The Revised Children's Communication Checklist-2 (CCC-R): Factor Structure and Psychometric Evaluation

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The Children's Communication Checklist-2 (CCC-2) is often applied to assess pragmatic language impairment which is highly prevalent in autism spectrum disorder (ASD) and several mental health conditions. We replicated previous findings on the limited applicability of the CCC-2 in clinical samples and the inconsistent findings concerning the factor structure. The aim of the present study was, thus, to develop a concise, simplified, and revised version of the CCC-2 in a large German-speaking sample. Four groups of children and adolescents aged 4 to 17 years were included: ASD (n = 195), intellectual disability (ID, n = 83), diverse mental health conditions (MHC, n = 144) and a typically developing control group (TD, n = 417). We reduced the original number of items from 70 to 39, based on item analysis, exploratory factor analysis and the exclusion of communication-unrelated items. The revised version, CCC-R (α = 0.96), consists of two empirically derived factors: a pragmatic-language (α = 0.96) and a grammatical-semantic-language factor (α = 0.93). All clinical groups (ASD, ID, and MHC) had significantly increased CCC-R total scores, with the highest scores being in the neurodevelopmental disorder groups (ASD and ID). In addition, we found group-specific patterns of elevated pragmatic-language scores in the ASD group and grammatical-semantic scores in the ID group. The CCC-R was comparable to the CCC-2 in distinguishing ASD from the other groups. The CCC-R is proposed as a simplified and easily applied, clinical questionnaire for caregivers, assessing pragmatic language impairments across neurodevelopmental disorders and mental health conditions. ***Autism Res*** *2021, 14: 759–772.* © 2021 The Authors. *Autism Research published by International Society for Autism Research* published by Wiley Periodicals LLC.

Lay Summary: The CCC-2 is a questionnaire designed to identify children who have problems in the social use of language, however, it is limited in its clinical application and exhibits inconsistent factors. We have created a shorter and simpler version of the CCC-2 that we have called the CCC-R which overcomes the previous limitations of the CCC-2. It consists of two subscales: pragmatic language and grammatical-semantic language. The CCC-R can be used as a short and clinically relevant caregiver questionnaire which assesses pragmatic language impairments in children and adolescents.

Keywords: autism; language impairment; social communication; intellectual disability; CCC-2

Introduction

The function of language is to allow verbal communication between humans. Pragmatic language is defined as the social language skills used in everyday interactions with others, including non-verbal communication [Schoen Simmons, Paul, & Volkmar, 2014]. A subgroup of children and adolescents show a "pragmatic language impairment" (PLI) [Bishop, 1998] that is defined by specific problems in the social use of language. This is represented as Social (Pragmatic) Communication Disorder (SPCD) within the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [American Psychiatric Association, 2013]. Mandy et al. [2017] described SPCD as a "borderland diagnosis" of ASD. PLI and SPCD have also been described in several mental health conditions [Topal, Demir Samurcu, Taskiran, Tufan, & Semerci, 2018]. Previous studies have discussed a lack of instruments that reliably screen for and quantitatively assess PLI and SPCD across the diagnoses [Cummings, 2017; Ketelaars, Jansonius, Cuperus, & Verhoeven, 2016; Schoen Simmons et al., 2014]. A promising instrument to identify difficulties with pragmatic language is the Children's Communication Checklist-2 (CCC-2) [Bishop, 2003].

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The objective of this study was to validate and improve the CCC-2 across different diagnoses.

The CCC-2 is a caregiver-rated questionnaire that quantifies the strengths and weaknesses of children's communication from 0 ("less than once a week") to 3 ("every day"). It includes 70 items on 10 pragmatically constructed subscales (see Table 1). The CCC-2 was designed as a screening instrument for (a) children with general language impairments, (b) children with pragmatic impairments, and (c) to identify children who need further ASD diagnostics [Bishop, 2003; Tanaka et al., 2016]. The CCC-2 has been validated in a UK sample of 542 typically developing (TD) children aged 4–16 years old [Norbury & Bishop, 2005]. In typical development, the CCC-2 mean scores were found to decrease with age, thus, the CCC-2 raw subscale scores were log-transformed and corrected by age norm scores. It remains unexplored as to whether the CCC-2 age dependency can be replicated in clinical samples including ASD.

A General Communication Composite (GCC) and a Social Interaction Deviance Composite (SIDC) can be generated from CCC-2 subscales. The GCC comprises the scales A-H and has been proposed to identify specific language impairments (SLI) that are characterized by aberrant communication abilities. The SIDC is calculated by subtracting the grammatical-semantic-language-related subscales ($A + B + C + D$) from the pragmatic-language-related subscales ($E + H + I + J$) and has been proposed to detect discrepancies between pragmatic and grammatical skills, which is common in ASD, SPCD and PLI [Bishop, 2003]. GCC and SIDC may be utilized in clinical applications to differentiate diagnostic groups.

Oi et al. [2017] examined the CCC-2's ability to differentiate diagnostic groups in a sample of TD children ($n = 64$), ASD children ($n = 48$) and children with communication problems ($n = 30$). There were significant overlaps between the CCC-2 density distributions of all the subgroups which indicated that communication problems manifest as a continuous trait and that no discrete cut-offs exist between diagnostic groups. The low discriminative power between different clinical samples has been replicated [Geurts & Embrechts, 2008; Norbury, Nash, Baird, & Bishop, 2004; Philofsky, Fidler, & Hepburn, 2007; Selas & Helland, 2016; Volden & Phillips, 2010]. Substantial CCC-2 group differences have only been reported between clinical groups and the TD controls [Norbury & Bishop, 2005], thus, the CCC-2 may be quite suitable in quantifying communication problems as a continuous trait in children across the diagnostic categories and to differentiate those with language impairments from TD children who have less prevalent communication problems.

The CCC-2 quantifies communication weaknesses (items 1–50) and strengths (items 51–70) by consecutive item blocks. A "consistency check" (COC) was established by comparing item block scores; this identifies caregivers who have failed to realize that the item content had changed. Bishop [2003] suggested that questionnaires with a failed COC must not be interpreted, although COC cut-offs have not been empirically derived. Previous studies have reported substantial rates (1.7–25%) of failed COC in clinical samples [Bishop, 2003; Geurts & Embrechts, 2008; Helland, Biringer, Helland, & Heimann, 2009; Norbury et al., 2004]. This suggests a limited applicability of the CCC-2 to clinical samples in which communication problems are most likely.

In the original version, the internal consistency of the CCC-2 subscales ranged from "insufficient" (alpha = 0.66) to "acceptable" (alpha = 0.80) [Bishop, 2003]. Across different language adaptations, a large range of internal inconsistency was found; in a Dutch version, the internal consistency ranged from 0.53 to 0.75 [Geurts & Embrechts, 2008], in a Quebec French version from 0.54 to 0.89 [Vézina, Sylvestre, & Fossard, 2013] and in a Brazilian Portuguese adaptation from 0.75 to 0.90 [Costa, Harsányi, Martins-Reis, & Kummer, 2013], while, in a Serbian version this ranged from 0.46 to 0.75 [Glumbic & Brojcin, 2012] and, in a Norwegian adaptation, from 0.73 to 0.89 [Helland et al., 2009]. This range of internal consistency might be explained by the small number of items per subscale (see Table 1), but may also be due to

Table 1. Subscales of the CCC-2

Subscale	Name	Items	Cronbach's alpha[a]
A	Discourse	2, 24, 29, 38, 44, 51, 58	0.893
B	Syntax	1, 17, 27, 36, 43, 55, 69	0.861
C	Semantics	4, 6, 12, 32, 46, 64, 66	0.787
D	Coherence	10, 25, 40, 48, 50, 53, 68	0.902
E	Inadequate initiation	5, 21, 35, 37, 45, 59, 70	0.901
F	Stereotyped language	11, 18, 23, 30, 42, 61, 62	0.846
G	Use of context	15, 19, 28, 34, 41, 54, 60	0.899
H	Non-verbal communication	8, 14, 20, 31, 39, 56, 65	0.897
I	Social relations	3, 7, 13, 16, 33, 57, 67	0.853
J	Interests	9, 22, 26, 47, 49, 52, 63	0.855

[a]Estimated based on data of the current study.

cultural differences and language adjustments. Importantly, this indicates further that the 10 pragmatically derived CCC-2 factors may not be reliable.

The CCC-2 factor structure has been investigated in the Serbian version by exploratory factor analysis [Glumbic & Brojcin, 2012] which indicated a three-factor solution with a variance explanation of 29.4%. The three factors were labeled "general communication ability", "pragmatics" and "structural language aspects". Three items were excluded due to low factor loadings (items 27, 50, and 60). In a large community sample in Japan (n = 22871), the factor structure of the CCC-2 sub-score GCC was investigated; this comprised 8 (A–H) out of the 10 CCC-2 subscales [Oi et al., 2017]. A confirmatory factor analysis supported a single factor solution that explained 64.7% of the variance. The CCC-2 factor structure needs to be further explored in different language versions to define reliable subscales that can be informative in clinical applications.

So far, the CCC-2 has not been validated in a German sample. The original CCC-2 has limitations concerning its applicability in clinical samples, psychometric properties and factor structure. Thus, the central aim of this study was to develop a concise, simplified and revised version of the CCC-2, the CCC-R, in a German-speaking sample based on psychometric analysis and empirically supported factors. The CCC-R was investigated in groups of children and adolescents with different diagnoses associated with pragmatic language impairments; these groups were Autism Spectrum Disorder (ASD), intellectual disability (ID) and a group of participants with different mental health conditions (MHC) (see also Table 2) in comparison to TD controls. In addition, we investigated the age dependency of the CCC-R and its discriminative power in comparison to the original CCC-2.

Table 2. Percentage of Participants in the Mental Health Conditions (MHC) Group above Clinical Cut-offs on Psychopathology Scales as Assessed by the Child Behavior Checklist (CBCL)

CBCL scale[a]	Percent above cutoff (%)
Withdrawn/Depressed	29.9
Somatic Complaints	11.2
Anxious/Depressed	24.3
Social Problems	39.3
Thought Problems	35.5
Attention Problems	30.8
Rule-Breaking Behavior	7.5
Aggressive Behavior	15.0
Internalizing Problems	55.1
Externalizing Problems	35.5
Total Problems Score	56.1

[a]Clinical cut-offs are t-scores > 70, which indicates values that are two standard deviations above population means. First 8 rows describe primary syndrome scale. Last 3 rows describe superordinate composite scales and a total score.

Method

Participants

In total, 1070 children and adolescents (4–17 years old) and their caregivers initially participated, however, 22 were excluded due to age, 44 excluded due to the inclusion criteria and 165 were excluded due to incomplete data (see Fig. 1). The final study sample consisted of 839 participants who were divided into four groups according to questionnaire-based inclusion criteria and caregiver-reported diagnoses (ASD: n = 195; ID: n = 83; MHC: n = 144 and TD: n = 417, see Fig. 1). The MHC sample is further described concerning psychopathology in Table 2, as assessed by the Child Behavior Checklist (CBCL) (see Measures). The majority of the study sample spoke German as their first language at home (ASD: 88.7%, ID: 90.4%, MHC: 87.5%,TD: 91.8%), while the remaining spoke German as a second language at home. Age and gender are further described below (see Table 3).

Procedure

The study was prospectively reviewed and approved by the ethical committee of the Medical Faculty at the Goethe-University Frankfurt/Main. Participants were assessed in two recruitment arms (see Fig. 1). In the first approach, a paper-pencil version was applied. Participants eligible for inclusion who had previously received a diagnosis of ASD, ID, or MHC, according to the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10), were identified in the clinical database of the Child and Adolescent Psychiatry of the Goethe University Frankfurt. We approached families who had previously given general informed consent to be contacted about research projects. Study material was sent out with a pre-paid envelope. The participants were asked to complete the study questionnaires (see Measures) and to return them. ICD-10 diagnoses were based on our standard diagnostic procedures following national guidelines and were confirmed by experienced clinicians (child psychiatrists and clinical child psychologists); for an ASD diagnosis, this included the Autism Diagnostic Observation Schedule (ADOS) and Autism Diagnostic Interview (ADI-R). The ICD-10 diagnosis defined the clinical group affiliation (see Fig. 1). The clinical groups were predominantly assessed using the paper-pencil version. The second approach used the online versions of the questionnaires to recruit participants for the TD group and further clinical participants. The online assessment was operationalized *via* the online portal *Unipark* (http://www.unipark.com/de/), an academic version of the

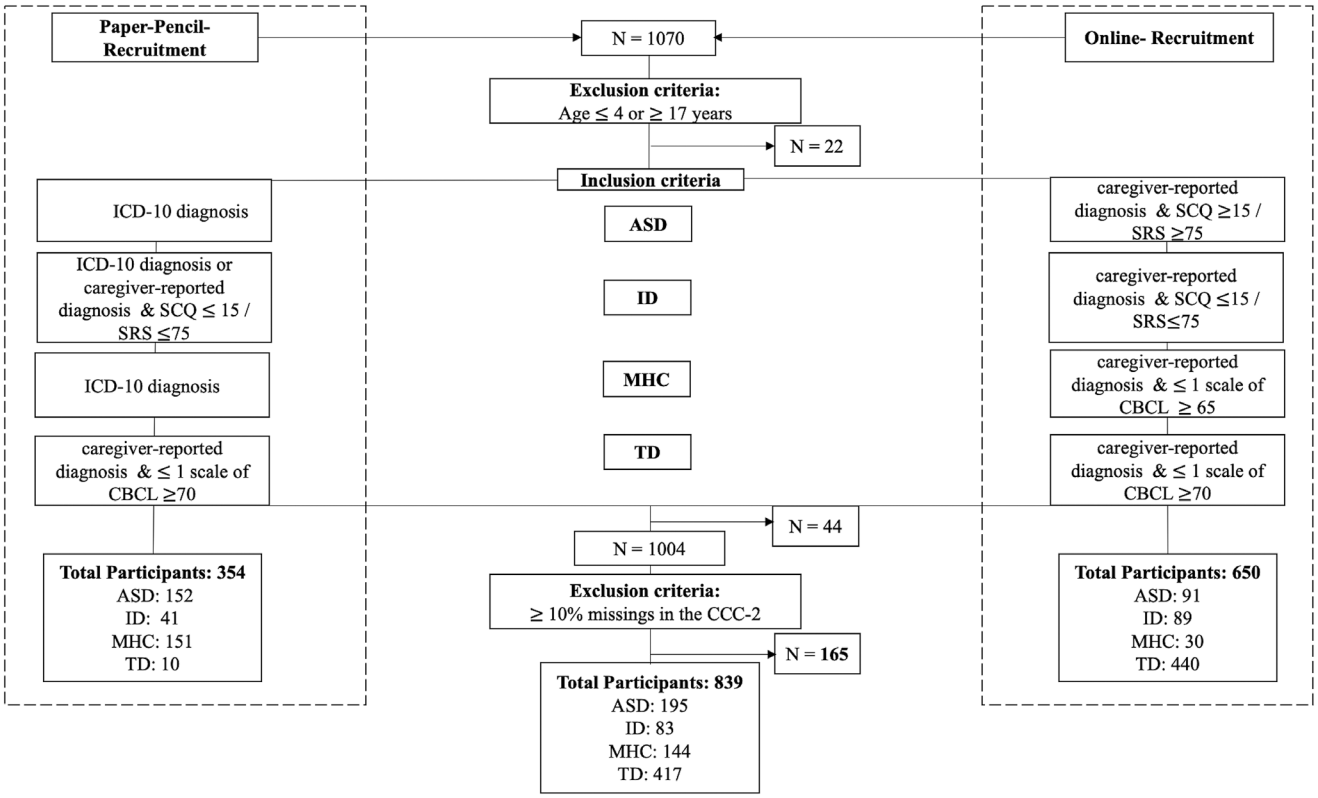

Figure 1. Flow chart of sample recruitment, inclusion/exclusion criteria and group affiliation definition. *Note*. ASD = Autism Spectrum Disorder, ID = intellectual disability (ID), MHC = mental health conditions, TD = typically developed controls, SCQ = Social Communication Questionnaire, SRS = Social Responsiveness Scale, CBCL = Child Behavior Checklist, ICD-10 = International Statistical Classification of Diseases and Related Health Problems—10th Revision.

internet platform *Questback* that fulfills high privacy and security requirements (ISO 27001). The link to the online assessment was distributed *via* flyers in schools and online *via* social media platforms. The caregiver-reported diagnosis ("Does your child have a diagnosis?") was confirmed by screening the questionnaires that defined group affiliation in the online assessment (see Fig. 1). Participants were only included if the caregiver-reported diagnosis matched the questionnaire outcome (see Fig. 1). For the ASD group, the Social Communication Questionnaire (SCQ) [Bölte & Poustka, 2006] and Social Responsiveness Scale (SRS) [Bölte & Poustka, 2008] total score had to reach the clinical cut-offs (see Fig. 1). For the ID group, the SCQ and SRS total score had to be below the clinical cutoffs. For the MHC group, at least one primary syndrome scale of the CBCL (see Table 2) had to be above the clinical cut-offs. Participants were assigned to the TD group if no clinical diagnosis was indicated by the caregiver and if their CBCL scores were below the clinical cutoffs. The TD group was predominantly assessed with the online version. The clinical cut-offs were derived from the literature (see Measures).

Measures

Children's Communication Checklist-2 (CCC-2). The German version of the CCC-2 was provided by Pearson *via* a personal correspondence and has not been officially published. The CCC-2 is a 70-item, caregiver-rated questionnaire assessing communication problems [Bishop, 2003; Bishop, Maybery, Wong, Maley, & Hallmayer, 2006]. The items have a 4-option response format that ranges from 0 ("less than once per week/or never") to 3 ("more than twice per day/or always").The questionnaire takes about 15 min to complete [Tanaka et al., 2016] and can be applied to children starting from 4 years of age who can speak fluent sentences [Bishop, 2003].

The CCC-2 consists of a weakness-related (1–50) and a strength-related (51–70) item block that proportionally contribute to each of the 10 pragmatically constructed subscales (see Table 1). If consistent subscales are assumed, caregivers would be required to adapt their ratings according to the item block, that is, high weakness should correspond to low strength ratings within subscales. The "consistency check" (COC) is applied to check

Table 3. Descriptive Data and Group Differences of the CCC-2 and CCC-R

	Total	ASD	ID	MHC	TD	Group comparison
N	839	195	83	144	417	—
CCC-2 total[a]	42.3/39.3*	67.3/41.2	76.2/41.2	60.7/34.3	17.45/17.77	F(3.835) = 189.7, *P* < 0.001 ASD, ID, MHC > TD ID > MHC
N (with COC)[b]	706	155	60	105	386	—
CCC-2 total (with COC)[a,b]	36.8/39.5	64.3/44.2	76.2/47.2	55.8/37.1	14.6/14.6	*F*(3.702) = 155.8, *P* < 0.001 ASD, ID, MHC > TD ID > MHC
CCC-2 SIDC: Social Interaction Deviance Composite (with COC)[a,b]	6.5/12.6	15.8/14.5	−1.6/17.9	10.3/14.7	2.9/6.0	*F*(3.702) = 63.2, *P* < 0.001 ASD, MHC, TD > ID ASD, MHC > TD ASD > MHC
CCC-2 GCC: General Communication Composite (with COC)[a,b]	27.9/31.6	47.7/35.1	61.6/41.1	42.0/31.3	10.8/11.5	*F*(3.702) = 138.7, *P* < 0.001 ASD, ID, MHC > TD ID > ASD, MHC
CCC-R total[a]	15.9/19.4	27.8/22.4	31.5/23.6	22.9/18.1	4.9/7.0	*F*(3.835) = 139.0, *P* < 0.001 ASD, ID, MHC > TD ASD, ID > MHC
CCC-R subscale 1: pragmatic[a]	13.1/15.6	24.49/19.15	21.3/14.95	19.22/14.14	3.99/5.74	*F*(3.835) = 149.7, *P* < 0.001 ASD, ID, MHC > TD ASD > MHC
CCC-R subscale 2: grammatical-semantic[a]	2.9/6.0	3.26/5.76	10.18/10.94	3.77/6.38	0.94/2.38	*F*(3.835) = 70.0, *P* < 0.001 ASD, ID, MHC > TD ID > ASD, MHC
Age[a]	11.2/4.0	12.2/4.0	11.5/4.0	11.8/3.5	10.5/4.0	*F*(3.835) = 9.58, *P* < 0.001 ASD, MHC > TD
Gender (female/male)	362/477	67/128	34/49	47/97	214/203	$\chi^2(3) = 24.14$, $p < 0.001$ TD > ASD, MHC

[a]Mean/SD.

[b]N and CCC-2 scores are presented after participant exclusion based on a failed "consistency check" (COC) according to the original publication. All other variables are based on the final study sample. (n= 839).

for this caregiver adaptation in the ratings. Strength-related ratings are inverted before analysis. The COC is only applied if the sum of the inverted strength-related items is higher than 30, i.e., the caregivers had rated low communication strengths. To pass the COC, the difference to the mean weakness-related-items mean score must be lower than 1.3. A mean difference higher than 1.3 has been suggested to indicate that the change from weakness-related (1–50) to strength-related (51–70) items between item blocks did not result in adapted ratings. As a result, the COC is deemed unsound and the corresponding questionnaire must not be interpreted.

A General Communication Composite (GCC) and a Social Interaction Deviance Composite (SIDC) can be generated from the CCC-2 subscales (see Table 1). The GCC is calculated as the sum of the subscales A to H, whereas the SIDC is calculated as the difference between the score of the pragmatic-language-related subscales ($E + H + I + J$) and the grammatical-semantic-language-related subscales ($A + B + C + D$).

The CCC-2 is usually converted to correct for a proposed age dependency. Firstly, each subscale raw score is log-transformed to reduce the variance between the age bands. Secondly, the obtained value is subtracted from a predicted age value and divided by the standard error. Thirdly, this residual score is scaled (standardized) to a mean of 10 and an SD of 3 [Bishop, 2003]. We have refrained from using this conversion and report the raw sum scores in the current analysis as age dependency has not been reported in clinical samples.

Child Behavior Checklist (CBCL). The German version of the CBCL 4–18 [Döpfner, Schmeck, Berner, Lehmkuhl, & Poustka, 1994] is a widely used parent-rating scale that measures the dimensional symptoms of mental disorders over the last 6 months in 4–18-year-olds. The 113 items are rated on a three-point Likert scale, ranging from 0 (not true) to 2 (often true). The CBCL 4–18 provides 8 subscales (first order syndrome scales) (I: "withdrawn/depressed", II: "somatic complaints," III: "anxious/depressed," IV: "social problems," V: "thought problems," VI: "attention problems," VII: "delinquent behavior," and VIII: "aggressive behavior"). The CBCL 4–18 also provides a total problem score (I–VIII), as well as second order syndrome scores for internalizing (I–III) and externalizing (VII + VIII) problems [Achenbach, 1991; Döpfner et al., 1994]. The CBCL takes about 15 min to complete [Pandolfi, Magyar, & Norris, 2014].

Social Responsiveness Scale (SRS). The SRS assesses social responsiveness over the last 6 months in children and adolescents [Bölte & Poustka, 2008; Cholemkery & Freitag, 2014]. We applied the parent-rated version in the current study; this includes 65 items and takes about 20 min to complete. The SRS is often applied as a screening measure for ASD symptoms. The reliability of the SRS is excellent (interrater reliability = 0.91, internal consistency = 0.91) [Bölte & Poustka, 2008; Cholemkery & Freitag, 2014].

Social Communication Questionnaire (SCQ). The German version of the Social Communication Questionnaire (SCQ) [Bölte & Poustka, 2006] is a caregiver-based screening instrument of lifetime ASD symptoms. The 40 items are constructed in a binary response format ("yes" or "no"). The internal consistency of the German version was acceptable in the ASD group ($\alpha = 0.83$).

Demographics data sheet. The demographics datasheet was developed to provide more information about the caregivers and the children. It contained questions about the person completing the questionnaire, the child's birthday, the child's educational provision, the language spoken at home and the place of residence.

Statistical Analysis

All statistical analyses were performed using R statistics 3.4. [R Core Team, 2014] with the additional packages of *psych* (exploratory factor analysis) (Revelle, 2015), *lavaan* (confirmatory factor analysis) [Rosseel, 2012], *sjPlot* (item analysis) [Lüdecke, Waggoner, & Makowski, 2019], *pROC* (Receiver Operating Characteristics) [Robin et al., 2011] and *ggplot2* (figures) [Wickham, 2016]. Concerning CCC-2, the sum scores and sample characteristics were derived with and without the application of the "consistency check" (COC). Age dependency was investigated by linear regression models. We applied item analyses, including the item-scale correlation and difficulty, which can be interpreted as the mean rating of that item. Confirmatory factor analyses (CFA) were conducted with maximum likelihood estimations and the 10 originally proposed factors as the latent variables. Latent variables were exclusively indexed by the items of the respective questionnaire factors (see Table 1). We allowed intercorrelations of the 10 latent variables. Our final sample size ($n = 839$) was substantially larger than the conventional CFA requirements with a total $n > 200$ [MacCallum, Widaman, Zhang, & Hong, 1999]. Furthermore, we applied an exploratory factor analysis (EFA) to estimate the number of factors in the observed data.

Inconsistent item analyses and CFA results suggested a revision of the weakness-related items only (1–50) in another item analysis and exploratory factor analysis with oblique rotation. These analyses provided a reduced CCC-R item pool ($i = 43$) that was further reduced by excluding the items unrelated to communication. This resulted in the final CCC-R ($i = 39$) that was compared to CCC-2 in its ability to discriminate between groups by

using Receiver Operating Characteristics (ROC). This also included a comparison of the CCC-2 composite scores (SIDC and GCC) and the CCC-2 factors (pragmatic language and grammatical-semantic language). 95% confidence intervals of Area Under the Curve (AUC) values were estimated by stratified bootstrapping with 2000 iterations [Sun & Xu, 2014]. Group differences were quantified by analysis of variance (ANOVA) and specified by post-hoc comparisons corrected for multiple testing (Tukey HSD) with 95% confidence intervals ([lower boundary; upper boundary]). Single group comparisons were carried out by parametric t-tests. Equal variances were not assumed in a group comparison of item difficulty between weakness- and strength-related items and, thus, Welch's approximation was applied to adjust degrees of freedom. Group comparisons for count data were carried out by the Pearson Chi-squared Test for count data. Internal consistency, as an estimate of reliability, was calculated for CCC-2, CCC-R, and respective subscales by Cronbach's alpha (α).

Results

CCC-2 Analysis

CCC-2 consistency check. The application of the CCC-2 "consistency check" (COC) would have led to the exclusion of 133 participants (15.9%). Exclusion rates were substantially higher in the clinical groups (ASD: 20.5%, ID: 27.2%, MHC: 27.1%) compared to the TD group (7.4%; $\chi(1) = 42.79$, $P < 0.001$). We replicated the limited applicability of the CCC-2 in the clinical samples [Helland et al., 2009].

CCC-2 group differences. CCC-2 descriptive data is provided in Table 3. Groups significantly differed in their CCC-2 total scores (without COC: $F(3.835) = 189.7$, $P < 0.001$; $R^2_{adj} = 0.40$; with COC: $F(3.702) = 155.8$, $P < 0.001$, $R^2_{adj} = 0.39$). Post-hoc comparisons showed significantly higher CCC-2 total scores in all clinical groups (ASD, ID and MHC) compared to TD (without COC: ASD-TD diff = 49.8 [43.1; 56.6], ID-TD diff = 58.8 [49.4; 68.2], MHC-TD diff = 43.2 [35.6; 50.8]; with COC: ASD-TD diff = 49.7 [42.2; 57.2], ID-TD diff = 61.6 [50.6; 72.5], MHC-TD diff = 41.2 [32.5; 49.9]). In addition, the ID group had significantly higher CCC-2 total scores compared to the MHC group (without COC: ID-MHC diff = 15.6 [4.8; 26.3]; with COC: ID-MHC diff = 20.3 [7.6; 33.1]). With or without using the COC application, the ASD group did not significantly differ from the MHC nor the ID group concerning the CCC-2 total scores.

CCC-2 age dependency. We found a linear decrease of the CCC-2 raw score with increasing age (without COC: $F(1.837) = 10.62$, $P = 0.001$, $b = -1.09$; with COC: $F(1.704) = 10.47$, $p = 0.001$, $b = -1.18$), although the association was weak ($R^2_{adj} = 0.011$ and $R^2_{adj} = 0.013$) and substantially differed between groups (see Fig. 2). The ASD and MHC groups displayed a slightly linear decrease of the CCC-2 raw scores with age, whereas the ID group showed a curve-linear course with the highest CCC-2 raw score in the 9–11 years' age band. Thus, a transformation of raw scores might not be appropriate across all clinical groups.

CCC-2 item analysis. The CCC-2 Cronbach's alpha was high with $\alpha = 0.97$, while Cronbach's alpha in the subscales ranged from $\alpha = 0.79$ to 0.90. The item-scale correlations ranged from $r = 0.37$ to 0.83, while the item difficulty ranged from 0.03 to 0.49. It was apparent that the inverted strength-related items 51 to 70 were of substantially lower difficulty (i.e., had a higher mean rating, $m = 0.28$) compared to weakness-related items 1 to 50 ($m = 0.13$, $t(28.7) = 6.85$, $p < 0.001$) despite the application of the COC. Within subscales, this indicated that the high weakness ratings did not proportionally

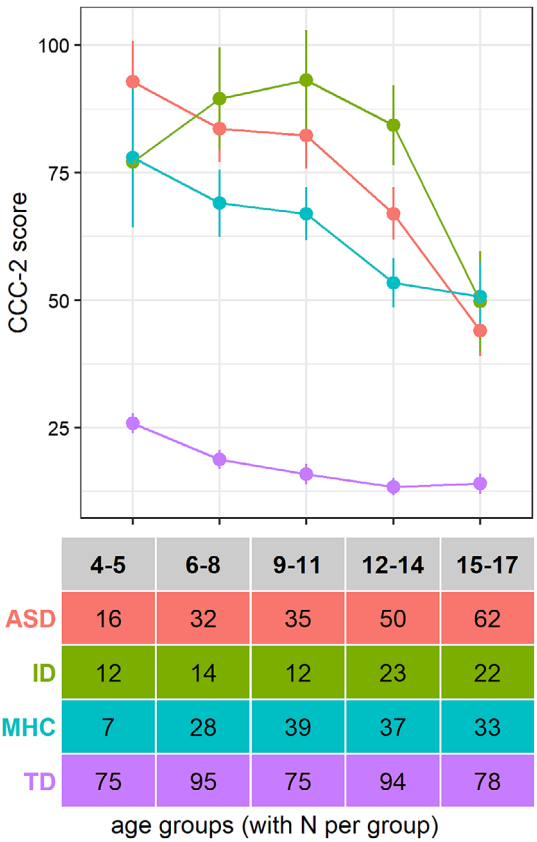

Figure 2. Age dependency of the CCC-2 total score by group. *Note*. ASD = Autism Spectrum Disorder, ID = intellectual disability (ID), MHC = mental health conditions, TD = typically developed controls, CCC-2 = Children's Communication Checklist-2, age is summarized in respective age bands (e.g., 4–5 years). Mean values (dots) are plotted with respective standard errors (vertical lines) in group-specific color codes.

correspond to low strength ratings and *vice versa*. Thus, the COC is not able to ensure consistency in item rating and the original CCC-2 cannot be considered as being consistent concerning subscales (see Fig. 3).

CCC-2 factor analysis. A confirmatory factor analysis (CFA) was performed to test the pragmatically constructed 10-factor structure of the CCC-2. The resulting covariance matrix was not positive definite. Only one eigenvalue was above 1, while two eigenvalues were negative. In addition, the correlation matrix of the model fit showed various high intercorrelations ($r > 0.9$) and one correlation greater than one due to the undefined covariance matrix. Thus, no further fit indices were calculated.

To explore further the structure of the CCC-2, we applied an exploratory factor analysis (EFA). Scree plot analysis suggested a 2–4 factor solution based on the relative reduction in eigenvalue drop-off. The eigenvalues of the first five factors were 30.25, 6.2, 2.4, 1.7, and 1.4, respectively. Strength-related items 51–70 loaded on one factor except for 2–3 items depending on factor solution (see Tables S1–S3). Even with application of the COC, factor loadings were defined by answering patterns that differed in strength-related (51–70) compared to weakness-related items (1–50). This suggests this item content change superimposed an expected factor structure that relates to CCC-2 subscales. Thus, strength-related items (item 51–70) were excluded in a revision of the CCC-2 due to inconsistent item difficulty and the factor analysis results; this made the COC redundant. As a result, clinical participants with previously failed COC were included in further analyses.

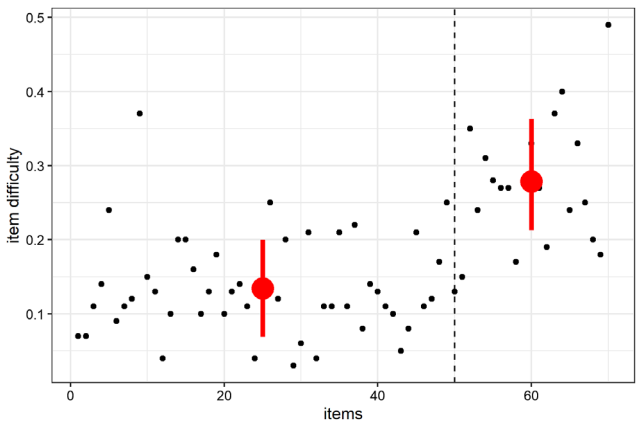

Figure 3. Item difficulty of the CCC-2. Item difficulty by items with mean (dot) and standard deviation (error bars). Dashed line indicates separate item blocks (weakness-related items: 1–50, strength-related items: 51–70).

Revision Process

Item analysis of weakness-related items. We initially considered all weakness-related items (1–50) of the CCC-2. Internal consistency was estimated by Cronbach's alpha with $\alpha = 0.97$ across all 50 items ($\alpha = 0.96$ for the final 39-item version below). Item difficulty was homogenous with values between 0.07 and 0.25, however, item 9 was an exception, having a difficulty of 0.39. Item-scale correlation values were between 0.20 and 0.80 (see Table 4). Thus, exclusion of the CCC-2 strength-related items (51–70) did not impair psychometric properties, while exclusion improved the consistency of item difficulty and, therefore, harmonized the ratings between items.

Factor analysis of weakness-related items. EFA scree plot analysis suggested a two-factor solution based on the relative reduction in the eigenvalue drop-off (see Fig. 4), whereas 6 factors had an eigenvalue greater than one. The two-factor solution explained 48% of the total variance with a root mean square residual of 0.04. A three-factor solution increased the explained variance to 51%, however, the third factor exhibited a substantially lower eigenvalue of 1.7. Thus, we decided to apply a two-factor-structure. The factor-loading cut-off for single items was set to $k = 0.50$ in order to retain factor-informative items. This led to the exclusion of 7 additional items (3, 4, 10, 21, 30, 34, and 46).

Exclusion of communication unrelated items. We decided to manually review the remaining items ($i = 43$) and to exclude those that were unrelated to communication (item 9: "has one or more overriding specific interests (e.g. computers, dinosaurs), and will prefer doing activities involving this to anything else"; item 13: "tends to be babied, teased or bullied by other children"; item 16: "a loner: neglected by other children, but not disliked" and item 47: "Shows interest in objects or activities that are regarded as being unusual such as traffic lights, washing machines, light switches").

Factors of the CCC-R. The first factor (see Table 5) is composed of the original CCC-2 subscales D to J (see Table 1). These scales included different areas of communication, collectively referred to as pragmatic communication. The marker items of the first factor were item 5 ("talks repetitively about things that no-one is interested in"), item 26 ("often turns the conversation to a favorite theme, rather than following what the other person wants to talk about") and item 39 ("may not realize when other people are upset or angry"). We labeled the resulting subscale score of factor-1 items as "pragmatic language" (subscale 1).

Table 4. CCC-R Item analysis and factor loadings

Item	Missings	Mean	SD	Difficulty	Item-scale correlation	Factor 1	Factor 2
1	0.12%	0.21	0.61	0.07	0.513		0.65
2	0.00%	0.21	0.66	0.07	0.507		0.86
3[b]	0.24%	0.37	0.73	0.12	0.425	0.46	
4[b]	0.00%	0.44	0.84	0.15	0.650	0.36	0.43
5	0.36%	0.76	1.04	0.25	0.782	0.81	
6	0.48%	0.27	0.65	0.09	0.581		0.51
7	0.12%	0.34	0.72	0.11	0.561	0.54	
8	0.24%	0.41	0.79	0.14	0.587	0.74	
9[a]	0.12%	1.17	1.15	0.39	0.650	0.68	
10[b]	0.12%	0.47	0.85	0.16	0.684	0.47	0.33
11	0.12%	0.39	0.74	0.13	0.603	0.57	
12	0.12%	0.11	0.43	0.04	0.517		0.66
13[a]	0.24%	0.31	0.68	0.10	0.582	0.56	
14	0.48%	0.66	0.96	0.22	0.615	0.73	
15	0.24%	0.65	1	0.22	0.768	0.69	
16[a]	0.83%	0.51	0.86	0.17	0.698	0.70	
17	0.60%	0.34	0.76	0.11	0.605		0.65
18	0.36%	0.37	0.78	0.12	0.626	0.59	
19	0.24%	0.57	0.93	0.19	0.771	0.68	
20	0.00%	0.29	0.69	0.10	0.615	0.54	
21[b]	0.12%	0.4	0.82	0.13	0.614	0.46	
22	0.24%	0.39	0.79	0.13	0.569	0.65	
23	0.12%	0.3	0.72	0.10	0.542	0.63	
24	0.36%	0.12	0.49	0.04	0.455		0.62
25	0.12%	0.42	0.82	0.14	0.673	0.57	
26	0.12%	0.76	1.02	0.25	0.690	0.81	
27	0.60%	0.38	0.81	0.13	0.569		0.69
28	0.60%	0.65	1.02	0.22	0.748	0.66	
29	0.00%	0.1	0.47	0.03	0.437		0.80
30[b]	0.24%	0.19	0.55	0.06	0.532	0.37	
31	0.36%	0.67	0.93	0.22	0.744	0.68	
32	0.48%	0.12	0.47	0.04	0.524		0.65
33	0.00%	0.36	0.73	0.12	0.643	0.63	
34[b]	0.36%	0.33	0.77	0.11	0.727	0.44	0.45
35	0.12%	0.62	0.93	0.21	0.651	0.68	
36	0.12%	0.34	0.76	0.11	0.597		0.68
37	0.60%	0.69	0.97	0.23	0.764	0.70	
38	0.12%	0.25	0.7	0.08	0.564		0.78
39	0.36%	0.45	0.83	0.15	0.654	0.82	
40	0.48%	0.4	0.77	0.13	0.708	0.50	0.34
41	0.12%	0.34	0.77	0.11	0.566	0.74	
42	0.12%	0.3	0.74	0.10	0.422	0.70	
43	0.12%	0.16	0.57	0.05	0.477		0.67
44	0.12%	0.26	0.75	0.09	0.497		0.70
45	0.48%	0.66	0.98	0.22	0.719	0.58	
46[b]	0.24%	0.33	0.68	0.11	0.612	0.34	0.44
47[a]	0.12%	0.4	0.85	0.13	0.613	0.67	
48	0.12%	0.52	0.86	0.17	0.722	0.69	
49	0.12%	0.71	0.99	0.24	0.351	0.66	−0.39
50	0.24%	0.43	0.8	0.14	0.751	0.60	

[a]Items excluded by manual review.
[b]Items excluded by factor-loading cut-off.

The second factor (see Table 5) is composed of the original CCC-2 subscales A to C (see Table 1). These scales mainly included aspects of grammatical-semantic language. The marker items of the second factor were item 2 ("production of speech sounds seems immature, like that of a younger child," e.g. he says things like: "*tat* for *cat*, or *chimbley* for *chimney*, or *bokkle* for *bottle*") and item 29 ("leaves off beginnings or ends of words, or omits entire syllables (e.g. *bella* for *umbrella*)"). We labeled the resulting subscale score of factor-2 items as "grammatical-semantic language" (subscale 2).

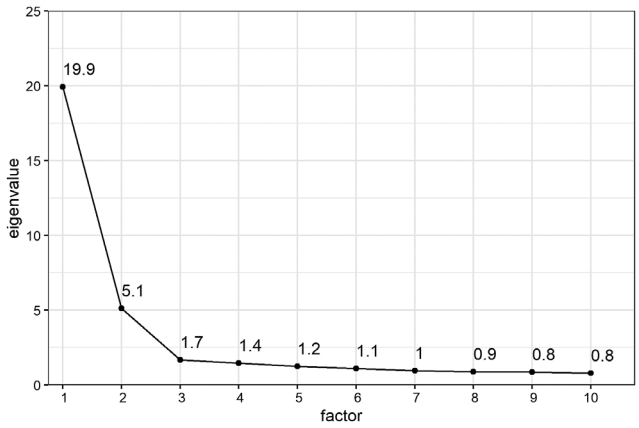

Figure 4. Scree-plot analysis. Scree plot analysis of CCC-2 weakness-related items (items 1–50). The first 10 factors with the highest eigenvalues are shown.

Table 5. CCC-R Subscales Based on Exploratory Factor Analysis of the Final 39 Items

	Name	Corresponding CCC-2 items
Subscale 1	Pragmatic language	5, 7, 8, 11, 14, 15, 18, 19, 20, 22, 23, 25, 26, 28, 31, 33, 35, 37, 39, 40, 41, 42, 45, 48, 49, 50
Subscale 2	Grammatical-semantic language	1, 2, 6, 12, 17, 24, 27, 29, 32, 36, 38, 43, 44

CCC-R Analysis

CCC-R group differences. After the revision process (see Fig. 6), the CCC-R consisted of 39 items (see Table 4). Descriptive data of the CCC-R sum score and corresponding subscales are presented above (see Table 3). The CCC-R showed significant group differences ($F(3, 835) = 139$, $P < 0.001$, $R^2_{adj} = 0.33$) with higher CCC-R sum scores in all clinical groups compared to TD (ASD-TD diff = 22.8 [19.3; 26.4], ID-TD diff = 26.5 [21.6; 31.4] and MHC-TD diff = 18.0 [14.1; 22.0]). In addition, post-hoc comparisons showed higher CCC-R scores in the ID and ASD groups compared to the MHC group (ASD-MHC diff = 4.7 [0.3; 9.2]; ID-MHC diff = 8.5 [2.9; 14.1]).

Concerning pragmatic language (subscale 1), significant group differences were found ($F(3, 835) = 150$, $P < 0.001$, $R^2_{adj} = 0.35$) with higher pragmatic language impairments in all clinical groups (ASD-TD diff = 20.5 [17.7; 23.3], ID-TD diff = 17.3 [13.4; 21.2] and MHC-TD diff = 15.2 [12.1; 18.4]). Post-hoc comparisons showed higher pragmatic language impairments in the ASD group compared to the MHC group (ASD-MHC diff = 5.3 [1.7; 8.8]).

Concerning grammatical-semantic language (subscale 2), significant group differences were found ($F(3, 835) = 70$, $P < 0.001$, $R^2_{adj} = 0.20$), with higher grammatical-semantic language impairments in all clinical groups (ASD-TD diff = 2.3 [1.1; 3.5], ID-TD diff = 9.2 [7.6; 10.9] and MHC-TD diff = 2.8 [1.5; 2.8]). Post-hoc comparisons showed higher grammatical-semantic impairments in the ID group compared to the ASD and MHC groups (ID-ASD diff = 6.9 [5.1; 8.7]; ID-MHC diff = 6.4 [4.5; 8.3]).

ROC-analysis. The CCC-2 (70 items) and CCC-R (39 items) were compared in their ability to discriminate between groups. The ROC analyses showed that, despite a substantially reduced number of items, CCC-R was comparable to CCC-2 in discriminating clinical samples from typical development (see Fig. 5). The CCC-R was further comparable to CCC-2 in discriminating specific clinical groups (ASD, ID, or MHC) from all other groups. The CCC-R pragmatic factor showed an improved ability to discriminate the clinical groups from TD compared to the CCC-2 SIDC. In contrast, the CCC-R grammatical-semantic factor performed worse than the similar CCC-2 GCC (see Table 6).

CCC-R. In summary, the CCC-R is the shortened and simplified version of the German CCC-2 ($\alpha = 0.96$, see Fig. 6). Based on the revision process, the "consistency check" (COC) and age dependent conversion of the raw scores is omitted. The CCC-R consists of 39 items, loading onto two empirically derived subscales (see Table 4): a "pragmatic language" subscale (26 items, $\alpha = 0.96$) and a "grammatical-semantic language" subscale (13 items, $\alpha = 0.93$). The subscales were moderately correlated in the current sample ($r(837) = 0.52$, $P < 0.001$).

Discussion

The current study investigated the CCC-2 in neurodevelopmental disorders and mental health conditions. In our German-speaking sample, the CCC-2 showed a high exclusion rate of clinical participants, questionable psychometric qualities and an unconfirmed factor structure. Thus, we developed a more concise, shortened and simplified version of the CCC-2, the CCC-R.

The original CCC-2 required a "consistency check" (COC) to ensure that the caregivers completing the questionnaire had realized the change in content between item blocks. The COC cut-offs were set arbitrarily and have not been validated empirically. In the original investigation by Bishop [2003], 1.7% of the data were excluded based on the COC, although the sample was limited to typical development. In a clinical validation sample (PLI, SLI and ASD), 7.4% failed the COC [Norbury et al., 2004]; this value was found to be even higher, up to 25%, in independent investigations of clinical samples [Helland et al., 2009; Geurts & Embrechts, 2008]. This is in line with our findings that provided exclusion rates, based on

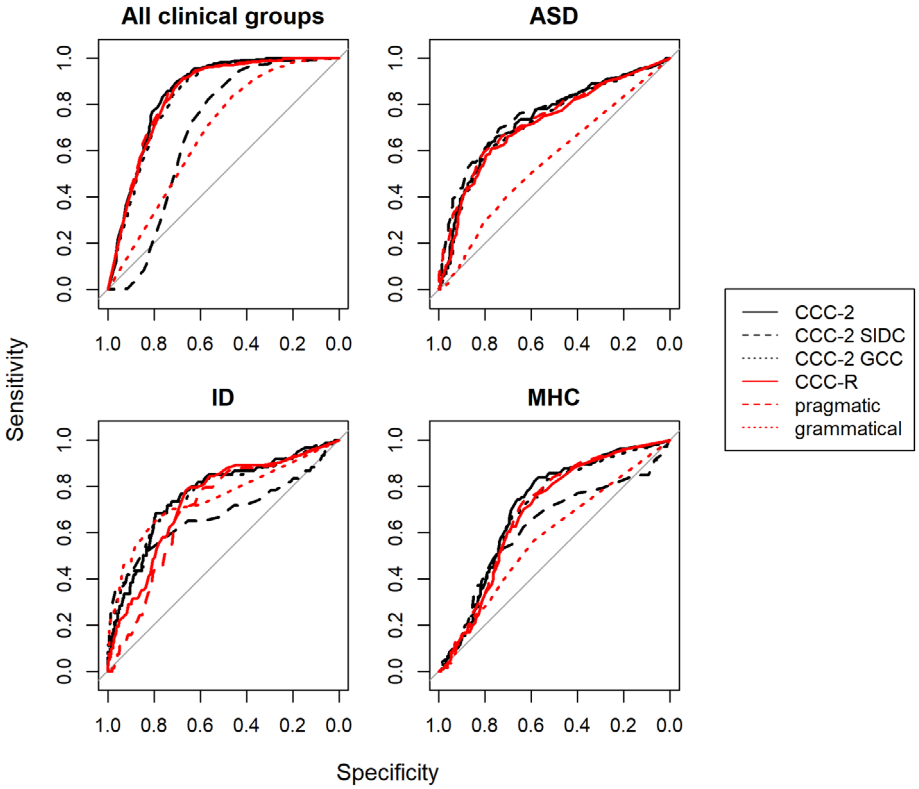

Figure 5. Receiver Operating Characteristic (ROC) curve analyses of CCC-2 with composites (SIDC and GCC) and CCC-R with factors (pragmatic and grammatical). *Note*. ASD = Autism Spectrum Disorder, ID = intellectual disability, MHC = mental health conditions, TD = typically developed controls, CCC-2 = Children's Communication Checklist-2, SIDC = Social Interaction Deviance Composite, GCC = General Communication Composite, CCC-R = Children's Communication Checklist-Revised, pragmatic = pragmatic language subscale, grammatical = grammatical-semantic language subscale. For all clinical groups (ASD + ID + MHC) compared to TD, for ASD compared to (ID + MHC + TD), for ID compared to (ASD + MHC + TD) and for MHC compared to (ASD + ID + TD). Black lines indicate CCC-2 and its composites SIDC and GCC. Red lines indicate CCC-R and its subscales (pragmatic language and grammatical-semantic language).

Table 6. Area-Under-the-Curve (AUC) Values and 95% Confidence Intervals of the Receiver Operating Characteristic (ROC) Curve

	Clinical groups[a] *vs* TD	ASD *vs* ID+MHC + TD	ID *vs* ASD + MHC + TD	MHC *vs* ASD + ID + TD
CCC-2	0.853 [0.823; 0.883]+	0.737 [0.69; 0.783]	0.764 [0.697; 0.832]	0.709 [0.661; 0.757]
CCC-2 – SIDC	0.685 [0.642; 0.729]	0.756 [0.709; 0.803]	0.678 [0.588; 0.767]	0.625 [0.563; 0.688]
CCC-2 – GCC	0.837 [0.805; 0.868]	0.722 [0.675; 0.77]	0.766 [0.697; 0.835]	0.694 [0.644; 744]
CCC-R	0.842 [0.815; 0.87]	0.715 [0.672; 0.758]	0.736 [0.68; 0.792]	0.684 [0.642; 0.726]
CCC-R—subscale 1: pragmatic language	0.849 [0.822; 0.875]	0.735 [0.693; 0.778]	0.698 [0.643; 0.753]	0.694 [0.652; 0.736]
CCC-R subscale 2: grammatical-semantic language	0.675 [0.643; 0.708]	0.557 [0.515; 0.6]	0.746 [0.683; 0.81]	0.582 [0.534; 0.629]

[a]Clinical groups = ASD + ID + MHC. ASD = Autism Spectrum Disorder, ID = Intellectual Disability, MHC = Mental Health Conditions, SIDC = Social Interaction Deviance Composite of the CCC-2, GCC = General Communication Composite of the CCC-2. + AUC [95% lower bound; 95% upper bound].

a failed COC, of 20.5% (ASD) to 27.2% (ID) of the clinical samples. These high exclusion rates indicate the limited applicability of the CCC-2 to samples in which communication problems are likely.

In the CCC-R, strength-related items were excluded which made the COC obsolete. This increased the applicability of the questionnaire and, thus, reduced the burden on the caregivers (39 *versus* 70 items). In addition, it

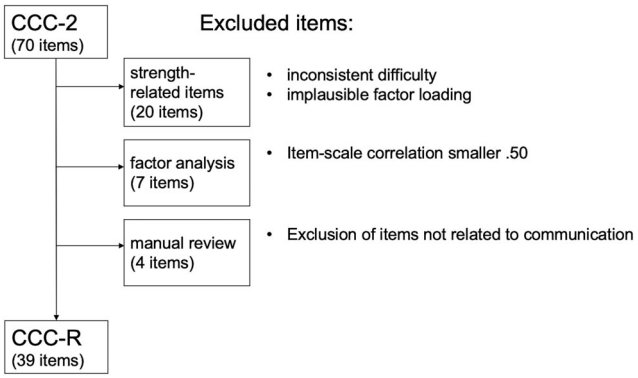

Figure 6. Revision process flowchart—from CCC-2 to CCC-R. *Note*. CCC-2 = Children's Communication Checklist-2; CCC-R = Children's Communication Checklist-Revised.

harmonized the difficulty of items and, thus, improved psychometric quality. The internal consistencies of the CCC-R (α = 0.96) and the two extracted factors (α = 0.96 and α = 0.93) were excellent and exceeded those of the original CCC-2 subscales [Bishop, 2003; Costa et al., 2013; Geurts & Embrechts, 2008; Glumbic & Brojcin, 2012; Helland et al., 2009; Vézina et al., 2013] which could be explained by improved scale consistency or the higher number of items per factor. Thus, sufficient reliability of the CCC-R and its subscales can be assumed.

Concerning the factor structure, the proposed 10-factor structure of the CCC-2 was untenable in a confirmatory factor analysis, despite the sufficient sample size [MacCallum et al., 1999]. Previous studies have reported a far lower number of CCC-2 factors, that is, a three-factor solution for the CCC-2 and a one-factor solution for the General Communication Composite sub-score (GCC) [Oi et al., 2017; Glumbic & Brojcin, 2012]. This is in line with our subsequent exploratory factor analysis on all CCC-2 items that indicated a two-factor solution that explained 48% of the variance. We also found a two-factor solution in our exploratory factor analysis on weakness-related items only. We labeled the resulting subscales "grammatical-semantic language" and "pragmatic language." This dissociation of the semantic-*versus*-pragmatic language is in line with previous exploratory factor analyses of the CCC-2 [Glumbic & Brojcin, 2012; Oi et al., 2017]. Grammatical-semantic language refers to general language skills, which are represented in the CCC-2 by the General Communication Composite (GCC). Pragmatic language indicates pragmatic difficulties, which are indirectly represented in the CCC-2 by the Social Interaction Deviance Composite (SIDC) as a discrepancy between pragmatic and general language skills.

The grammatical-semantic language subscale comprises 13 items and is composed of the original CCC-2 scales A to C (semantics, syntax and discourse). This may be applied to identify children with SLI and to distinguish them from children with pragmatic language impairments; which should be investigated in future studies.

The pragmatic language subscale comprises 26 items and is composed of the original CCC-2 scales D–J (coherence, inadequate initiation, stereotyped language, use of context, non-verbal communication, social relations, and interests). It may be used to identify children with pragmatic language impairment (PLI) and, thus, is comparable to the SIDC of the original CCC-2. However, the pragmatic language subscale differs significantly from the SIDC in the way it is calculated. The SIDC is a difference score that describes the relationship between the two linguistic areas. Thus, a child with both poor grammatical-semantic language ratings and poor pragmatic language ratings may receive a lower SIDC score compared to a child with good general communication ratings but with mediocre pragmatic language ratings, even though the child with the poor pragmatic language ratings probably has more severe pragmatic language impairments. This is indicated by findings in the ID group as the SIDC scores were lowest in this group (see Table 3). The CCC-R pragmatic language subscale provides direct information about the child's abilities in the field of pragmatic language and, thus, the scores were the lowest in the TD group. This may explain the increased ability of the CCC-R pragmatic language subscale, in comparison to the SIDC, to differentiate the clinical groups from the TD group and MHC group from all the other groups (see Table 6). This suggests that the CCC-R pragmatic language factor is more flexible in identifying pragmatic difficulties across different conditions and disorders. Thus, the pragmatic language subscale may further aid in identifying children with SPCD. This should be investigated by future studies that compare participants with SPCD to those with other mental health conditions.

The CCC-R total score, as well as the two subscales, sufficiently discriminated between the TD and clinical subgroups; this is comparable to previous findings using the CCC-2 [Helland et al., 2009; Norbury et al., 2004; Philofsky et al., 2007]. However, the CCC-R total score did not differ between the different clinical groups; this is also comparable to previous studies using the CCC-2 [Geurts & Embrechts, 2008; Norbury et al., 2004]. This could be explained by an overlap of general communication problems between clinical groups. Thus, the CCC-R total score might be suitable to identify children with communication problems as a continuous trait across disorders, but not to differentiate between clinical disorders.

In addition to the revisions discussed above, we excluded a further four items that were not related to communication but more to ASD-specific behavior. This was expected to increase the CCC-R specificity with regard to communication problems. However, the ROC curves showed that CCC-R neither differed from CCC-2 in distinguishing between autism and non-autism, nor between clinical samples and neurotypical controls.

Thus, the discriminative power of the CCC-R was comparable to the original CCC-2, despite a substantially lower item count. A notable exception was the grammatical-semantic subscale that showed impaired discriminative power compared to the GCC of the CCC-2.

Our results are limited as we lacked a sample with specific language disorders, such as SLI or SPCD, in addition to an independent screening measure of language problems needed to validate the CCC-R scorings. Future studies are invited to test the sensitivity and specificity of the CCC-R between pragmatic language impairments (PLI and SPCD) and ASD. In addition, an independent sample is required to confirm the proposed 2-factor structure. Another limitation of the study is the lack of diagnosis confirmation by clinical experts in the online recruitment arm and the overall lack of a cognitive ability measure. The CCC-R raw values were not scaled according to age, although an overall age dependent trend was observed. We argue that the unscaled raw values represent more comparable and interpretable scores, especially between diagnostic groups. Further validation is needed in an age stratified sample to investigate further the different CCC-R age trajectory of the ID subgroup. In addition, the original CCC-2 requires the participants to speak fluent sentences [Bishop, 2003] which cannot be assumed in a substantial proportion of the ASD participants and, thus, impairs its applicability. This limitation also applies to the CCC-R and needs to be considered in clinical applications.

Conclusion

The CCC-R was developed by shortening and simplifying the original CCC-2. This delivered excellent reliability and provided an empirically supported factor structure that relates to the composite scores (SIDC and GCC) of the original CCC-2. The revised questionnaire, despite a substantially lower number of items, was comparable to CCC-2 in its ability to differentiate between clinical samples and typically developing children. The CCC-R provides grammatical-semantic and pragmatic language subscales that further characterize language impairment profiles in clinical samples. In line with clinical phenotypes, we found the highest scores for grammatical-semantic language impairments in the ID group and for pragmatic language impairments in the ASD group (only significant relative to the MHC and TD groups). The CCC-R pragmatic language subscale provided increased discriminative power (AUC) compared to the SIDC, indicating an improved ability to detect pragmatic difficulties across conditions and disorders. The CCC-R is proposed, therefore, as a simplified-, easily applied, clinical questionnaire for caregivers to assess pragmatic language impairments across neurodevelopmental disorders and mental health conditions.

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Conflict of Interest

CMF currently receives research funding by the German Ministry of Science and Education (BMBF), the German Research Association (DFG) and the European Commission. She receives royalties for books on ASD, ADHD, and MHC. NB and HC receive royalties for lecturing at institutes for training in psychotherapy. The present work is unrelated to these relationships. The other authors declare no conflict of interest.

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Supporting Information

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

Appendix S1: Supporting information.