	
Factor 1 - Soc. Int.			
M (*SD*)	3.18 (3.32)	9.42 (5.10)	χ^2 (2, $N = 167$) = 58.6, $p < 0.001$, $\varepsilon^2 = 0.353$
Range	0–18	0–18	
Factor 2 - Commun.			
M (*SD*)	0.96 (1.25)	2.82 (1.65)	χ^2 (2, $N = 167$) = 50.7, $p < 0.001$, $\varepsilon^2 = 0.305$
Range	0–5	0–6	
Factor 3 - Ab. Lang.			
M (*SD*)	1.55 (1.57)	3.76 (1.10)	χ^2 (2, $N = 154$) = 57.3, $p < 0.001$, $\varepsilon^2 = 0.374$
Range	0–5	1–5	
Factor 4 - Ster. Behav.			
M (*SD*)	1.10 (1.49)	5.44 (2.01)	χ^2 (2, $N = 167$) = 98.2, $p < 0.001$, $\varepsilon^2 = 0.591$
Range	0–7	0–8	
Sample B - SCQ Current			
Measure	**Typical (NT-C)**	**ASD (ASD-C)**	**Comparison**
N	93	51	n/a
Gender (boys:girls)	49:44	40:11	χ^2 (2, $N = 144$) = 9.25, $p = 0.003$
Age			
M (*SD*)	7.10 (2.03)	7.87 (2.27)	χ^2 (2, $N = 144$) = 3.23, $p = 0.07$, $\varepsilon^2 = 0.022$
Range	4.06–12.80	4.43–12.40	
Total score			
M (*SD*)	5.03 (3.12)	16.65 (5.57)	χ^2 (2, $N = 144$) = 84.36, $p < 0.001$, $\varepsilon^2 = 0.287$
Range	0–16	3–33	
Factor 1 - Soc. Int.			
M (*SD*)	2.99 (1.96)	7.04 (3.82)	χ^2 (2, $N = 144$) = 41.09, $p < 0.001$, $\varepsilon^2 = 0.437$
Range	0–9	0–17	
Factor 2 - Commun.			
M (*SD*)	0.54 (0.95)	2.63 (1.44)	χ^2 (2, $N = 144$) = 62.55, $p < 0.001$, $\varepsilon^2 = 0.408$
Range	0–3	0–5	
Factor 3 - Ab. Lang.			
M (*SD*)	0.80 (1.19)	2.98 (1.18)	χ^2 (2, $N = 136$) = 55.02, $p < 0.001$, $\varepsilon^2 = 0.605$
Range	0–5	0–5	
Factor 4 - Ster. Behav.			
M (*SD*)	0.69 (1.00)	5.47 (1.77)	χ^2 (2, $N = 144$) = 86.55, $p < 0.001$, $\varepsilon^2 = 0.591$
Range	0–5	0–8	

square residual (SRMR). Conditions for acceptable fitting were considered an RMSEA <0.08, descriptive fit indices CFI and TLI >0.900, a ratio χ^2/df <2, and an SRMR <0.08 (Alavi et al., 2020; Hu & Bentler, 1999; Kline, 2005). We also examined whether individual items contributed significantly to the corresponding latent factors and established that factors were significantly correlated with each other. Finally, we compared the fit of the different models with an Anova test.

Second, we examined known-group validity, that is, we assessed whether SCQ total and subscale scores were lower in autistic than in neurotypical participants. We examined differences related to diagnostic status using a generalized additive modeling (GAM) framework (Wood, 2011, 2017). GAM enabled us to consider, in the same model, the effects of multiple demographic factors, namely diagnostic status, gender, whether children were verbal or non-verbal (have responded YES to item SCQ1; only some autistic children had a NO response), and age. This was important as autistic and neurotypical children in samples A and B were not necessarily matched on all the demographic variables (see Table 1). Furthermore, GAM enabled us to consider the possibility that the relationships between SCQ scores and age is non-linear, and could be accounted for by non-parametric smooth functions ("wiggly lines"). We conducted a GAM analysis using the R package mgcv (Wood, 2017). We fitted data from sample A and B with the following model SCQ_Total ~ DIAGNOSIS + GENDER + VERBAL + s(AGE, bs = "cr") + s(AGE, bs = "cr", by = DIAGNOSIS) + s(AGE, bs = "cr", by = GENDER) + s(AGE, bs = "cr", by = VERBAL), which included fixed effects of diagnostic status, gender and verbal ability status, as well as non-linear effects of age, with smooth terms being modeled with cubic regression splines, and broken down by diagnostic group, gender and verbal ability status. A restricted maximum likelihood (REML) smoothing parameter estimation method was used. Similar models were also fitted to subscale scores from samples A to B (with the exception that the model for subscale score for factor 3 - abnormal language did not include a VERBAL status variable, that is, we focused on verbal children).

Internal consistency reliability

Internal consistency reliability refers to the degree to which items that are meant to assess the same factor are correlated with each other. We examined internal consistency reliability using the Omega Coefficient (McDonald, 1970, 1999) index, which is calculated based as follows:

$$\text{Omega} = \frac{\left(\sum \lambda_i\right)^2}{\left(\sum \lambda_i\right)^2 + \sum Var(\varepsilon_i)} \quad (1)$$

where λ_i is the factor loadings for the item i and ΣVar is their error variance. We examined Omega coefficients for the total scores as well as for the four subscales/factors. Acceptable values were considered those greater than 0.70.

Item discrimination

We also explored the construct validity of the Lifetime and the Current versions at an item level within an item response theory (IRT) framework. In broad terms, IRT enables the mapping of responses to latent traits (measured construct), which can be used to define a continuum of ability for participants and to characterize individual items in terms of their so-called difficulty. We performed an IRT analysis with the *mIRT* package (Chalmers, 2012). We fitted the data (and subsets of data corresponding to the four subscales) using a Rasch model for individual items and examined how well the SCQ items discriminated between autistic and typical children. We examined the quality of the fit of individual items to data using the infit and outfit measures (acceptable range: 0.5–1.7, Wright et al., 1994). We also produced a Wright map to examine the correspondence between the distribution of items in terms of their difficulty and autistic and typical children in terms of their ability.

Finally, we conducted a preliminary gender bias analysis, where we assessed the extent to which individual items were differentially sensitive to data from boys and girls. This analysis, which was motivated by the increasing recognition of the importance of taking into account gender differences in the diagnosis of autism (see Evans et al., 2019), was performed using the *difR* package (Magis et al., 2010) and Raju's method (Raju et al., 1995). The main measure examined was Raju's statistic, which identified items that were biased at a statistical significance value of 0.05.

Sensitivity, specificity, and cutoff estimation

To assess the tradeoff between sensitivity (true positives rate) and sensitivity (1 - false positives rate) of the Greek SCQ in differentiating between autistic and neurotypical participants, we computed Receiver Operating Characteristics curves. ROC curves were generated for the SCQ Total score and the four subscales using the ROCR package (Sing et al., 2005). We examined the area-under-the-curve (AUC) index, which was considered acceptable when it fell between 0.7 and 0.8, excellent when it fell between 0.8 and 0.9, and outstanding when it was above 0.9. ROC curves were also compared with the diagonal (corresponding to chance performance) at a level of statistical significance of 0.001

Additionally, we estimated the cutoff point by identifying the threshold value that optimized the F-measure, a measure of classifying performance that considers corrections for the cost of erroneous classifications and uneven distributions. For the cutoff point, we computed six more measures of diagnostic validity, namely, H-measure, sensitivity (recall), specificity, precision, positive predictive value (PPV), and negative predictive value (NPV)

Given that a number of non-verbal autistic children was not scored on some questions of the SCQ (the instrument does not require responses), we conducted a separate analysis for the estimation of a cutoff point in which responses for non-verbal children were excluded from Samples A and B

RESULTS

Descriptive statistics

In Sample A (SCQ Lifetime), the average SCQ Total score of autistic children was 20.75 (SD = 7.38) and the average total score of neurotypical children was 6.79 (SD = 4.87). In Sample B (SCQ Current), the average SCQ Total score was 16.65 (5.57) for autistic children and 5.18 (3.46) for typical children. The total SCQ scores plotted against age for children with ASD and typical children in Samples A and Sample B are shown in Figure S1.

Construct validity

Confirmatory factor analysis

For the Lifetime version (sample A), the combined results from CFA fit indices (RMSEA = 0.061, 95% CI = 0.054–0.068, CFI = 0.960, TLI = 0.957, χ^2/df = 1.566, SRMR = 0.093) suggested that the four related factors model was overall acceptable: four of the five indices were in the range of acceptable values; SRMR was marginally above the threshold of 0.08 however, this value was acceptable under a combinatorial rule (TLI and SRMR; Hu & Bentler, 1999). All items contributed significantly to the corresponding latent variable, and the four factors were significantly correlated with each other as required. The four-factor model (Figure S2) was also significantly better than the unidimensional model [$\Delta\chi^2(6) = 441.13$, $p < 0.001$], and better than the two-factor model [$\Delta\chi^2(6) = 314.77$, $p < 0.001$], the latter presenting a marginally non-acceptable fit to the data (RMSEA = 0.081, 90% CI = 0.075–0.087, CFI = 0.918, TLI = 0.924, χ^2/df = 2.004, SRMR = 0.105).

For the Current version (sample B), the combined results from CFA fit induced suggested that the four related factors model was again acceptable (RMSEA = 0.017, 95% CI = 0.006–0.038, CFI = 0.981, TLI = 0.980, χ^2/df = 1.096, SRMR = 0.095), as four of the five indices were in the range of acceptable values; and SRMR was marginally above threshold; but acceptable based on a combinatorial rule (Hu & Bentler, 1999). All but four items, namely SCQ20 (showing friendliness), SCQ21 (spontaneous imitation), SCQ23 (using gestures), and SCQ30 (seeking to share enjoyment), contributed significantly to the corresponding latent variable, and the four factors were significantly correlated with each other. The four-factor model was also significantly better than the unidimensional model, [$\Delta\chi^2(6) = 54.037$, $p < 0.001$], and significantly better than the two-factor model [$\Delta\chi^2(6) = 51.276$, $p < 0.001$], which also had an acceptable fit to the data (RMSEA = 0.034, 90% CI = 0.022–0.044, CFI = 0.967, TLI = 0.965, χ^2/df = 1.160, SRMR = 0.099).

Known-group validity and differences with regards to gender, being verbal and age

Table 2 presents the parametric coefficients for the fixed factors of the GAM model fitted to the SCQ Total scores and the complexity (estimated degrees of freedom) and significance of the smooth terms. The predictions of the GAM model for Samples A (Lifetime) and B (Current), by diagnostic status and gender, and for verbal and non-verbal children are shown in Figure S3. In Sample A, the GAM model, which explained 61.2% of deviance (adjusted R-squared = 0.595), included a highly significant fixed effect of diagnostic status ($p < 0.0001$), whereby the SCQ Total of neurotypical children was lower than the corresponding score of autistic children. A similarly high effect of diagnostic status ($p < 0.0001$) was found in the GAM model fitted to sample B, which explained 72.0% of deviance (adjusted R-squared = 0.698). Furthermore, in both samples A and B, the GAM models for all four subscale scores also included significant fixed effects of diagnostic status. Combined together, these results suggest that the two forms of the Greek SCQ presented high construct validity (in terms of known-group differences).

By contrast, with regards to the fixed effect of gender, there was no significant effect on total score in either sample A or B. The same held for all subscales, with the exception of the subscale repetitive, repetitive and stereotypical behaviors of the Current version, in which girls presented lower scores than boys ($p = 0.023$).

With regards to the fixed effect of verbal ability status, there was a significant effect on total score in sample A ($p = 0.003$) but not in sample B ($p = 0.481$). In terms of subscale scores, there was a significant fixed effect of this factor on subscale 2 (communication) of the Current version, as non-verbal children presented lower scores than verbal children ($p = 0.001$). The effect of this factor was non-significant on all other subscales (at an alpha level of 0.05).

Finally, with regards to the effect of age, the GAM models included linear smoothing terms for the overall effect of age on Total score, which was non-significant in the Lifetime version ($p = 0.239$) but significant in the Current version ($p = 0.004$). Smoothing terms for the effects of age focusing on the individual levels of

TABLE 2 Parametric coefficients and approximate complexity and significance of smooth terms for the fitted GAM model to SCQ total score.

Sample A - SCQ Lifetime			
Fixed factor	*β*	*SE*	*p*
Intercept	16.529	1.778	<2e-16***
Diagnosis	−15.114	0.995	<2e-16***
Neurotypical	−1.204	0.963	0.213
Gender girl verbal	5.895	1.929	0.003**
Smooth term		Estimated degrees of freedom	*p*
s(AGE)		1.000	0.239
s(AGE):Diagnosis ASD		1.000	0.259
s(AGE):Diagnosis neurotypical		7.373e-05	0.995
s(AGE):Gender boy		1.000	0.539
s(AGE):Gender girl		2.728e-06	1.000
s(AGE):Non-verbal		1.628e-04	0.998
s(AGE):Verbal		1.000	0.109
Sample B - SCQ Current			
Fixed factor	*β*	*SE*	*p*
Intercept	17.083	1.604	<2e-16***
Diagnosis neurotypical	−10.796	0.738	<2e-16***
Gender girl	−0.120	0.685	0.861
Verbal	−1.216	1.720	0.481
Smooth term		Estimated degrees of freedom	*p*
s(AGE)		1.000	0.0041*
s(AGE):Diagnosis ASD		1.533	0.181
s(AGE):Diagnosis neurotypical		1.000	0.420
s(AGE):GENDER BOY		1.2243–04	0.997
s(AGE):Gender girl		2.825	0.256
s(AGE):Non-verbal		1.000	0.999
s(AGE):Verbal		2.145e-05	0.999

diagnostic status, gender and being verbal were linear and non-significant for Sample A and non-linear and non-significant for sample B. Turning to the effect of age on subscales, there was a significant non-linear smoothing term for the effect of age on subscale 1 for autistic children in sample B (Current version, estimated degrees of freedom = 2.202, $p = 0.031$), a significant linear smoothing term for the effect of age on subscale 3 for girls in sample A (Lifetime version, estimated degrees of freedom = 1.000, $p = 0.009$). All other smoothing terms for the effects of age by individual levels of other factors were non-significant.

Internal consistency reliability

For the Lifetime version (Sample A), the Omega coefficient was 0 0.949 for the total scores suggesting excellent levels of internal consistency. This was also the case for subscales, as the levels of internal consistency were $\Omega = 0.925$ for social interaction, $\Omega = 0.828$ for communication, $\Omega = 0.827$ for atypical language and $\Omega = 0.898$ for stereotypical behavior. Similarly, high levels of internal consistency were found for the Current version (Sample B). The Omega coefficient was $\Omega = 0$ 0.918 for the total score, and with regards to the subscales this measure was $\Omega = 0.838$ for social interaction, $\Omega = 0.852$ for communication, $\Omega = 0.797$ for atypical language and $\Omega = 0.858$ for stereotypical behavior.

Item discrimination

The Rasch model differentiated autistic and typical children well in terms of their latent ability (see ability histograms on the top of Figure S4, where ability is shown in logarithmic units). The average ability in the SCQ Lifetime was 1.34 logarithmic units for autistic and −0.809 for typical children, and ability levels were significantly different between the two groups, $t(123.84) = 14.52$, $p < 0.0001$. The same held for the Current version (autistic: 1.220, typical: −0.588), $t(79.59) = 12.81$, $p < 0.001$. A

TABLE 3 Infit and outfit statistics for individual SCQ items.

	Lifetime		Current			Lifetime		Current	
Item	Infit	Outfit	Infit	Outfit	Item	Infit	Outfit	Infit	Outfit
SCQ2	0.889	0.944	0.438	0.873	SCQ21	1.257	1.265	1.411	1.339
SCQ3	0.924	0.922	0.589	0.663	SCQ22	1.599	1.383	1.505	1.405
SCQ4	1.363	1.392	1.285	1.293	SCQ23	2.125	1.618	1.711	1.139
SCQ5	0.712	0.781	0.702	0.926	SCQ24	1.05	1.16	0.636	0.813
SCQ6	1.073	1.123	1.086	1.151	SCQ25	1.15	1.243	0.689	0.838
SCQ7	0.669	0.781	0.566	0.692	SCQ26	0.509	0.682	0.9	1.036
SCQ8	0.852	0.9	0.8	0.815	SCQ27	0.606	0.712	0.512	0.892
SCQ9	0.46	0.795	2.108	1.131	SCQ28	0.743	0.876	1.041	1.094
SCQ10	0.697	0.872	0.753	0.915	SCQ29	0.472	0.708	0.745	0.948
SCQ11	0.683	0.769	0.58	0.745	SCQ30	0.578	0.874	1.338	1.045
SCQ12	0.792	0.861	0.628	0.754	SCQ31	0.461	0.789	0.443	0.891
SCQ13	0.998	1.034	0.825	0.888	SCQ32	1.453	1.372	1.494	1.527
SCQ14	0.699	0.836	0.659	0.863	SCQ33	0.403	0.684	0.413	0.82
SCQ15	0.59	0.815	0.572	0.762	SCQ34	0.59	0.809	0.884	0.999
SCQ16	1.001	1.049	0.869	1.022	SCQ35	0.723	0.905	0.772	0.976
SCQ17	1.472	1.068	0.382	0.989	SCQ36	0.927	0.924	0.846	0.935
SCQ18	0.899	1.003	1.97	1.175	SCQ37	0.448	0.61	0.753	0.889
SCQ19	1.193	1.187	0.887	0.945	SCQ38	0.508	0.709	0.873	0.943
SCQ20	0.922	1.017	1.279	1.272	SCQ39	1.027	1.115	0.67	0.794
					SCQ40	0.783	0.939	0.544	0.737

Note: Red ink indicates infit/outfit scores that fall outside the recommended range of 0.5–1.7 of acceptable values for clinical observation.

similar pattern of results was also found for data corresponding to the four subscales (all *p*s <0.001 for both the Lifetime and the Current version).

In terms of the fit of the Rasch model for individual items, Table 3 shows the infit and the outfit estimates for different items. For sample A (ifetime), six items (∼15%) presented infit/outfit values outside the recommended range of 0.5–1.5 for clinical evaluation. These were SCQ9 (facial expression[2]), SCQ23 (gestures), SCQ29 (offering to share), SCQ31 (offering comfort), SCQ33 (range of facial expressions), SCQ37 (response to other children's approaches). For sample B (Current), seven items (∼17%) presented items that fell outside the recommended range of 0.5–1.7. These were SCQ2 (conversation), SCQ9 (facial expressions), SCQ15 (hand and finger mannerisms), SCQ22 (pointing to express interest), SCQ23 (gestures), SCQ31 (offering comfort), SCQ33 (range of facial expression). Thus, three items (SCQ9, SCQ23, and SCQ33) were problematic in terms of fit in both versions.

The Wright maps (Figure S5) suggested that the distribution of item difficulties (left panels) matched sufficiently the distribution of ability of autistic children (right panels), a finding suggesting the appropriateness of the instrument for screening purposes. However, the SCQ items did not cover the full range of ability of typical children.

Finally, the preliminary bias analysis (see Figure S6) for gender with Raju's method (Raju et al., 1995), identified the following five items that presented a statistically significant gender bias: SCQ13 (circumscribed interests), SCQ22 (pointing to express interest), SCQ24 (nodding to mean yes), SCQ25 (head shaking to mean no), SCQ36 (interest in children). As shown in Figure S6, SCQ22, SCQ24, SCQ25, were more difficult for girls, whereas SCQ13 and SCQ36 were more difficult for boys. For Sample B, the bias analysis suggested that six items presented a gender bias: SCQ13 (circumscribed interests), SCQ20 (social chat), SCQ23 (gestures), SCQ24 (nodding to mean yes), SCQ32 (quality of social overtures), SCQ35 (pretend or make-believe games). SCQ20, SCQ23, SCQ24, and SCQ32 were more difficult for girls, but SCQ13 and SCQ35 were more difficult for boys.

Sensitivity, specificity, and cutoff estimation

The ROC curves for the total score and for the four factors in the SCQ for the Lifetime (sample A, left panels) and the Current version (sample B, right panels) are shown in Figure S7. For both versions, the diagnostic validity of the questionnaire for both the total score and

[2]We adopt the descriptive phrases for SCQ items used in Aldosari et al. (2019).

TABLE 4 Diagnostic performance indices

	Total score	Factor 1 social interaction	Factor 2 communication	Factor 3 abnormal language	Factor 4 stereotyped behaviors
AUC	0.937/0.963	0.846/0.821	0.814/0.875	0.737/0.787	0.942/0.955
Cutoff for Lifetime/Current	12/11	6/6	1/1	3/2	3/3
Sensitivity (recall)	0.887/0.863	0.718/0.647	0.944/0.922	0.879/0.784	0.901/0.843
Specificity	0.906/0.968	0.864/0.882	0.531/0.699	0.677/0.753	0.875/0.957
Precision	0.875/0.936	0.797/0.750	0.598/0.627	0.622/0.635	0.842/0.915
F-measure	0.881/0.898	0.755/0.695	0.732/0.746	0.729/0.755	0.871/0.878
H-measure	0.681/0.757	0.401/0.355	0.285/0.421	0.349/0.495	0.652/0.740
Positive predictive value	0.875/0.936	0.797/0.750	0.594/0.627	0.622/0.635	0.842/0.915
Negative predictive value	0.916/0.928	0.806/0.820	0.927/0.942	0.903/0.864	0.923/0.918
Verbal children only cutoff for Lifetime/Current	14/11	6/7	1/1	3/2	3/2
Sensitivity (recall)	0.914/0.837	0.759/0.512	0.948/0.907	0.879/0.784	0.843/0.941
Specificity	0.938/0.968	0.864/0.957	0.531/0.699	0.677/0.753	0.957/0.839
Precision	0.898/0.923	0.772/0.846	0.550/0.582	0.622/0.635	0.915/0.761
F-measure	0.906/0.878	0.765/0.638	0.696/0.709	0.729/0.755	0.877/0.842
H-measure	0.771/0.728	0.452/0.340	0.279/0.396	0.349/0.495	0.712/0.644
Positive predictive value	0.898/0.923	0.771/0.846	0.550/0.582	0.622/0.635	0.915/0.762
Negative predictive value	0.947/0.927	0.856/0.809	0.944/0.942	0.903/0.864	0.917/0.963

the four factors was highly satisfactory and at excellent levels based on statistical as well as effect-size criteria (*p*s <0.001)

Table 4 presents results for a set of indices related to the differentiation of autistic and neurotypical children, namely AUC, sensitivity (recall), specificity, precision, recall, H-score, PPV, and NPV for the SCQ Total and the four subscales and for the Lifetime and the Current version. These indices (apart from AUC) were calculated for different thresholds, and results are reported for the threshold value (cutoff point) that maximized the F-score for the target score or subscale. The estimated cutoff point for the SCQ Total was 12 for the Lifetime version (sample A) and 11 for the Current version (sample B)

As shown in the lower part of Table 4, when the diagnostic indices were calculated with non-verbal children (who did not answer questions 2–7) excluded from Samples A and B, the cutoff was 14 for SCQ Lifetime and 11 for SCQ Current.

DISCUSSION

In this study, we conducted a psychometric evaluation of the recently published Greek version of the SCQ (Karaminis et al., 2019). Given the scarcity of standardized screening instruments for autism in Greek-speaking populations, the availability of the Greek translation aids the identification and the diagnosis and the study of the condition in Greece and Cyprus. Furthermore, the Greek SCQ is a recent addition to a set of 17 available SCQ translations. This addition also broadens the range of available cross-cultural SCQ data and may be used for cross-cultural autism research and comparisons. Cross-cultural investigations can suggest key similarities and differences in the manifestation of autism in different cultures (e.g., Carruthers et al., 2018). This evidence is valuable for the further validation of screening instruments, as well as for our understanding of the condition.

Our analysis suggested that the Greek SCQ presents satisfactory psychometric properties. Construct validity was corroborated by confirming the four-factor structure considered in the development of the original version of the instrument, while, as expected, autistic children presented lower SCQ total and subscale scores than neurotypical children. Our study is the first to validate the four-factor construct of ASD in Greek-speaking populations with a CFA analysis, and one of the few studies that use this method to examine construct validity in a cross-cultural adaptation of SCQ (examples of other studies: Chinese: Gau et al., 2011; simplified Chinese: Liu et al., 2022).

Furthermore, our study evaluated the four-factor structure, which has been used in the original instrument (Berument et al., 1999) and which maps onto the three DSM-IV domains. This approach is consistent with some recent cross-linguistic adaptations of SCQ (Arabic: Aldosari et al. 2019; simplified Chinese: Liu et al., 2022). Additionally, we considered a two-factor structure, consistent with the two domains of DSM-5 (the S- and R-domains discussed in Liu et al., 2022). Our results suggested that the fit of the four-factor model was better than that of the two-factor model, with the fit of the latter being at the margins of acceptability thresholds. These findings chime with Grove et al. (2019), who showed that the four-factor model was the best-fitting model in English SCQ data from preschool-aged autistic children, as well as a study by Frazier et al. (2014) on English SRS-2, in which fit indices of the four-factor model were often better than those of a two-factor model. However, in Frazier et al. (2014), the two-factor model clearly exhibited an acceptable model fit. More research is warranted towards the development of cross-cultural screening tools consistent with the recent diagnostic criteria.

In terms of differentiating between autistic and typical children, our analyses suggested an optimal cutoff of 14 yielded high levels of specificity and sensitivity in discriminating between autistic and typical children with the Lifetime version and when a subgroup of non-verbal autistic children was excluded. This value is close to the proposed cutoff of 15 in earlier studies in other languages, for example, English (Berument et al., 1999), Arabic (Aldosari et al., 2019), German (Bölte et al., 2008), Portuguese (Sato et al., 2009) and Turkish (Avcil et al., 2015; Öner et al., 2012). It is also similar to the cutoff in the pilot study performed by Zarokanellou et al. (2017).

However, the optimal cutoff was lower for the Current version. Although the Lifetime and the Current versions differ with regards to the timeframe to which items refer, one possibility for the different cutoff points in the two versions is that they arose from the differential severity of autistic symptomatology in autistic children in Samples A and B. It is often recommended that a lower cutoff point may be used to differentiate children with diagnostic labels such as Asperger's, High Functioning Autism and PDD-NOS from neurotypical children (Corsello et al., 2007; Schanding Jr et al., 2012). However, it was not possible to investigate the cutoff discrepancy in Samples A and B further as this study is limited by the absence of detailed diagnostic information for samples A and B. Replication studies with larger samples and further diagnostic data are warranted to address this issue. In our analyses, the SCQ threshold was also contingent on the inclusion (or not) of non-verbal children in sample A. When non-verbal children were included in the cutoff estimation, this resulted in a lower optimal cutoff (12 as opposed to 14).

Our preliminary analysis of gender biases suggested that a small number of items (Lifetime: five; current: six) might have differential sensitivity ("difficulty"). The majority of these items referred to the social interaction and communication subscales (and the relevant ADI-R domains), and only one item referred to Repetitive and Stereotypical Behaviors. Across the two versions, item SCQ24 (nodding to mean yes) was more difficult (less frequently endorsed) for boys; item SCQ13 (circumcised interests) was more difficult for girls. These results are relevant to recent studies suggesting the importance of taking into account gender differences in screening for autism (Evans et al., 2019; see also Lockwood Estrin et al., 2020; Ratto et al., 2018). For example, Evans et al. (2019) found differences between boys and girls in social communication symptoms but not in repetitive/restricted behaviors as measured with SCQ (similar to the dominance of socially-relevant items in our differential item functioning analysis).

This study is one of the few psychometrics studies to examine both SCQ Lifetime and Current (see Wei et al., 2015; also Rynkiewicz et al., 2021). Wei et al. (2015) suggested that the SCQ Current version presented psychometric measurement issues, including lower internal consistencies, a weaker factor structure, and lower item-based discrimination. In our study, the two parallel analyses yielded, overall, similar or overlapping results, suggesting sufficient psychometric validity for both versions of the Greek SCQ. However, in the CFA analysis for SCQ current, although the four-factor model was confirmed, four items did not contribute significantly to their corresponding latent variable, suggesting a limitation consistent with Wei et al. (2015).

The present study is not without limitations. Our psychometric analysis did not address concurrent validity, that is, the congruency of SCQ scores with other established measures of autistic symptomatology. This type of validity was challenging to address as (to our knowledge) there are no officially published and standardized screening and diagnostic instruments for the diagnosis of autism in Greek-speaking populations. However, future studies should measure the concurrent validity of the Greek SCQ. Furthermore, the ASD diagnoses in this study (data collected in 2016–2017) were, largely, based on earlier diagnostic classifications DSM-IV and ICD-10. Although the class of autistic children in our analyses included children with a diagnosis of autism as well as children with an Asperger's syndrome label (i.e., aligning with DSM-V), future studies should corroborate our results with samples in which diagnoses were based on the current diagnostic criteria.

Another psychometric property that has not been evaluated in this study is test–retest reliability, which is important for establishing the consistency of measurements across time. For example, test–retest reliability has been recently shown for the Turkish (Avcil et al., 2015) and the simplified Chinese (Liu et al., 2022) versions of the SCQ.

In terms of sample size, we employed a sample size of a total of 311 children. This sample is comparable to other psychometric studies carried out with Greek-speaking populations (e.g., Zarokanellou et al., 2017), however, it is smaller than the samples used in psychometric studies conducted in bigger countries/cultures, for example, Arabic (Aldosari et al., 2019; $N = 412$) or Chinese (Liu et al., 2022; $N = 819$). Bigger sample sizes will enable the investigation of the psychometric properties of SCQ in further detail, for example, considering metric invariance with respect to gender or age (see Barnard-Brak et al., 2016, as well as Frazier et al., 2014 for SRS-2).

In sum, the Greek version of the SCQ is a useful tool for an initial assessment of social interaction and communication in children and, consequently, the detection of atypicalities related to the autism spectrum. This instrument may produce measurements of ASD-related behaviors with sound construct validity and internal consistency, and it has high sensitivity and specificity for ASD screening. Similar to the English version, the SCQ Greek can be used as a reliable measure for assessing the communicative abilities of children based on Total Score. Nevertheless, additional psychometric properties need to be tested before developing guidelines for its wider use. Finally, as a screening tool, the Greek SCQ could not be used to carry out individualized diagnoses and to describe the behavior of individuals.

ACKNOWLEDGMENTS

Thanks to the children and their parents who took part in the study. We are grateful to Dr. Georgios Sideridis for his contribution to the psychometric analysis of the data in the published translation of the SCQ. We are also grateful to George Makris, Ioanna Talli, Katerina Afentenou, Fani Nasika, Theodora Kehagia, and postgraduate students of the MA course Science of Language and Culture: Language Disorders and Educational intervention, Aristotle University Thessaloniki for supporting data collection for this study; and Stela Setaki, George Exarhos and Maria Fotiadou and Glafki for their help in the translation of the instrument.

DATA AVAILABILITY STATEMENT

The data that support the findings will be available upon request, subject to the instrument's publisher's permission.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Karaminis, T., & Stavrakaki, S. (2022). The psychometric properties of the Greek version of the Social Communication Questionnaire. *Autism Research*, 1–13. https://doi.org/10.1002/aur.2790