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Screening for Acquired Cognitive Impairment and Dementia in Deaf Users of German Sign Language: The Cognition Test German Sign Language

Lisa Stockleben[1,*], Bencie Woll[2], Joanna Atkinson[2]

[1]Department of Rehabilitation and Special Education, University of Cologne, Cologne, Germany
[2]Deafness Cognition and Language Research Centre, University College London, London, UK

*Corresponding author at: Department of Rehabilitation and Special Education, University of Cologne, Klosterstr. 79b, Cologne 50931, Germany.
Tel.: +49 221-470-8324.
E-mail address: lisa.stockleben@uni-koeln.de (L. Stockleben).

ABSTRACT

Objective: There is a lack of appropriate cognitive assessment tools to detect acquired cognitive impairment or dementia in deaf sign language users in Germany. To address this, the British Sign Language Cognitive Screening Test (BSL-CST) was culturally and linguistically adapted to German Sign Language and the German Deaf community, to be administered using a standardized video format.

Method: A comprehensive 15-step cultural test adaptation paradigm was applied, involving focus groups, clinical experts and members of the Deaf community. Norming data were collected for the newly adapted Cognition Test German Sign Language (KoDGS), resulting in a cognitively healthy sample ($n = 86$; age 50–92) and a sample of individuals with neurological history ($n = 13$).

Results: The KoDGS demonstrated robust test validity through convergent measures, sensitivity to age and education, and applicability across the heterogeneous German deaf population. Percentiles for the cognitively healthy sample were reported, and receiver operating characteristic curve analysis revealed high clinical reliability in distinguishing between the groups.

Conclusion: This study breaks new ground in the cross-linguistic and cross-cultural adaptation of dementia assessments in signed languages. The statistical reliability and clinical applicability of the test, along with the presented adaptation paradigm, provide a foundation for future adaptations of other cognitive assessments. As the first screening tool for cognitive impairment and dementia in deaf sign language users in Germany, the KoDGS has the potential to improve how deaf individuals are cognitively assessed for dementia.

Keywords: Dementia; Assessment; Test construction; Cross-cultural/minority; Alzheimer's disease; Sign Language; Deaf

INTRODUCTION

The present study introduces a novel culturally-adapted neurocognitive test designed for the early detection of dementia in deaf signers of German Sign Language (DGS – Deutsche Gebärdensprache) (note: when a capitalized "D" for "Deaf" is used, it refers to cultural entities like Deaf school or Deaf community. Small "d" is used otherwise, e.g., deaf signers, deaf population etc.). In addition, a comprehensive paradigm for adaptations of cognitive screening tools between two sign languages is proposed.

Cognitive Screening Tools

Neurocognitive screening is an initial step in assessing changes in cognitive functions as part of diagnostic work-up for dementia and neurodegenerative brain conditions. Commonly used tools for spoken languages include the Mini-Mental Status Exam (MMSE) (Folstein et al., 1975) and the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005). Another screening specifically developed for the German context is the DemTect (Kessler et al., 2000) which is used in German clinical assessments and in research. Besides the screenings, longer assessments like the Addenbrooke's Cognitive Examination-Revised (ACE-R) (Mioshi et al., 2006) can be applied and have been adapted into different languages and cultures (e.g., to Italian: Pigliautile et al., 2011; to Japanese: Dos Santos Kawata et al., 2012; to Arabic: Al-Salman, 2013). Spoken language adaptations from English to German include the German versions of the ACE-R (Alexopoulos et al., 2010) and MoCA (Thomann et al., 2018). All of these tests employ spoken language instructions, listening tasks, and rely on the tested individual to process and communicate in a spoken language—whether it is English, Hindi, or German—with norms for the general hearing population using those languages.

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Cognitive Screening Tools to Assess Hard-of-Hearing Individuals

In recent years, there has been a growing focus on adapting cognitive screening tests to better suit diverse populations. For instance, the DemTect test has been adapted for use with German-speaking individuals who are hard of hearing or have vision limitations (Brünecke et al., 2018). Other recent adaptations in the German context encompass the O-Dem (Ballasch et al., 2023) and the German MoCA-HI (Völter et al., 2023), which have been adapted to accommodate hard-of-hearing individuals, modifying the test to be more visual in its administration. The cross-cultural comparison of test adaptations of the MoCA-HI (Theocharous et al., 2024) represents a further step in the adaptation of tests for people with limited hearing who use spoken language for communication. While the adapted and validated German MoCA-HI (Völter et al., 2023) has been demonstrated to be sensitive and specific for hard-of-hearing individuals, signers of DGS were not included in the norming process (Brünecke et al., 2018; Völter et al., 2023). The German MoCA-HI is not a sign language-based tool, and deaf individuals rely on assessment in their local sign language for reliable testing. In general, adaptations of existing tests for use with the deaf signing population remain scarce. Deaf individuals who sign are often underrepresented in research studies and underserved with regard to cognitive screenings for an adequate diagnostic procedure (Atkinson et al., 2015; Denmark et al., 2016; Kaul et al., 2009).

Social and Linguistic Factors of the Deaf Population

Deaf communities constitute linguistic and cultural minorities, using sign languages to ensure full participation in society. For most deaf signers, sign language is preferred over spoken language, as deaf individuals face significant challenges in processing auditory input and speech. However, the majority of deaf individuals are born and raised in environments where hearing and speaking are the dominant modes of communication. Approximately 92% of deaf children are born into hearing families (Mitchell & Karchmer, 2004), which limits their exposure to language (spoken and signed) in early life. Reduced access to the phonology and morphology of spoken language makes its acquisition and the development of literacy challenging (Goldin-Meadow & Mayberry, 2001; Mayberry et al., 2010). For our study, broad outreach and liberal recruitment criteria have yielded a diverse database. The sample of deaf older adults from the Deaf community included in the study exhibited a representative range of communication modalities, including deaf individuals who acquired sign language from birth (native signers) and deaf individuals who acquired sign language after the age of six (non-native signers) or even later in life (late-learners).

Effects of Oralist Education

The extensive variety of communication modes can be attributed to the historical practice of oral education in Deaf schools in Germany—as in many countries (Ladd, 2003)—which compelled deaf individuals to practice speech articulation and lip reading and forbade the use of sign language (Löwe, 1983). As a consequence of this educational approach, which was prevalent until the 1980s and 1990s in Germany, fingerspelling is an infrequently utilized method among deaf signers over the age of 65 (Kaul et al., 2009). In particular, within the former German Democratic Republic (GDR), East Germany, the practice of fingerspelling was virtually non-existent. As a result, fingerspelling of DGS is challenging for many older deaf individuals in Germany to perceive or produce. Acquiring a first language during their formative years was significantly challenging, particularly for those who were raised in hearing families, because of the limited exposure to deaf individuals and sign language (Kaul et al., 2009; Mayberry et al., 2002). The acquisition of sign language for this population took place through interactions with other deaf children at school who signed with each other. This limited context for language acquisition has resulted in many deaf individuals acquiring their first (and potentially only) language late, possibly impacting other areas of cognitive development (Cormier et al., 2012; Mayberry, 2002).

Challenges with Written Language

Administering a written test to a deaf signer can be both unreliable and potentially invalid (Kaul et al., 2009). Sign languages, such as DGS, are unrelated to spoken languages like German, which presents significant challenges for deaf individuals in acquiring and processing written forms of spoken languages (Fellinger et al., 2012; Traxler, 2000). As a result, many deaf individuals—especially those with poor literacy skills—demonstrate lesser written language proficiency compared to the hearing population (Musselman & Szanto, 1998). Written tests may not capture the true abilities of a deaf person due to the linguistic mismatch between sign language and written/spoken language, as well as differences in overall language exposure.

For a deaf person with limited literacy, using a written screening test leads to unreliable results. Factors such as language competence, limited exposure to written language, and discomfort with the test format (which may feel unsuitable for a deaf sign language user) can distort the outcomes and fail to measure the intended construct (Harris et al., 2021). Therefore, it is crucial to use sign language as the modality for test administration. Screening should not rely on spoken or written language but instead use sign language to ensure the assessment is linguistically and culturally appropriate (Denmark & Atkinson, 2015). This approach guarantees more valid and accurate diagnostic results when testing the cognitive functions of deaf signers (Atkinson et al., 2015; Hall et al., 2017).

Test Adaptations

Adaptation of existing tests is a common practice in providing assessments to a variety of populations, and various steps have been identified as useful and necessary for maintaining equivalence. In many instances, the only step preceding piloting an adapted test with the target population is translating and back translating the original test (e.g., Albanna et al., 2017 or Caldas et al., 2012).

However, a systematic review of ACE, ACE-R, and ACE-III identified seven steps of cultural adaptation procedures (Mirza et al., 2017). These steps, which have been applied to varying extents across multiple studies, include translation, back translation, co-production with users, expert recommendations, revision based on step-by-step feedback, involvement of the original author, and pilot studies. Mirza et al. (2017) provide a comprehensive list of studies that have utilized these steps, although it is notable that none of the studies reviewed adhered to the entirety of the prescribed steps in a single adaptation.

The foundation for adaptations is the translation and back-translation of the original test. These are then evaluated and revised by a chosen committee of experts, and this process has been shown to be highly valuable for many adaptations with diverse populations (Al-Salman, 2013; Dos Santos Kawata et al., 2012; Pigliautile et al., 2011). In the case of populations with a limited number of language users, individuals dispersed across a country, and a high degree of linguistic diversity, additional considerations must be taken into account.

Adaptations of Sign Language Assessment

Haug (2012) proposed an adaptation model for sign language tests designed to assess language competence. This adaptation model emphasized important considerations related to sign languages and the deaf population. These include precise monitoring of the process by expert panels and sign language linguists, as well as the application of culturally appropriate test materials.

Representing a small and heterogeneous population and validating the test instrument accordingly has been shown to be challenging in studies including deaf populations (Haug & Mann, 2007; Mann et al., 2013; Haug, 2012). To facilitate equivalence between test items during adaptation and a general good fit with a population, an increasing number of researchers in recent years have recognized the value of engaging stakeholders and including Deaf community members as co-researchers in the research process. To build upon models of participation (Arnstein, 1969), incorporating stakeholders into the decision-making process enhances their sense of self-determination and fosters greater acceptance of the tool and the decisions taken in its development, thereby amplifying the impact of the final outcome (Ackermann & Schubotz, 2020; Rojas-Rozo et al., 2024).

In this study, we employed a participatory (including members of the Deaf community in the research process) and transdisciplinary (including clinicians with expertise in cognitive assessment of deaf people) research approach to ensure the maintenance of the quality of the diagnostic screening tool during the adaptation process. Due to the limited numbers of deaf signers with advanced research qualifications, the inclusion of individuals with a lived experience of deafness is important and part of building capacity in the field, Throughout the adaptation phase, co-researchers, encompassing cognitive screen stakeholders, who were clinical psychologists, neurologists, and psychiatrists with expertise in psychometrics (some of them deaf themselves), as well as Deaf community members who work as professional caregivers, social workers, and consultants to deaf seniors—were engaged in the decision-making process. Regular meetings with test adaptation experts strengthened the process. A process going beyond mere translation (Dean et al., 2009) and which considered good practice recommendations in the field (Denmark & Atkinson, 2015) resulted in the comprehensive adaptation paradigm which is illustrated in Table 1 below.

Cognitive Screening for Deaf Signers

An attempt to translate a standard cognitive screening such as the MMSE into American Sign Language (ASL) (Dean et al., 2009) revealed scores for cognitively healthy deaf individuals below the clinical MMSE cutoff ($M = 25.9$, $SD = 3.5$, range 7–30) despite the high educational level of the study sample. The study demonstrated that a translated screening tool like the MMSE is inappropriate and will result in invalid and unreliable diagnoses. Dean et al. (2009) recognized that cultural and linguistic factors, rather than cognitive impairment, were the primary factors influencing the results. However, it seems that there is an unknown extent of unknown cognitive impairment among deaf signers as well. Atkinson et al. (2015) found a high rate of hidden cognitive impairment in the British Deaf community, even in a study that screened out neurological conditions. This emphasizes the need for neurocognitive assessment tools that consider linguistic as well as cultural features in assessing the deaf population appropriately and staying carefully aware of possible unknown cognitive impairment beyond diagnosed neurological conditions. Hill-Briggs et al. (2007) demonstrate factors for consideration for clinicians when choosing and conducting a cognitive assessment with this population. Besides the etiology of deafness, access to language, cultural socialization, and the educational setting are essential to choose a tool for reliable and valid testing. Using a general screening tool with sign language interpreters also puts reliability and validity at risk, which emphasizes the need for training of both interpreters and clinicians in relation to the assessment of deaf people. The essential requirements for valid and reliable cognitive testing in individuals for whom a sign language is the preferred language were outlined by British researchers Atkinson et al. (2015), who developed the pioneering sign language-based cognitive screening instrument, the British Sign Language Cognitive Screening Test (BSL-CST), to detect cognitive impairment and dementia in deaf signers. The BSL-CST is structured similarly to the ACE-R (Mioshi et al., 2006). Items from the MoCA (Nasreddine et al., 2005) were incorporated in the design of the BSL-CST, as well as novel items which were culturally and linguistically tailored for BSL. The BSL-CST was developed using British Sign Language (BSL) as the only language of administration and incorporates cultural references that are familiar to the Deaf community in the UK. Age norms are provided based on a sample of 226 signers aged 50–89 years. The validated test is routinely used in clinical settings with deaf patients in the United Kingdom. It is an evidence-based instrument with good test–retest reliability, which makes it highly amenable to adaptation into other sign languages and within different Deaf cultural contexts (Atkinson et al., 2015).

No dementia screening tool is currently available for deaf individuals in Germany who use DGS. As a result, clinicians conducting neurocognitive examinations of deaf individuals lack a standardized screening tool, which may lead to an overreliance on spoken language tests like the MMSE (Folstein et al., 1975) and DemTect (Kessler et al., 2000), false test results and their interpretation (Kaul et al., 2009); alternatively, screening tests are not used at all. Current clinical practice for assessing dementia in deaf individuals in Germany lacks access to valid, reliable, and objective cognitive tests.

Table 1. Adaption steps with details about action steps, applied modifications, challenges, research approach, and recommendations for future adaptions

#	Adaptation step	Action step	Applied modifications	Challenges	Research approach		Recommendations for future adaptations
					Participatory	Transdiciplinary	x
1	Foundation	Setting the ground for a collaborative adaptation. Considering the matters around exchange of scientific materials and copyright in a transnational context.	–	Institutions may have different approaches to collaborative exchange of scientific materials	–	–	Trustful and open communication helps to follow good scientific practice—acknowledging the original test developer. Including the original test developers with their expertise into the process.
2	Translation	Translation BSL to DGS: by two deaf BSL-DGS bilingual signers (1 professional interpreter, 1 highly proficient bilingual): video format and remote live translations	A first ("raw") translation into DGS	Qualified BSL-DGS interpreters are rare	X	–	If qualified interpreters are hard to get, a highly proficient bilingual signer of the two sign languages is the next best fit.
3	Consultation	The translation into DGS was watched by two deaf signers (one of them bilingual DGS and Auslan signer which is closely related to BSL) and discussed. Alternatives were suggested when regional variants were used by the translators/interpreters. Regional variation was (back-)checked against the open-access DGS-Corpus data.	Removal of regional variants where possible	DGS has high regional variation in signs for days of the week and months	X	–	Look for corpus-based data/natural language data to check for regional variation. Be aware of higher variation for signs, for example, days of the week, months, and colors.
4	Translation	Translation of the manual from English to German by the first author.	–	–	–	–	–
5	Translation and Back-translation	German-DGS-German translation: Two deaf DGS signers (one of them a deaf translator) cross-translated (one German to DGS, the other DGS-German) - > changes were made accordingly	Linguistic changes to the item instructions	Agreeing on a sentence/syntactic form when DGS syntax allows flexibility	X	–	Discussion with deaf signers and deaf interpreters
6	Focus group: Participation of deaf people with age-related background /the deaf perspective	Four tasks were discussed by a focus group of deaf people including health care professionals, social workers, representatives of the association of the deaf and representatives of the Deaf older adults' association	Cultural and age-specific language adjustment	To provide an inclusive and understandable transfer of what the cognitive test assesses and what limitations there are	X	X	Thoughtful selection of the focus group participants with topic-specific background facilitates a valuable contribution to the cultural modifications and practice-based adjustments.
7	Clinical focus group: Participation of sign fluent German clinicians.	Novel item considered due to possible less use of fingerspelling in Germany: the digit span test (from DemTect)	This item was added to the tasks assessing "attention". Cultural and clinical practice-based adjustment	Finding the time to meet in a full clinical schedule.	X	X	Regular meetings with clinicians over the adaptation process increased clinical applicability and are recommended.
8	Ongoing consultation with original test developers	Results of the focus groups were discussed with the original BSL-CS test developers, and changes were formulated	Results from focus groups were discussed and evaluated/ validated in relation to clinical practice in the United Kingdom	Intercultural exchange about the degree of modifications (a) to the cognitive assessment, (b) due to differences between deaf culture within Germany and the United Kingdom	–	–	An ongoing conversation about the adaptation process provides valuable guidance to ensure test integrity.

(continued)

Table 1. Continued.

#	Adaptation step	Action step	Applied modifications	Challenges	Research approach		Recommendations for future adaptations
					Participa-tory	Trans-diciplinary	x
9	Psycholinguistic norming of the language items	The DGS study results showed ratings for iconicity, frequency and AoA. A list of signs with low iconicity, low and medium frequency and early AoA was selected for test items.	All language items of the KoDGS were selected based on the study results	Normative DGS language data was not available hence needed. An additional psycholinguistic study was therefore conducted.	X	–	Psycholinguistic norms are a key component to valid test development. To base the selection of language items on norms helps to control for possible measuring construct errors.
10	Test video recording	A deaf senior health (care) professional was contacted to be the test instructor in the video. She had more than twenty years of experience in deaf older care and a lived deaf experience of the differences between former East and West Germany. She was aware of the diverse communicative needs of deaf older adults, including clear mouthing/mouth patterns, and pace of signing. The pre-prototype version was filmed.	–	The person selected was not a professional deaf interpreter, and was not used to sign in front of the camera. The process required sensitive and encouraging communication.	X	X	Adaptation requires sufficient time investment to do well and to create an ecologically valid instrument.
11	Pretest	A prototype was presented to the clinical focus group meetings.	Increase in clinical acceptance and real-world applicability. Clinical practice-based adjustments	One standardized assessment is needed that can be used with a heterogeneous older deaf German signing population	–	–	A careful and iterative proceeding in adapting step by step with a high degree of stakeholder involvement proved to raise clinical as well as community acceptance.
12	Prototyping and pilot	A prototype was developed, including all the results of the above. The prototype was tested with five deaf older adults in cognitive interviews. BSL-CS test developers suggested a practice-based modification.	One item was changed based on clinical practice experience with the BSL-CST. A second item (Fingerspelling a name backward) the name was changed due to the same error pattern among the five healthy pilot participants.		X		The iterative process supports ongoing modifications and flexibility, enabling small but necessary adjustments. It requires a large degree of flexibility of the researchers and test instructor.
13	Second recording	The same test instructor signed the modified KoDGS instructions.	Clinical practice-based adjustments	see above 10	X	X	Having a written signed agreement about the extent of the collaboration, e.g., two recording sessions, rights and payment was useful.
14	Norming study	Normative data were collected ($n = 86$; neurological sample $n = 13$).	–	Collecting data Germany-wide/nation-wide for a sample as representative as possible.	–	–	The decision was made to collect data from all parts of the country to reduce bias. Financial, time and human resources have to be considered generously in order to obtain a sufficiently diverse sample.
15	Publication	Making the KoDGS available for research and clinical contexts.	–	–	–	–	To follow good scientific practice, and collaborative publication with the original test developers is recommended.

The present study describes the adaptation of the BSL-CST to the German Deaf cultural context and to DGS. We present the KoDGS (Cognition Test German Sign Language, or Kognitionstest Deutsche Gebärdensprache), as the first German cognitive screening test designed and calibrated for deaf individuals who sign DGS. Furthermore, we present our cultural and sign language adaptation model (Table 1) as an example of participatory and transdisciplinary research.

MATERIALS AND METHODS

Format of the KoDGS

The KoDGS, like the BSL-CST, assesses a range of seven cognitive domains, including memory, attention, orientation, language, visual–spatial abilities and perception, verbal fluency, and executive functions. The language of the instructions is DGS. The entire test is conducted in a standardized video format on a laptop or computer and typically takes between 30 and 45 min to complete as part of a comprehensive clinical neurocognitive assessment in a clinic or specialized medical practice that includes an estimate of premorbid cognition function based on history and demographic factors such as independent living, educational attainment, and occupation. The test administrator is present throughout the testing process to ensure accurate screening procedures. All responses are recorded on video for subsequent re-scoring, in addition to real-time documentation of the responses and observations made on the score sheet by the investigator. In the event that the investigator lacks competence in sign language, a DGS interpreter is present to facilitate general interaction and to clarify instructions that may not be readily comprehensible to the subject.

Adaptation Design

The entire adaptation was structured in 15 steps and is displayed in detail with action steps, applied modifications, challenges, the research approach, and recommendations for future adaptations in Table 1. Several of the steps where issues arose during adaptation will be discussed in detail below.

Adapted Items—Adaptation Steps

All items underwent a process of examination to ascertain whether cultural divergences between the source (British) and the target (German) sign languages would necessitate further adaptation.

Adaptation step #6—Focus group: In a focus group with a group of deaf signers from the areas of professional care, dementia services, social services, and representatives of the German Deaf Association for the needs of deaf older people from various regions of Germany, four items were identified as exhibiting cultural differences from those observed in British Deaf culture. To assess orientation (KoDGS items 1 and 2), the BSL-CST requests the name of the building at the precise location where the test is being conducted. In the German context, however, this is not appropriate. Buildings in Germany are not named; instead, they are numbered. Asking for the specific address with the correct building number was considered challenging even for a cognitively healthy population. The focus group agreed that a general question, "THIS BUILDING IS WHAT OR WHERE"? would allow respondents to name a hospital, a doctor's office, or a similar response while still assessing their ability to orient themselves in a particular location.

Additionally, the BSL-CST assesses working memory and attention through several tasks using fingerspelled letters and words (KoDGS items 3 and 4). The focus group generated a short list of names that are commonly used in Germany among individuals aged 60 and above (used for KoDGS item 10 as well). While the fingerspelled items could be translated, a significant cultural discrepancy between British and German older signers in terms of fingerspelling skills and use became apparent. Considering this, the focus group proposed that no fingerspelled items should be utilized for the DGS version and that a forward and backward digit span item would be a preferable alternative to screen working memory and attention.

Adaptation step #7, #8, and #11—Clinical expert panel and test developer consultations: The original BSL-CST test developers and a clinical focus group comprising practicing doctors, psychiatrists, and clinical psychologists from special clinics in Germany with expertise in the field of deafness were consulted over the period of the test adaptation. Following these discussions, in addition to the translated fingerspelled item, a digit span test was incorporated (KoDGS item 5) to facilitate a comparative analysis. Furthermore, the focus group confirmed that the Deaf school in Leipzig is the most well-known among older generations in Germany, so it was included in the fictitious profile of a deaf man to screen immediate memory recall (KoDGS item 10).

Accurate assessment of memory for past events (KoDGS item 13) is contingent upon an individual's world knowledge and asking about collectively experienced events that are specific to the German and Deaf cultural context. The focus group (in adaptation step #6) had engaged in a discussion of the disparate German Deaf cultures that existed in the former East Germany (GDR) and West Germany. The Berlin Wall constituted a significant barrier to the dissemination of political and societal news (Werner, 2024), resulting in a considerable deficit of shared cultural knowledge between individuals residing on either side. It is noteworthy that renowned deaf individuals from the 1960s, 1970s, and 1980s were not generally known in the other German state. However, the one memory they all share is the fall of the Berlin Wall in 1989, which was therefore selected as a test item. Additionally, Helmut Kohl, the Chancellor of the newly unified Germany, was attacked in 1991 when he first visited regions of former East Germany. This event was perceived as widely known by the majority of individuals across Germany. The victory of the German national football team in the 1990 FIFA World Cup was a pivotal moment in German collective memory. Consequently, it was included as a test item, which requested the name of one of the players or the coach. During piloting of the KoDGS, it was confirmed that there were few historical events that both former East Germans and West Germans could recall equally well. The fifth question was added to provide a cushion due to the challenging nature of the task, with scores as best of 4 out of 5 questions. Recalling the name of the German chancellor, the first woman chancellor and the fall of the Berlin Wall were reliable items, but the other questions relied on knowledge about politics and sport so the scoring system was designed to reduce the variability in normative responding. The mean response out of 4 was 4.4 (SD = 0.7).

Adaptation step #8—Original test developer consultation: In regular consultations with the original BSL-CST test developers, minor modifications to the initial test were proposed based on the accumulated expertise in the clinical application of the BSL-CST. These suggestions were incorporated into the KoDGS. The instructions for the DGS language comprehension item (KoDGS item 15), which call for the left hand to take a paper sheet, differ from the original BSL-CST instructions, which call for the right hand to take the sheet. This recommendation was made on the basis that the majority of people use their right hand as their dominant hand and might therefore score correctly without consciously processing the signed instruction.

With regard to DGS production (KoDGS item 16), a comparable photograph to that use in the BSL assessment, featuring a man and a woman in a kitchen, was selected, and the rights to use this image were obtained. This item was scored according to whether two nouns and two verbs were produced in a coherent DGS sentence. The task instructions were translated without any cultural modifications.

Adaptation step #9—Psycholinguistic norming of language items: An important step in the adaptation was to control for psycholinguistic features of the test items, including: (a) sign frequency; (b) typical age of acquisition in native signers who learned to sign from their deaf parents and in non-native signers who typically learned from deaf peers or teachers; and (c) sign iconicity, which refers to the relationship between form and meaning in language (Perniss et al., 2010). In a separate study, the first author of this paper and colleagues collected data from DGS signers who rated over 350 signs in accordance with these criteria. The study design was comparable to that of the BSL psycholinguistic rating study (Vinson et al., 2008), which was used to select language items for the BSL-CST. These DGS ratings informed sign selection for the KoDGS. Furthermore, DGS corpus data (see https://www.sign-lang.uni-hamburg.de/dgs-korpus/index_en.html) were examined to establish whether regional variability existed among the selected signs, and signs with extensive variation were eliminated (see Langer (2012, 2018) for work on regional variation based on the DGS Corpus). In general, the criteria employed for inclusion were consistent with those utilized in the BSL-CST, namely, low regional variability, low to medium iconicity, and medium frequency, where necessary for the tested cognitive domain.

The careful selection of items based on psychometric properties was particularly important with regard to the memory task for immediate and delayed recall (KoDGS items 8 and 9). In the BSL version of the test, the individual is required to recall three signs: "*BALL*," "*TREE*," and "*PEN*" (upper case represents signs of DGS, while upper case in italics stands for BSL signs). The DGS corpus data indicated that there was low regional variability between these signs. However, *TREE* was replaced by FLOWER based on the aforementioned criteria of low to medium sign frequency to assess memory recall. The criteria low to medium sign iconicity and frequency were applied to the object naming task (KoDGS item 18), which involved CANDLE and CAMERA (replacing *STRAW* and kept *CANDLE*, as used in the BSL-CST). This was to ensure that a gesture was not mistaken for the correct answer. For the picture naming task (KoDGS item 19), the words used for the pictures were selected according to the same criteria in order to prevent the test person from easily guessing the correct answer if the sign was highly iconic or similar to a gesture. The greater the perceived iconicity of a sign, the more likely it is that the meaning can be guessed by someone who does not know the sign (Vinson et al., 2008). To guarantee the reliability of the items, the selected signs and picture equivalents were chosen to be relatively non-iconic and infrequent. The recognition task (KoDGS item 20) for the DGS language comprehension questions was modified according to the images presented. Seven items were selected, and five of these exhibited high scores in the normative sample. The other two items were removed because they elicited false answers and were shown not to be reliable with healthy signers. The KoDGS domains and all items with details about the translation, adaptation, or development of novel items are presented in Table 2.

Test Material Development

Adaptation step #10 and #13—Test video recording and re-recording: The filming was conducted in collaboration with a deaf co-researcher and a hearing linguist fluent in DGS. In order to ensure suitability for use across Germany, we attempted to avoid signs which show regional variation. This was achieved by cross-checking for any regional lexical variants with the published DGS Corpus (Konrad et al., 2020). Given the considerable heterogeneity of the population of deaf signers, the test instructor signed in DGS with both clear manual signs and clear grammatical DGS coherent mouth movements to ensure accessibility even to individuals who prefer more German-influenced signing.

Adaptation step #10—Prototyping and Pilot: Piloting showed that it was well understood by all deaf signers. Throughout the test adaptation into DGS, community experts were consulted to ensure the use of culturally sensitive and older age-appropriate DGS.

Procedure

The first author (95.05%) and a second investigator (4.95%) collaborated in the collection of the normative data. The responses recorded on video were subsequently verified and evaluated by the first author. A second DGS fluent rater evaluated 9.9% of the sample to assess inter-rater reliability. All testing and evaluation were done in DGS without interpreters.

Ethics

The study was ethically approved by the Ethical Committee at the Faculty of Human Sciences at the University of Cologne (Number: LSHF0161) in accordance with the guidelines set forth in the Declaration of Helsinki. All participants provided informed consent in accordance with the Declaration of Helsinki, after both the information and the consent form were explained in DGS.

Participants

The data set comprised the responses of 99 participants, of whom 58 were female (58.59%), and 41 were male (41.41%). In order to ensure the inclusion of a hitherto unrepresented demographic, we were committed to reaching out to members of the Deaf community in Germany who typically do not

Table 2. KoDGS domains and items and details about translated, adapted and novel items

Domain	Item number	KoDGS items (*added or changed items in italics*)	Adaptation degree	Modifications/justification	Score
Orientation	1	Orientation to time: week day, date, month, year, season	Translation	No modification	5
	2	Orientation to place: country, *federal state*, town, *institution*, floor	Adaptation	Federal state was added based on the results from the focus group and because of the strong federal system in Germany. The item "institution" was used instead of "name of the building," which is unusual in Germany: so "this building is what or where."	4
Attention	3	Fingerspell T-A-U-B (German for "deaf") backward	Translation	No modification	4
	4	Fingerspell the name *H-E-L-G-A* backward	Adaptation	A common name in the age group over 50 in former East and West Germany	5
	5	*Digit Span: four, five, and six digits backward*	Novel	Fingerspelling is uncommon among older adults in Germany and has rarely been used in former East Germany at all.	4 + 5 + 6 = 15
	6	Tapping task: tap the table when you see the fingerspelled letter "A"	Translation	No modification	1
	7	Months of the year backward	Translation	No modification	1
Memory	8	Memory immediate recall: BALL, *FLOWER*, PEN	Adaptation	Signs were changed to DGS signs with low regional variability and low frequency.	3
	9	Memory delayed recall		No modifications	3
	10	Anterograde memory: Learning information about a fictitious deaf man (*name, age, wife's name, where lives, and school attended*)	Adaptation	Stimuli were adapted for common German older names, city and commonly known deaf schools	
		Immediate recall (after third trial)			6
	11	Delayed recall			6
	12	Recognition			5
	13	Retrograde memory: *Name of current German chancellor, Name of first woman German chancellor, Historic event of reunion of former East and West Germany, German chancellor who was attacked in 1990s, Footballer or coach of the German football world champion in 1990*	Adaptation	The items were modified to questions about historic German events and figures. Due to German history from the 1950s to late 80s, the shared German deaf collective memory of events and figures is limited.	4
Verbal fluency	14	Semantic sign fluency for animals within one minute	Translation	No modification	7
Language	15	Language comprehension: DGS three-stage command: "Take the paper in your *left* hand. Fold in half. Put the paper on your lap."	Adaptation	The right hand is the major dominant hand and might be used unconsciously. Left hand for assessing a conscious comprehension of the signed video instruction.	3
	16	Language production: DGS sentence production: "Look at the picture. There are two people; tell me what they are doing"? Response must contain: two nouns, two verbs and be a coherent sentence	Translation	No modification	5
	17	DGS sentence repetition: Two sentences reproduction	Adaptation	Signs were checked for iconicity, frequency, and regional variability. Flexible DGS syntax/grammar is allowed/considered.	15
	18	Object naming: *CANDLE, CAMERA*	Adaptation	Signs were changed to low-frequency DGS signs.	2
	19	Picture naming:	Adaptation	Signs were changed to DGS signs with low frequency and iconicity.	9
	20	Language comprehension questions: recognition	Adaptation	Novel questions about the adapted picture naming items.	5
Visuospatial	21	Copy overlapping pentagons	Translation	No modification	1
	22	Copy wire cube	Translation	No modification	2
	23	Perceptual abilities: Count the dots	Translation	No modification	4
	24	Perceptual abilities: Identify degraded letters	Translation	No modification	4

(continued)

Table 2. Continued.

Domain	Item number	KoDGS items (*added or changed items in italics*)	Adaptation degree	Modifications/justification	Score
Executive function	25	Clock drawing: "Draw a clock with numbers and hands to show the time at 1:45"	Translation	No modification	5
	26	Alternating trails: Draw a line alternating between numbers and letters	Translation	No modification	1
				Total KoDGS Score	**110**
				Orientation	9
				Attention	11
				Memory	27
				Verbal fluency	7
				Language	39
				Visuospatial and perception	11
				Executive function	6

participate in research projects pertaining to sign language and deafness. This was driven by recent discourse and studies about populations that are challenging to reach and their underrepresentation in research, research-based practice recommendations, and guidelines. If research studies are limited to participants who are easily accessible, a significant bias is created in the perception of the population (see Etti et al., 2021; Gottesman & Hamilton, 2021; Pichler et al., 2018). Accordingly, considerable effort was made to ensure the inclusion of deaf individuals from all regions of Germany and from various socioeconomic backgrounds, representing a diverse range of demographic characteristics by using community channels. First, we reached out to all deaf-related associations that we were aware of in all 16 German federal states, including religious associations of the deaf and clubs of deaf older adults, to find possible gatekeepers for recruitment. Several people then contacted us asking for more information about the study. In these ways, our gatekeepers provided intensive support for local recruitment, invited us to their region and facilitated local testing. On some occasions, we were invited to open community meetings and deaf older adults were informed about the opportunity to participate in our study. Another recruitment strategy was to inform the general Deaf community through an open invitation to participate in the study. The research endeavor in general and the recruitment in particular were supported by the German Deaf Association. By means of gatekeepers enabling local in-person meeting opportunities, and reaching out through common social media platforms and newsletters, we were able to collect data from a diverse range of the heterogeneous deaf population. The participants were aged between 50 and 96 years ($M = 64.3$), were sign language users and self-identified as deaf. Individuals from various educational and socioeconomic backgrounds were included, with varying degrees of vision impairment (ranging from the use of reading glasses to the presence of Usher syndrome [deafness + Retinitis Pigmentosa]), and with self-reported DGS skills ranging from low to high proficiency. The common communication factor among them was their preference for sign language-based communication.

Prior to the administration of the test, a screening interview was conducted with each participant to obtain data regarding their general health status and personal sociodemographic background. Due to the absence of tests which are designed and normed for the population of deaf signers of DGS, self-reports were used during the development of the assessment. Some variables were not answered or documented by the investigator when the participant was undecided or irritated why that question was necessary, which resulted in missing data, as displayed in Table 3. Among the participants, the age of DGS acquisition was a mean of 7.6 years (range 0–50 years; SD = 8.2). The sample has an overall mean of 13.2 years of education (range 4–22 years; SD = 2.9).

Following a comprehensive examination of the sociodemographic characteristics and history of neurological health of each case, the sample was split into two groups. Thirteen participants were identified as unsuitable for the normative sample in accordance with the following exclusion criteria with some persons having reported more than one condition: neurological conditions such as schizophrenia (1), epilepsy (3), multiple sclerosis (1), stroke (1), as well as a history of substantial alcoholism with related everyday adaptive dysfunction (2), and a lifetime spent in a deaf residential home (3), major depression (2), a history of cognitive impairment at age below 70 (2), and very high age (1). Their data showed an age mean $M = 72.5$ years, range 56–96, SD = 11; female = 10, male = 3. These 13 individuals comprised a group of individuals who self-reported a neurological condition, which we added as a sample of people with a neurological history or indicative life profile (e.g., life in a deaf residential home or alcoholism [PwNH]) for comparison with cognitively healthy people (CHP). Participants were classified as either cognitively healthy (reporting no history of neurological conditions) or as neurologically affected (reporting at least one non-age-related neurological condition, such as multiple sclerosis, epilepsy, or depression). This binary group membership, based on self-reported neurological status, was the outcome variable for the ROC analysis.

Detailed demographic characteristics of the normative sample CHP ($n = 86$) aged 50 to 92 and a selection of demographic variables of the PwNH ($n = 13$) appropriate to the small sample size, are presented in Table 3.

Table 3. Demographic variables of cognitively healthy sample (CHP) and sample of people with neurological history (PwNH)

CHP sample						**PwNH sample**				
Variable		***n***	**%**	**KoDGS Mean**	**Score SD**	**Variable**	***n***	**%**	**KoDGS Mean**	**Score SD**
TOTAL		86	100	100.4	6.4	**TOTAL**	13	100	69.2	14.7
Age groups	50–59	32	37.2	105	3.7	**Age groups**	2	15.4	61.5	9.5
n = 86	60–69	36	41.9	98.4	6.3	*n* = 13	2	15.4	73.5	17.5
	70–79	14	16.3	98.1	4.9		5	38.5	72.8	8.5
	80+	4	4.7	90.3	2.9		4	30.8	66.3	2.9
Sex	Female	48	55.8	100.2	6.8	**Sex**	10	76.9	67.9	3.8
n = 86	Male	38	44.2	100.7	5.9	*n* = 13	3	23.1	73.3	14.2
Age of acquisition (DGS)	Native	17	19.8	102.8	5.1	**Age of acquisition (DGS)**	1	7.7	61*	NA
	>0/<6	24	27.9	101	5.4		0	0	NA	NA
n = 86	6+	45	52.3	99.3	7.1	*n* = 13	12	92.3	69.8	4.4
Years of education	6–10.5 years	6	7.1	93.7	8	**Years of education**	7	53.8	63.7	3.3
	11–12.5 years	27	32.1	98.3	5.9		4	30.8	73.8	10.6
n = 84	13–14.5 years	27	32.1	100.7	5.8	*n* = 13	2	15.4	79	12
	15–17.5 years	17	20.2	103.8	5.7		0	0	NA	NA
	> = 18 years	7	8.3	104.3	4.8		0	0	NA	NA
Relatives	Hearing	19	22.6	99.5	5.8					
n = 84	Deaf parent and/or sibling	16	19	100.4	5.2					
	Deaf partner and/or child	34	40.5	99.7	7.4					
	Deaf parents/siblings AND partner/child	15	17.9	102.9	5.8					
School type	Deaf school	54	65.1	100.4	6.1					
n = 83	Hard-of-hearing school	15	18.1	101.9	6.3					
	Mainstream school	6	7.2	97.2	8.3					
	Mixed-change of schools	8	9.6	99.5	7.9					
Highest educational degree	Junior high school	2	2.3	97	14.1					
	GCSD/GED	3	3.5	100	3					
	Apprenticeship/voca-tional training	66	76.7	100.4	5.9					
n = 81	University/studies	10	11.6	103	6.4					
Region	North	14	20.3	102.9	5.2					
n = 69	East	7	10.1	96.7	6.2					
	South	15	21.7	98.4	7					
	West	27	39.1	101.3	6.8					
	Mix	6	8.7	104.3	3.8					

*Raw single value.

Measures

In addition to the KoDGS tests, MMSE (Folstein et al., 1975) and MoCA (Nasreddine et al., 2005) scores were collected from all participants as measures of content validity. The KoDGS includes items that are similar to those from the MMSE (29 out of 30) and MoCA (21 out of 24); thus, these tests were utilized as convergent measures for overall cognitive performance due to the lack of objective measures in DGS. However, it should be noted that: (a) the MMSE and MoCA do not contain equivalent items for many of the KoDGS tasks; (b) the two scales were not conducted as single tests separately and were demonstrated as not effectively screening deaf signers if not culturally and linguistically adapted (Dean et al., 2009; Taylor, 2017). Therefore, it is not appropriate to interpret these results as indicative of cognitive performance in deaf signers. However, they were useful for providing orientation in evaluating this study, with an approximate indication of construct convergence.

As in Atkinson et al. (2015) for the BSL-CST, additional subtests were administered after the KoDGS, including memory tasks comparable to the CERAD-NAB (Fillenbaum & Mohs, 2023; Fillenbaum et al., 2008; CERAD-PLUS task "world-list learning") and subtasks of the BSL Verbal Memory and Learning Test (Denmark et al., 2016). This involved presenting a list of 10 words on the screen in written form, with three repetitions and immediate and delayed recall. To assess short-term and working memory, the sample was evaluated using a forward and backward digit span test with increasing lengths, which were signed digits presented on video for immediate recall.

Analysis

Descriptive statistics were conducted on the sociodemographic variables. Correlations were calculated for age, age of acquisition, sex, and years of education.

Performance norms were derived from the normative sample CHP to determine the level of cognitive functioning exhibited by healthy deaf individuals aged over 50 in Germany. The data were analyzed for age group differences and percentiles were generated.

Inter-rater reliability was evaluated through the use of intraclass correlation. Cronbach's alpha (α) was also calculated for test internal consistency.

The lack of cognitive screening tools in DGS for testing deaf signers in Germany posed a challenge to the testing of convergent validity. We therefore assessed content validity by calculating correlations for the KoDGS score and the included MMSE and MoCA scores, as well as the additional tests of word-list and digit span, which served as convergent measures for the normative sample CHP.

To investigate the impact of the applied modifications to the adaptation, item 2 regarding federal state in the subtask Orientation of Place was examined in detail. The BSL-CST did not include any item pertaining to regional counties of the UK, as it was deemed to be incongruous with the socio-cultural context of the British Deaf community. During the adaptation process, it was proposed that the federal state item be removed, as it was deemed to present certain difficulties within the context of the German Deaf community.

In order to ascertain whether an appropriate item could be substituted when fingerspelling tasks were inaccessible, a numerical digit span task had been added to the KoDGS (item 5). This was then compared to the backward word spelling task using Spearman's *rho* correlation coefficient. Correlations were calculated to assess the relationship between the KoDGS score and both the word spelling and signed numerical digit span tasks.

To test diagnostic utility, a ROC curve analysis with the AUC was used to examine false-positive and false-negative rate and indicate a possible threshold of the KoDGS as a novel measure to accurately differentiate between the two self-identified sample groups (CHP and PwNH).

RESULTS

Associations between KoDGS Score and Demographic Variables for the Normative Sample CHP

The KoDGS normative score data were visually inspected using a Normal Q-Q plot and indicated approximately normal distribution, but a Shapiro–Wilk test of normality showed a significant deviation from normal distribution ($W = 0.94$, $p < .001$). Sample size may influence the sensitivity of normality testing. For consistency, the assumption of normality of all metric variables was checked statistically and is presented in Table 4.

Table 5 presents the associations: there was a significant negative correlation between the KoDGS score and age for CHP and a significant positive correlation between the KoDGS score and the number of years of education. No significant correlation was identified between the KoDGS score and age of acquisition. Biserial correlation showed there was no relationship between the KoDGS score and participant's sex.

In contrast, there were no significant correlations identified between age, years of education, or age of acquisition and KoDGS score for PwNH, as displayed in Table 5. The small group size requires cautious interpretation of these data but may still inform future studies' power analysis.

Table 3 above presents the demographic variables and the KoDGS mean scores and SD for each age group. Due to the age distribution of our sample, with fewer participants over the age of 70 ($n = 18$), percentiles for the age bands 70–79 and 80+ were not calculated. Instead, we report percentiles for two age bands. The age band 50–64 ($n = 50$) had a mean score of 102.6 (SD = 5.9) and a median of 103.5. The second age band 65+ ($n = 36$) had a mean of 97.4 (SD = 6.1) and a median of 99. The groups differed significantly ($p > .001$, Cohen's $d = 0.9$) on their KoDGS scores and were approximately normally distributed. In terms of age distribution, the two groups showed a different pattern. Within the age band 50–64 around 50% of the cases were in their early and mid-fifties and early sixties (around 30%) while the age band 65+ consisted of 50% of cases in their mid to late sixties. Due to an overlap of the 1st and 2nd as well as 90th and 95th percentiles, we collapsed them, respectively. The overlap may have occurred in the samples because of few cases with low KoDGS scores ($n = 1$ or 2) and proportionally many cases for the highest three score values within each age band (36% for age band 50–64 and 19.4% for age band 65+). The full percentile scores for the normative sample CHP are presented in Table 6.

Inter-rater Reliability

The intraclass correlation coefficient of 0.99 ($p < .001$) demonstrated excellent inter-rater reliability between the first and second raters, who showed close agreement on the scoring of the KoDGS.

Internal Consistency

The internal consistency of the KoDGS calculated how each of the test domains, such as memory and executive functions, contributed to the overall test score. As the KoDGS consisted of seven test domains, Cronbach's alpha of $\alpha = 0.63$ indicated an acceptable correlation between the KoDGS components.

Content Validity

The convergent measures MMSE and MoCA showed mean scores below cutoff. Spearman correlation indicated significant positive correlations between KoDGS and both MMSE and MoCA. Table 7 displays the descriptives and correlation coefficient for both CHP and PwNH.

Both the additional word-list task and the additional convergent measure digit span overall score showed a positive correlation with the overall KoDGS score, with details in Table 8.

Differences between CHP and PwNH

The results of the independent sample t-test indicated a statistically significant difference between the two groups with regard to the KoDGS score ($t(97) = 13.3$, $p < .001$). The data of both subsamples are presented in a scatterplot in Fig. 1.

The receiver operating characteristic (ROC) curve was used to evaluate the diagnostic utility of the KoDGS and is presented in Fig. 2. With the current sample, the ROC analysis examined how reliable the KoDGS distinguishes between a cognitively healthy group (CHP) and a group of individuals with a neurological history or indicative life profile (PwNH).

Table 4. Test of Normality: Shapiro–Wilk for both sample groups

	CNP			PwNH		
	n	*W*	*p**	*n*	*W*	*p**
KoDGS score	86	0.94	<.001	13	0.93	.381
Age in years	86	0.95	.003	13	0.96	.739
AoA in years	84	0.74	<.001	13	0.86	.038
Years of education	84	0.97	.026	13	0.925	.289
MMSE score	86	0.94	<.001	13	0.889	.093
MoCA score	86	0.92	<.001	13	0.948	.572

*Significance level < .05.

Table 5. Correlation table of demographics and KoDGS score of both samples

	CHP sample				PwNH sample			
Variable	*n*	*r/rho*	*p*	95% CI	*n*	*r/rho*	*p*	95% CI
Age	86	*rho* = −0.56	<.001	−0.69, −0.39	13	*r* = −0.05	.868	−0.59, 0.51
Age of acquisition	84	*rho* = −0.17	.132	−0.37, 0.06	13	*r* = 0.15	.632	−0.44, 0.65
Years of education	84	*rho* = 0.45	<.001	0.26, 0.61	13	*rho* = 0.46	.110	−0.13, 0.81

Table 6. Normative sample percentile scores for KoDGS

Percentile	1st–2nd	5th	10th	20th	30th	40th	50th	60th	70th	80th	90th–95th
50–64	88	91	94	97	100	102	104	106	107	108	109
65+	86	86	88	90	93	98	99	100	101	104	105

Table 7. Convergent measures MMSE and MoCA with correlations with KoDGS scores for content validity

		n	Mean	Median	SD	min	max	*r/rho*	*p*	95% CI
CHP	**MMSE**	86	24.9	25	3	17	29	0.81	<.001	0.72, 0.87
	MoCA	86	18.8	19	1.8	13	21	0.77	<.001	0.66, 0.85
	KoDGS	86	100.4	102	6.4	86	109	–	–	–
PwNH	**MMSE**	13	15.4	15	4.8	9	28	0.74	.004	0.32, 0.92
	MoCA	13	13.6	13	2.4	9	17	0.78	.002	0.4, 0.93
	KoDGS	13	69.2	69	14.7	50	99	–	–	–

Table 8. Adaptation-related results

	n	*M*	SD	min-max	*rho*	*p*	95% CI
Spelling signed words backwards	86	9.9	1.8	2–11	0.69	<.001	0.55, 0.79
Additional signed numerical digit span	86	6.1	3.8	0–15	0.28	.009	0.07, 0.47
Federal state*	86	NA	NA	0–1	0.18	.09	−0.03, 0.38

*Biserial correlation.

The ROC area under the curve (AUC) score of 0.965 ($p < .001$, 95% CI: 0.912–1) indicates highly reliable accuracy for this model. Considering the trade-off between sensitivity and specificity, the maximum value of Youden's index (Youden, 1950) J of 0.846 generated a cutoff with a KoDGS score of 85. This likely cutoff at 85 classifies 100% ($n = 86$) of the normative sample CHP and 84.6% ($n = 11$) of PwNH correctly, with only two individuals from PwNH erroneously categorized as cognitively healthy. A higher cutoff would increase the false-positive rate, misclassifying healthy individuals and a lower cutoff would increase the false-negative rate, misclassifying individuals with a neurological history.

Adaptation-related Results

The item "federal state" within the subtask orientation of place was correctly identified by 81 of the 86 participants (94.2%), with 5.8% of the participants unable to correctly name the federal state in which they were located. No significant effect was

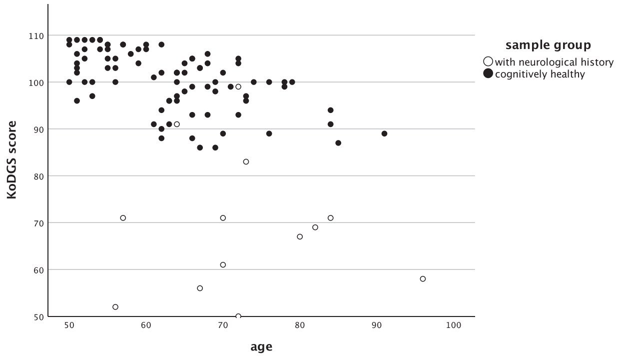

Fig. 1. Scatterplot of KoDGS score × age: CHP and PwNH samples.

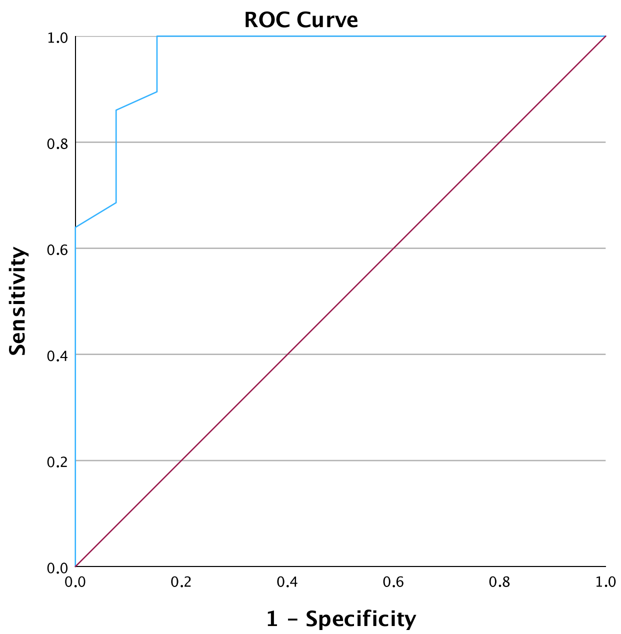

Fig. 2. Receiver operating characteristic (ROC) curve for KoDGS score.

observed on a biserial correlation between correct or incorrect answer with the overall KoDGS score. The results are presented in Table 8.

DISCUSSION

This paper presents the adaptation process and normative data for the first neurocognitive screening tool in DGS, the KoDGS. A strength of the study was the inclusive participant recruitment which drew widely from the German deaf signing population. Based on health data the sample was divided into a cognitively healthy sample (CHP) and a sample with neurological history or indicative life profile (PwNH) which enabled the generation of clinical norms, a determination of test specificity and sensitivity in correctly distinguishing the two groups. The percentiles and cutoff support clinicians in improving the way deaf individuals are cognitively assessed.

Looking at the ROC curve, supported by the scatterplot of CHP versus PwNH samples, a cutoff of 85 is suggested. There should be concern about acquired cognitive impairment if a person below the cutoff was previously a cognitively healthy deaf signer, as they fall outside the normal range for the normative sample. Like the validated BSL-CST, the KoDGS can be used for baseline testing as well as for re-testing, as demonstrated by Atkinson et al. (2015).

A major weakness of this study is that PwNH is a self-reported, mixed sample with varying neurological conditions, with some participants reporting an indicative life profile and some lacking a clear or confirmed neurological diagnosis. Relying on self-reports comes with a possible risk of anosognosia, which results in incorrectly including participants into the cognitively healthy group because individuals are not aware or do not accept their own difficulties. However, due to lack of appropriate tests in DGS, we used self-reports in the form of an extensive screening interview to assess neurological health. Brain conditions are often clinically overlooked or undiagnosed in deaf signers because of the unsuitability of current assessment tools or lack of confidence among clinicians who usually cannot sign (Harris et al., 2021). The data showed no relationship between education or age of acquisition and KoDGS score for PwNH, which strengthens the understanding and future interpretation of KoDGS performance in people with neurological conditions. Further work is required to clinically validate this tool using samples of individuals with a confirmed diagnosis of acquired cognitive impairment or dementia. More data are required to establish finer-grained age bands because the age distribution and number of data points of the current sample were not sufficient to create more than two age bands. We would recommend targeted data collection to ensure a more even spread of ages for future research, particularly focusing on older age groups from 70–79 and 80–89 who have greater risk of dementia. Future studies should include additional measures such as verbal memory and learning, digit span and spatial span to look for relationships with the KoDGS performance.

Careful Interpretation of Correlations with Convergent Measures

The study included MMSE (29 of 30) and MoCA (21 of 24) items, which correlated positively with the KoDGS score. However, the MMSE and MoCA data disclosed lower score values than is the norm for cognitively healthy individuals. Dean et al. (2009) found the same effect for the ASL version of the MMSE, with scores below the clinical cutoff, and they state that it is not cognitive impairment but rather linguistic and cultural factors which impact performance on the signed version of the MMSE. Atkinson et al. (2015), however, found hidden cognitive impairment in their normative sample using WASI Matrix Reasoning (Wechsler Abbreviated Scale of Intelligence, Wechsler, 1999), which indicates a careful interpretation of cognitive assessments in the deaf population for which only limited measures are available to-date. It is very likely that the same factors produce the same effect with the MoCA scores. The low MMSE and MoCA scores point toward the inadequacy of test design and test items for deaf individuals, supporting Dean et al.'s (2009) previous findings. The general correlations between those tools and the KoDGS need to be interpreted carefully. The KoDGS offers the first cognitive screening specifically designed for DGS users with a deaf norming sample, enabling clinicians to test deaf individuals appropriately, while using a reliable and valid assessment tool. The MMSE and MoCA, as strong established and widely used tools, function only as a proxy to report content validity in the absence of cognitive screenings and additional objective measures in DGS.

It is important for clinicians to distinguish between users of spoken language and users of sign language. The same considerations apply as for clinicians assessing the dominant language of hearing bilinguals in a test setting, and applying the appropriate tests (Briceño et al., 2021) is required with deaf individuals. Cognitive screenings that demonstrated sensitivity and specificity for hard-of-hearing individuals such as the German MoCA-HI (Völter et al., 2023), DemTect^{Ear} (Brünecke et al., 2018), or O-Dem (Ballasch et al., 2023), all focus on spoken language test administration, with speech or writing/reading. These specifically adapted tools are reliable in testing individuals who were born hard of hearing or became deaf later in life and use spoken German. The KoDGS, however, should be used with prelingually deaf individuals who use sign language (DGS or German influenced signing). For individuals who are deaf from an early age but do not use sign language, the MoCA-HI will only be appropriate if they have solid command of German and German cultural references.

The Adaptation

Our adaptation paradigm emphasizes the importance of a collaborative approach with the Deaf community in adapting and developing tests for deaf signers, without which the test would not be client-friendly or culturally or linguistically valid. This study reports the first test adaptation of a cognitive screening from one sign language to another: from the BSL-CST to the KoDGS; so offers unique insights for future international test adaptations. The KoDGS may be used for future research on signers with brain conditions in Germany. It should be noted that it is unclear how suitable the KoDGS is for use with people with suspected developmental cognitive impairments. A cautious use, with liberal score interpretation, may be an appropriate application for investigation. For British deaf signers and the BSL-CST, Atkinson et al. (2015) found that such individuals performed well on this test, which is purely designed to distinguish acquired cognitive impairment in previously healthy deaf signers. For clinical use, high proficiency in DGS and good Deaf cultural competence are required to administer and interpret the KoDGS findings within the context of broader neurological assessment and workup. The test format of a standardized administration via signed video instructions facilitates future clinical applicability and objectivity, while increasing test reliability and validity. Participants in the study showed no difficulty with the two-dimensional on-screen presentation of what is actually a language articulated in three-dimensional space. It is possible to administer test sessions via a spoken German-DGS interpreter, but any impact on test scores has not been investigated and the clinical validity of this approach has not been confirmed.

Further Limitations

The original recruited sample included deaf older adults who self-identified as cognitively healthy, but subsequent investigation via medical records and investigations revealed that this sample actually included 13 people with self-reported neurological conditions, showing the extent of hidden impairment in the German Deaf community, which was already found by Atkinson et al. (2015). The wide inclusion criteria were designed to encourage participation of people who might otherwise have been excluded by more stringent criteria. This differs from the BSL-CST norming study, which had stricter criteria for inclusion and had fewer excluded participants or outliers. A weakness of the current study is that we did not control for general nonverbal intelligence, so it was difficult to ascertain any individuals with likely preexisting cognitive disability in the sample. People with confirmed or suspected neurological conditions were subsequently excluded to ensure, as far as we could, that the normative sample was cognitively healthy, and the data of the excluded group were examined separately as the PwNH sample. Controlling for mood and mental health with a depression scale is recommended for future studies as long as a clinically validated sign language measure of depression is available, which is not the case for most sign languages at present. These currently exist for BSL (Rogers et al., 2018) but not for DGS.

In terms of sample size, the data from 86 cognitively healthy individuals may not appear to be a large number—even though diagnostic tools such as the ACE-III were established with comparably sized samples (Hodges & Larner, 2017). The Deaf community is a relatively small population in general, so the percentage of the total population of deaf older signers in Germany represented here is not unreasonable. Unfortunately, the age groups are not evenly filled, with fewer individuals over the age of 75.

The sample size should be taken into account when interpreting internal consistency. With larger sample sizes and more data, the estimate of the effect becomes more precise, reducing random error. So, even a subtle effect can reach significance in a large sample, while small samples might only detect very large effects. This emphasizes the importance of larger sample sizes, which is a challenge when working with small populations. For the frame of this study, there are two additional points to be noted about the sample size: the time of data collection and the recruitment method. The present study was conducted between 2019 and 2023, when the world was metaphorically turned upside down during the pandemic. Scientific research, including community outreach, recruitment, data collection, and presentation of study results back to the community, was highly challenging, especially such research with older populations. The broad recruitment method helped to achieve a normative sample of 86. Also, a strong overrepresentation of high-functioning individuals can be ruled out. However, data in the oldest age group, adults aged 80+, are scarce and the collection of further data in this age group would allow more robust clinical norms.

Applications of the KoDGS to a Diverse Population

The KoDGS was widely understood across all federal states of Germany and by all signers, including those who prefer signing that is influenced by spoken German, indicating suitability for clinical use across a diverse community of deaf signers. The diversity of the sample in our study provides a foundation for future applications with the heterogeneous Deaf community (Cormier et al., 2012; Mayberry, 2002). There was no effect of age of acquisition or of the presence or absence of deaf relatives (which indicates whether a person was raised in a deaf or hearing environment) like for the BSL-CST (Atkinson et al., 2015). This indicates that it is a good screening tool for deaf signers with all types of developmental language learning background. Clinicians need to be aware of the impact of (a) late language exposure due to mostly hearing environments in early years and (b) the largely oral education system which older deaf people were exposed to in childhood which limited access to language and left gaps in education. A careful background check is recommended to control for possible bias effects arising from limited education.

Identifying Differences During Adaptation

The study identified linguistic and cultural differences between BSL and DGS, as well as between British and German Deaf cultures and historical contexts. There are important lessons for other countries who may wish to adapt the original BSL test, about consideration of these issues during adaptation. Sign language tests should not just be translated from one signed language to another but carefully adapted and changed to ensure that the same psychological constructs are accurately measured for the new cultural context (both national and within that Deaf community) and signed language. In order to ascertain linguistic differences and item equivalence, collecting psycholinguistic data sets are a vital requirement for the evidence-based selection of linguistic items in adapted tests (Stockleben et al., under review). The application of all the steps of cultural test adaptation, as described by Mirza et al. (2017), enabled the identification of culturally dependent test items during the BSL-CST to KoDGS adaptation. We found aspects unrelated to differences in Deaf culture, such as personal identification with the federal state of one's current location and the use of house numbers in place of building names. Culturally dependent aspects, rooted in Deaf education or Deaf history, were identified in the fingerspelling tasks for attention and short-term memory, as well as in the retrograde memory task with questions about collective memory. Such cultural differences became particularly apparent during the "users in co-production" and "expert recommendations" stages (Mirza et al., 2017), which were pivotal in the present study's adaptation process and are recommended for future adaptations in other signed languages.

Applications of the Adaptation Paradigm

The adaptation was informed by a transdisciplinary and participatory research paradigm. The inclusion of the views of stakeholders in the adaptation of the test provided several advantages (Arnstein, 1969). A population with a low prevalence of clinical cases, such as the Deaf community, is characterized by a relatively small number of individuals. This can present challenges for clinicians in the context of diagnostic screenings. In many cases, the knowledge required to perform a given task and the methodology for testing it are provided by a small number of experts in the field, some of whom are culturally competent but are not clinically qualified. The involvement of stakeholders from practice fields who are clinically competent but may not be Deaf culturally competent or know how to sign, such as clinical doctors and therapists, or caring and nursing staff, is also required. Bringing these groups together facilitates the integration of dual DGS and clinical perspectives into the adaptation process, thereby bridging the gap between scientific theory and practice. Throughout the KoDGS adaptation process, both sets of stakeholders ensured the applicability of the proposed adaptation to clinical real-world practice.

It is vital to include people with lived deaf experience to enable a more precise alignment of the test with the community's cultural and linguistic characteristics. In other contexts where there is a limited evidence base, tests are often used that do not align with the characteristics of the population in question (e.g., those who do not speak German, or those who are blind or have low vision). It would be advantageous to apply our stakeholder adaptation paradigm to other small populations in order to enhance the quality of test adaptations.

Future Research

A subsequent study should be conducted with a confirmed clinical dementia sample in order to verify an appropriate threshold and refine the interpretation of the KoDGS score. The best way to achieve this is to collect data using the test as part of routine clinical practice with deaf dementia patients. Further investigation into the potential associations between biomarkers and the KoDGS score is of significant interest. Furthermore, a future study may investigate further adapting the KoDGS to distinct sub-groups within the Deaf signing community, such as those who are deaf-blind. Future research should include an evaluation of interpreter use and remote administration of the KoDGS. The impact of remote testing and the use of interpreters to translate the patient's signed responses on test scores should be established. This would require future appropriate training for interpreters working in such settings. A significant area for future investigation is the development of trained sign language test personnel who are able to assess and evaluate deaf individuals with the KoDGS. Given the necessity of a high level of proficiency in DGS and a certain level of awareness for the deaf population for the application of the KoDGS, the development of new approaches for the assessment of deaf individuals in the context of general medical care, such as in memory clinics, through the use of trained personnel with proficiency in sign language, including deaf clinicians, is essential. Deaf awareness training for clinicians would lower barriers in general clinical care and facilitate the implementation of diagnostic tools like the KoDGS.

CONCLUSION

The proposed adaptation paradigm is characterized by high levels of participatory involvement of the community and interdisciplinary consultation, and may motivate future test adaptations for small populations. The presented KoDGS, as the first screening for cognitive impairment and dementia in deaf sign language users in Germany, has the potential to improve the way deaf individuals are cognitively assessed for dementia.

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CONFLICT OF INTEREST

None declared.

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