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Original Article

The Bamberg Dementia Screening Test (BDST) – First Evidence Regarding the Diagnostic Usability of a "True Bedside" Test for Geriatric Inpatients

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Abstract: Due to physical limitations (e. g. difficulties in reading and writing), geriatric inpatients are often not able to complete relevant dementia screening tests. The Bamberg Dementia Screening Test (BDST) is a new dementia screening measure that can be administered in a few minutes as "true bedside" – test.
150 patients suffering from mild cognitive impairment (MCI) and mild or moderate dementia as well as a control sample of 40 cognitively unimpaired participants completed the BDST and the CERAD-Plus test battery.
High correlations of BDST-subscores with CERAD subtests of corresponding content and between the total scores of the two tests could be found. Using the BDST, mild dementia and MCI patients could be discriminated from healthy controls with high sensitivity and specificity.

Keywords: memory, dementia, mild cognitive impairment, diagnostic, screening, geriatrics

Der Bamberger Demenz Screening Test (BDST) – Erste empirische Evidenz hinsichtlich der Brauchbarkeit eines „true bedside" Tests für geriatrische Patienten

Zusammenfassung: Patienten geriatrischer Stationen sind, da sie z. B. aufgrund ihrer körperlichen Einschränkungen schlecht zeichnen, lesen oder schreiben können, oft nicht in der Lage, klassische Demenzscreenings zu bearbeiten. Beim Bamberger Demenz Screening Test (BDST) handelt es sich um ein neu entwickeltes Screeningverfahren, das in wenigen Minuten als Bedside-Test durchführbar ist.
150 Patienten mit leichter kognitiver Störung (MCI), leichter und mittelschwerer Demenz sowie einer Kontrollgruppe von 40 unbeeinträchtigten Personen wurden der BDST und die CERAD-Plus Testbatterie vorgegeben.
Es finden sich hohe Korrelationen der BDST-Subscores mit den inhaltlich entsprechenden CERAD Subtests sowie zwischen den Gesamtscores der beiden Verfahren. Mittels des BDST konnte zudem mit hoher Sensitivität und Spezifität zwischen gesunden Personen, Personen mit leichter kognitiver Störung (MCI) und Personen mit dementiellem Syndrom differenziert werden.

Schlüsselwörter: Gedächtnis, Demenz, Mild Cognitive Impairment, Diagnostik, Screening, Geriatrie

Introduction

Dementia is a common health problem in industrialized countries (Ferri et al., 2005) and, as life expectancy increases, incidence rates are on the rise (Hebert, Beckert, Scherr & Evans, 2001). An early diagnosis of dementia has many benefits: Drug treatment and cognitive training interventions are most effective in earlier stages of the disease. Decisions shared by patients and their relatives about further care and about utilization of dementia specific resources and support systems can be made while patients are still competent enough (Solomon & Murphy, 2005; Boustani, Peterson, Hanson, Harris & Lohr, 2003). It has been shown that all of these actions improve quality of life and delay admission to institutional care, which in turn results in overall cost savings (Banerjee & Wittenberg, 2009; Getsios, Blume, Ishak, Maclaine & Hernandez, 2012).

Although common among hospital and primary care patients, at present, dementia still remains under-diagnosed. According to several reviews, more than half of the patients suffering from dementia in primary care as well as in general hospitals remain unrecognized (Sampson, Blanchard, Jones, Tookman & King 2009; Boustani et al., 2003). Screening tests for dementia provide a possible solution for this problem. Ideally, they can be administered in a few minutes of time without too much equipment needed and potential cases of dementia can be identified by the use of a defined cut-off score: If test scores are below this threshold value, patients under suspicion of dementia can be referred to specialists for thorough diagnosis including administration of an extended neuropsychological test battery, laboratory screening, lues serology, a cranial CT or MRT scan, electroencephalography, ECG and psychiatric, neurological and physical examinations.

Since the ubiquitously used Mini Mental State Examination (Folstein, Folstein & McHugh, 1975) has some limitations in sensitivity and specificity regarding the detection of mild forms of dementia (Mitchell, 2009), many efforts have been made in the last decade to develop screening tests that show improved diagnostic performance and/or require even less time to administer.

Some of them, like the general practitioner assessment of cognition (GPCOG; Brodaty, Kemp & Low, 2004), the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), the DemTect (Kalbe et al., 2004) or the Mini-Cog (Borson, Scanlan, Brush, Vitaliano & Dokmak, 2000) have already been considered in current clinical guidelines recommending the use of screening tests to utilize the stepwise diagnostic strategy explained above (National Institute for Health and Clinical Excellence/Social Care Institute for Excellence [NICE], 2006; Deutsche Gesellschaft für Psychiatrie, Psychotherapie und Nervenheilkunde [DGPPN] & Deutsche Gesellschaft für Neurologie [DGN], 2009; British Geriatrics Society, 2005; American College of Surgeons/American Geriatrics Society [ACS NSQIP/AGS], 2012).

However, most screening tests still suffer from some drawbacks. For simplicity reasons, they often provide only one total score that can be compared to a critical cut-off value. Although screening tests can never substitute thorough neuropsychological assessments, some authors demand that at least numerical indices regarding the patients' 'cognitive profile' in key cognitive domains should be provided. Separate scores for nonverbal (episodic) memory, verbal fluency, visual construction, reasoning etc. could help in creating hypotheses about probable subtypes of dementia in a symptom oriented approach to assessment (Kipps & Hodges, 2005; Cullen, O'Neill, Evans, Coen & Lawlor, 2007). This could be accomplished by the use of subscores for these domains.

Furthermore, although many cognitive screening tests claim to be "bedside tests", they nevertheless make heavy demands on fine motor skills like drawing or demonstration of complex gestures and vision (reading of texts, connecting figures by lines etc.), which hampers application in geriatric inpatients in general hospitals. For those patients however, it has been proven that early detection of dementia is of great importance for the prevention of new medical events like falls, changes in blood pressure or fecal and urinary incontinence (Meccoci et al., 2005).

Therefore, the aim of this study was to evaluate reliability, validity and diagnostic accuracy of a small battery of "true bedside" tasks making minimal demands on vision and fine motor skills, that can be administered without any special material and do not require the participant to write, read or draw on paper.

Methods

Participants

A total of 190 participants were recruited including 150 patients suffering from either mild cognitive impairment (MCI, n = 30) or mild (DEM mi, n = 90) to moderate (DEM mo, n = 30) dementia as well as a clinical control sample (CNT) of 40 subjects.

150 patients suffering from either mild cognitive impairment (MCI, n = 30), Alzheimer's Disease (AD, n = 78), vascular dementia (VD, n = 22), Parkinson's disease dementia (PDD, n = 5), dementia with Lewy Bodies (DLB, n = 3) or frontotemporal dementia (FTD, n = 12) were recruited from the departments of geriatric internal medicine and geriatric psychiatry of a general hospital in Bamberg, Germany. All of them underwent routine laboratory screening including thyroid function parameters, lues serology, B12 and folic acid levels, a cranial CT or MRT scan, electroencephalography, ECG and a thorough psychiatric, neurological and physical examination.

Diagnoses of MCI, AD, VD, PDD, DLB and FTD were made following ICD 10 criteria for the diagnosis of dementia and additional established criteria (McKhann et al., 1984; Portet et al., 2006; Neary et al., 1998; McKeith et al., 2000; Román et al., 1999; Goetz, Emre & Dubois, 2008) for the diagnosis of subtypes.

The clinical control sample was recruited from the department of internal medicine's geriatric rehabilitation ward of the same general hospital in Bamberg, Germany. Inclusion criteria were: Age above 60, no indication of any cognitive impairment according to the scores obtained in a neuropsychological test battery described in detail below (standardized scores better than one standard deviation under norm population mean scores), and no hints for depressive or other psychiatric symptoms.

Written informed consent was obtained after complete description of the study either from participants themselves or from their legal guardians.

The study protocol was approved by the Ethical Review Board of the University of Bamberg ("Ethikrat").

Neuropsychological and symptom measures

The German version of the Consortium to Establish a Rationale in Alzheimer's Diagnostic neuropsychological battery (CERAD-Plus; Aebi, 2002), which includes the Mini Mental State Examination (MMSE), and the Bamberg Dementia Screening Test (BDST) were administered to all participants.

In its current version, the CERAD-Plus battery includes beside the MMST 11 tasks covering phonematic fluency, semantic fluency, naming (Boston Naming Test), word list learning, delayed free recall and recognition of a word list, figure drawing (copying geometric shapes), delayed figure recall as well as the Trail-Making Tests form A and B.

Statistical analyses included raw scores for all of the CERAD-Plus and BDST subtests.

In its current version, the Bamberg dementia screening test (BDST) includes 6 tasks that can be administered in about 7 minutes (see table 1 for cognitive domains, scoring and sample items; domain and total scores are obtained by simply adding the scores for the corresponding items). The goal in constructing this screening measure was to waive any additional material like paper, pencils, pictures, word cards etc. in order to increase feasibility for geriatric patients as much as possible. Therefore all answers have to be given in oral form or using gestures. Creating drawing and cognitive flexibility tasks that can be accomplished without paper and pencil was especially challenging. Instead of copying, for example, simple shapes on paper with a pencil, in the BDST participants are asked to copy simple shapes in the air with their index finger that were previously specified by the test administrator. Tapping tasks are a popular method to assess executive dysfunction (see for example Dubois, Slachevsky, Litvan & Pillon, 2000).

Thus, for the 'cognitive flexibility' domain, a series of tapping sequences with increasing levels of difficulty was developed, where patterns in the tapping sequences given by the test administrator have to be recognized and correctly repeated by the subject.

The BDST sum score as well as scores for each subtask were used for further analyses.

Furthermore, all patients completed the German short version of the Geriatric Depression Scale (GDS-K; Sheikh &Yesavage, 1986), a brief screening instrument for depressive symptoms in the elderly. Participants with scores higher than 5, indicating possible depression, were excluded from further analyses.

CERAD-Plus, BDST and GDS were administered by psychologists of the geriatric or psychiatric ward.

Statistical analyses

Comparability of the four diagnostic groups

Univariate analyses of variance with Scheffé a posteriori analyses were performed to compare age and years of education in the four diagnostic groups (CNT, MCI, DEM mi, DEM mo) and a chi-square test was used to test for differences in male to female ratio.

Reliability and validity of the BDST

Cronbach's alpha score was computed to assess the BDST's internal consistency as an estimate of the BDST total score's reliability. To gather information about the BDST's concurrent validity, Pearson correlation coefficients were computed between BDST and CERAD-Plus subtasks and total scores. Following the procedure applied by Schmidt, Becker & Zerr (2014), a CERAD "composite" value was obtained by extracting one principal component from the highly intercorrelated CERAD-Plus subtests to obtain one summative CERAD score that can be correlated with the BDST and MMST total scores. To assess construct validity, a factor analysis (principal component analysis, varimax rotation) was performed for all BDST and CERAD-Plus subtests to evaluate whether BDST and CERAD subtests with similar content loaded on the same factors. Kaiser criterion (eigenvalues greater than 1) was used to determine the number of factors extracted.

Diagnostic quality of the BDST

Univariate analyses of variance with Scheffé a posteriori analyses were performed to compare the diagnostic groups' (CNT, MCI, DEM mild, DEM moderate) test performance.

MMSE and BDST total scores from patients with mild dementia and controls were used to plot receiver operating characteristic (ROC) curves of sensitivity against 1-specificity. The same ROC curves were plotted for MCI patients and controls. Optimum cutoff scores were determined using the Youden index. Sensitivity, specificity, positive predictive validity and negative predictive validity were computed for both MMSE and BDST on the basis of the cutoff scores found.

In order to determine, which BDST subtests best predict cognitive deficits associated with mild cognitive impairment, a stepwise logistic regression analysis was performed using diagnostic group (CNT vs. MCI) as dependent variable and all BDST subscores as independent variables. As only the scores for the "visual memory" and "cognitive flexibility" subtests remained in the final equation, a BDST "MCI score" (sum of the "visual memory" and "cognitive flexibility" scores) was computed for all subjects. A ROC curve for MCI patients vs. controls, an optimum cutoff score and scores regarding sensitivity,

Table 1
Cognitive domains, scoring and sample items of the BDST

Cognitive domain	Task and sample item	Scoring
Semantic memory (5 items)	Description of animals, participant has to name the animal's names. *"What is the animal that gives the name for a striped pedestrian crossing?"* If answer not 'zebra': *"The animal looks like a striped horse."* Item 5: *"Which animal do people fear more: a rabbit or a lion?"* If "lion" is named: *"Why?"*	Items 1 to 4: 2/1 points for correct answer to the first/second question. Item 5: 1 point for correct answer: "lion", another point for correct substantiation of answer Maximum score: 10 points
Verbal memory (4 items)	Free recall (*"What are the animals I've just asked you for before we talked about the rabbit and the lion?"*) or recognition (*"Did I ask for a zebra, tiger or a monkey?"*) of the first four animals asked in the semantic memory subtask. Recognition question is asked for every animal not named during free recall	2 points for free, 1 point for cued recall of each item. Maximum score: 8 points
Visual construction (4 items)	Drawing of shapes with index finger *"Please watch carefully and then try to redraw the following shape in the air."* [Administrator draws the following symbol with her/his index finger]  If not redrawn correctly (shape can be clearly recognized, no matter if drawn mirrored or not) by the participant: "I'll draw the figure again." "Now try it once more"	2/1 points if symbol is correctly redrawn in first/second attempt Maximum score: 8 points
Verbal fluency	Naming of larger cities anywhere in the world in 60 seconds	1 point for each 3 cities (8 points for 24 or more cities) named. Maximum score: 8 points
Visual memory (4 items)	Free or cued (*"one shape looked like a letter"*) recall of the four shapes presented in the visual construction subtask. Recognition question for every shape not drawn correctly during free recall	2 points for free, 1 point for cued recall of each item. Maximum score: 8 points
Cognitive flexibility (4 items)	Reproduction of tapping patterns *"Please watch carefully what I do and then try it yourself following the same pattern"* Administrator is tapping with both hands on the table/bed blanket or thigh:  If tapping not performed correctly by the participant: "I'll do it again." "First watch and then give it one more try"	2/1 points if tapping sequence performed correctly in first/second attempt Maximum score: 8 points

specificity, positive predictive validity and negative predictive validity were also obtained for this "MCI score".

Effects of age and years of education on BDST performance

To estimate, to what extent the BDST sum score is influenced by age and years of education independently from cognitive achievement, a stepwise linear regression was performed using the BDST total score as dependent variable and all CERAD-Plus scores as well as age and years of education as predictors in order to examine whether age and years of education or cognitive achievement primarily influences test performance.

Alpha level was set to 0.05 for all tests.

Table 2
Correlations between BDST and CERAD Plus scores corresponding by content (p<.0005 for all coefficients)

BDST (sub-)score	CERAD-Plus subscore(s)		
Semantic memory	*Boston naming test* .46		*Semantic fluency* .48
Verbal memory	*learning* .58	*word list delayed free recall* .62	*recognition* .55
Visual construction		*figure drawing* .60	
Verbal Fluency	*semantic* .72	*fluency*	*phonematic* .54
Visual memory		*delayed recall figures* .65	
Cognitive flexibility		*Trail Making Test B* -.57	

Results

Sample characteristics

No difference was found between the four groups with respect to age (mean/std for CNT, MCI, DEM mild, DEM moderate: 73.2/8.5, 76.8/8.4, 75.4/7.1, 77.4/6.0; $F(3/186) = 2.26$, $p > .10$) and years of education (mean/std for CNT, MCI, DEM mild, DEM moderate: 12.5/2.5, 12.0/1.9, 12.0/1.8, 11.6/1.4 $F(3/186) = 1.31$, $p = .39$).

Male to female ratio however tends to be different across groups (m/f for CNT, MCI, DEM mild and DEM moderate: 19/21, 7/23, 45/45, 12/18, $\chi^2(3) = 6.91$, $p = .08$) because of a higher proportion of female participants in the MCI group.

Reliability and validity

The Cronbach's alpha reliability score is .79 for the total score of the BDST, which is an acceptable value for a brief screening measure.

Table 2 shows correlation coefficients between all CERAD Plus and selected BDST subtests of corresponding content.

Subtests covering similar contents revealed meaningful correlations between each other. Remarkably, even conceptually similar subtests that differ drastically with respect to their mode of presentation (recognition of tapping patterns vs. connecting of letters and figures, drawing of simple shapes "in the air" vs. drawing of geometric shapes on paper) were highly correlated.

Furthermore, the BDST total score correlated significantly with the MMST and "total" CERAD- Plus scores of the participants ($r = .70$, and $r = .86$ respectively, $p < .0005$ each).

The factor analysis for the 16 CERAD-Plus and BDST subtests yielded a three factor solution that explains 68.2 % of the total variance. As can be seen in table 3, which displays the rotated factor matrix, only the memory tasks of both tests show substantial factor loadings on the first factor. All CERAD-Plus speed tests – regardless of their content – as well as the only BDST speed test loaded on the second factor. Two other BDST subtests also show substantial loadings on this factor: The "cognitive flexibility" subtest, which probably shares similar content compared to the CERAD Trail Making Test B and the "semantic memory" task, which is somewhat comparable to the CERAD "semantic fluency" subtest (naming of animals that fit a given description vs. paced naming of as many animals as possible). The third factor contains high loadings for the two "drawing tasks" of both tests. While it is somewhat plausible that, as motor skills are needed for this task, BDST's "cognitive flexibility" subtest loaded on this factor, it is more difficult to explain, why the CERAD's Boston Naming Test also loaded on this factor. One reason might be that recognition and interpretation of figural information is needed to complete Boston Naming Test's more difficult items.

Differentiation of mild and moderate dementia as well as mild cognitive impairment by use of the BDST

Table 4 shows mean values and standard deviations for all BDST scores and the MMSE total score.

All BDST subtest scores, the BDST total score and the MMST score differentiated between the four groups ($F(3/186)$ between 14.29 and 129.22, $p < .0005$ for all values).

Scheffé a posteriori comparisons show that MMSE as well as BDST total scores were different for all subgroups ($p < .0005$ each) – except the MCI participants, whose BDST scores ($p < .0005$) but not MMSE scores ($p = .430$) are different from the CNT group.

Table 3
Rotated factor matrix resulting from a factor analysis of all CERAD plus and BDST subtests (principal component analysis, for reasons of clarity only factor loadings > = .500 are listed)

test	subtest	factor *"memory"*	factor *"cognitive speed/flexibility/semantic"*	factor *"visuospatial"*
CERAD-Plus	*semantic fluency*		,656	
	Boston Naming Test			,546
	word list learning	,802		
	word list free recall	,840		
	word list recognition	,751		
	figure drawing			,773
	delayed recall figures	,582		
	Trail Making Test A		-,706	
	Trail Making Test B		-,701	
	phonematic fluency		,658	
BDST	*semantic memory*		,619	
	verbal memory	,768		
	visual construction			,806
	verbal fluency		,676	
	visual memory	,723		
	cognitive flexibility		,517	,600

Table 4
Mean values and standard deviations for BDST and MMSE scores. BDST: Bamberg Dementia Screening Test, MMSE: Mini Mental State Examination, CNT: cognitively unimpaired control subjects, MCI: mild cognitive impairment, DEM: dementia

		CNT		MCI		DEM mild		DEM moderate	
		mean	std	mean	std	mean	std	mean	std
BDST	Semantic memory	9.78	0.66	9.57	0.86	8.64	1.74	6.67	2.76
	Verbal memory	6.90	1.08	6.77	0.86	5.03	1.61	3.67	1.54
	Visual construction	7.75	0.54	6.97	1.40	6.29	1.67	5.47	1.96
	Verbal fluency	5.28	2.93	3.23	2.25	2.06	2.01	1.33	1.37
	Visual memory	7.10	1.10	5.53	1.76	3.38	2.22	1.87	1.72
	Cognitive flexibility	5.46	1.75	3.79	1.35	4.05	1.65	2.38	0.77
	Total	42.46	4.13	36.04	4.48	29.49	6.26	21.54	3.50
MMSE		28.25	2.55	27.13	2.29	23.18	2.77	16.00	3.44

Furthermore, mild dementia patients scored significantly less than control subjects in all BDST subtest scores ($p < .0005$ each, except semantic memory: $p = .007$ and cognitive flexibility: $p = .003$).

In the MCI group however, only the BDST scores for verbal fluency ($p = .002$), visual memory ($p = .009$) and cognitive flexibility ($p = .002$) were significantly lower compared to the control group. Finally, patients suffering from moderate dementia scored significantly lower compared to mild dementia patients in four subtests: verbal and semantic memory ($p < .0005$ each), visual memory ($p = .003$) and cognitive flexibility ($p = .014$).

As only a part of the BDST subtests seems to separate MCI patients from healthy controls, a logistic stepwise regression (pin = .05, pout = .10), using the BDST subtests as predictors and diagnostic group (MCI vs. CNT) as dependent variable was performed. The stepwise procedure stopped when two subtests – "visual memory" (Wald statistic = 12.36, $p < .0005$) and "cognitive flexibility" (Wald statistic = 9.14, $p < .003$) – were included in the

Table 5
Sensitivity (SEN), specificity (SPE), positive (PPV) and negative predictive validities (NPV) and total percentages of correct classifications (TOT) for MMST and BDST total scores using the cutoff points determined by the ROC curves displayed in figure 1

	Cutoff score <=	SEN	SPE	PPV	NPV	TOT
Diagnosis of mild dementia using …						
MMSE	26	86.7	90.0	95.1	75.0	87.7
BDST	37	91.9	85.7	87.8	90.9	88.9
Diagnosis of mild impairment using …						
MMSE	28	76.7	62.5	60.5	78.1	68.6
BDST total score	40	83.3	77.1	71.4	87.1	79.7
BDST MCI score	10	83.3	88.6	83.3	88.6	86.4

equation. Hence a BDST "MCI score" (sum of the "visual memory" and "cognitive flexibility" scores) was computed for all subjects.

Figure 1 shows ROC curves for the comparison of mild dementia patients and controls as well as MCI patients and controls based on their BDST (total and "MCI-score") and MMSE total scores. The areas under the ROC curves for differentiating between patients suffering from mild dementia and controls were .924 and .954 for MMSE and BDST, respectively. Optimum cutoff points were 26 and 37, respectively. This means that patients achieving a MMSE score of 26 or less or a BDST score of 37 or less have positive test results for (mild) dementia.

The areas under the ROC curves for differentiating between MCI patients and controls were .710, .855 and .882 for MMSE, BDST total and BDST "MCI"-scores respectively. Optimum cutoff points were 28, 40 and 10. This means that patients achieving a MMSE score of 28 or less, a BDST total score of 40 or less and a BDST "MCI-" score of 10 or less have positive test results for mild cognitive impairment.

The values for the area under the ROC curves indicate that both MMST and BDST have an excellent diagnostic ability to discriminate between mild dementia patients and healthy control persons. However, the MMST has only a poor to fair ability to discriminate between MCI patients and controls. The values for the BDST total and "MCI-" scores on the other hand point to a good accuracy to discriminate between MCI patients and controls.

Table 5 displays sensitivity, specificity, positive and negative predictive validities and total percentages of correct classifications for both tests using the cutoff points determined by the ROC curves.

As can be seen in table 5, both MMSE and BDST show good overall diagnostic ability to discriminate between mild dementia patients and cognitively unimpaired controls. BDST's sensitivity is slightly higher compared to MMSE (92 % vs. 87 %) while the MMSE achieves somewhat higher specificity (90 % vs. 86 %) values. Negative predictive validity however is unsatisfying for MMSE in our sample: A quarter of those subjects suffering from mild dementia are classified as "unimpaired" by the MMSE compared to only five percent by the BDST.

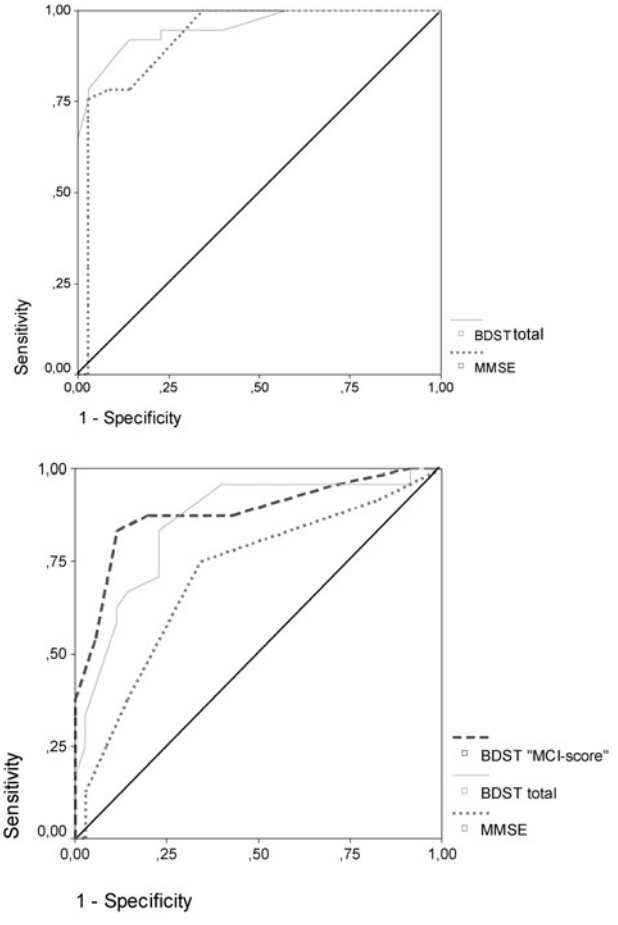

Figure 1. Receiver operating characteristic curves for BDST total score and MMSE scores. Top: mild dementia patients vs. unimpaired controls. Bottom: MCI patients vs. unimpaired controls. BDST "MCI-score" is obtained by adding the scores for visual memory and cognitive flexibility.

MMSE's characteristics are unsatisfying for the diagnosis of MCI with all values below 80 percent and specificity and positive predictive values of only 62.5 and 60.5 percent. BDST has satisfactory values for sensitivity and negative predictive validity while its values for specificity

and positive predictive validity are – albeit higher compared to MMSE's values – still not sufficient.

The BDST "MCI-score", however, achieves sufficient diagnostic quality with all values above 80 percent and an area under the ROC curve of .882.

Effects of age, sex and education on BDST test score

BDST total score is not affected by gender ($t(188) = 1.65$, $p = .100$). However, for the entire sample, age ($r = .26$, $p = < .0005$) and years of education ($r = .20$, $p = .007$) correlate significantly with the BDST total score.

When years of education and age together with all CERAD Plus subscores including the MMSE are entered as predictors in a stepwise linear regression using BDST total score as dependent variable, only the CERAD Plus scores for word list delayed recall (beta = .285, $p < .0005$), figure drawing (beta = .171, $p = .003$), delayed figure recall (beta = .204, $p = .004$), semantic fluency (beta = .173, $p = .007$) and MMSE (beta = .165, $p = .017$) are selected into the final equation. Hence, BDST scores are not affected by age and education when cognitive performance of the participants is controlled for.

Discussion

Our aim was to develop a true bedside screening measure for geriatric patients drawing minimal demands on fine motor skills and vision that would be capable to detect beginning dementia syndromes with similar diagnostic accuracy compared to standard screening measures.

We arrived at a small screening battery containing solely tasks that can be accomplished without further aids like pencils, papers etc., with some of its tasks being completely novel approaches to assess relevant neuropsychological domains that to our knowledge have not been implemented in any cognitive test so far.

We found high correlations of BDST subscores with CERAD subtests corresponding in content, despite of partly different modes of required test behavior (e.g. drawing "in the air" with the index fingers vs. drawing on paper, tapping with both hands vs. alternately connecting letters and figures) as well as very high correlations between MMSE, CERAD and BDST total scores. The BDST total score showed a satisfactory to good internal consistency. By using the total score, an excellent separation of patients suffering from mild dementia and cognitively unimpaired control patients could be achieved, which outperforms MMSE's diagnostic accuracy. Using the BDST's "MCI-score", even patients suffering from mild cognitive impairment could be identified with reasonable accuracy.

In any case, it is an encouraging result that the BDST was at least comparable to the MMSE with respect to the identification of possible cases of dementia or MCI, even when newer and stricter cut-off scores for the MMSE were used. However, in contrast to the MMSE, the BDST can even be used in geriatric settings, when an assessment of the cognitive status is necessary but the physical status makes it impossible to read, write or draw on a paper. To our knowledge, none of the screening tests available at the moment can be used under such circumstances.

It would have been favorable to compare the BDST's diagnostic power also with the more elaborated CERAD-Plus test battery. Unfortunately, for two reasons it was not possible to compare the BDST with the CERAD-Plus: First, as the CERAD-Plus is an assembly of subtests that are evaluated and interpreted independently from each other, the test does not provide a total score. To arrive at a total score, we tentatively used the factor score of a one-factor solution, which resulted from a factor analysis of the CERAD subtests. However, in our sample this factor only explained 53 percent of the variance of all CERAD-Plus subscores and hence may not be a truly representative measure of the participants' total CERAD performance. Second, due to established criteria, our diagnoses of MCI and mild dementia partly relied on the participants' CERAD-Plus test profile.

Although cognitively healthy control patients experienced virtually no difficulties with the completion of the tasks, no ceiling effects occurred in this sample when using the BDST in contrast to the MMSE (the average BDST score was nearby two standard deviations below the BDST's maximum score, whereas the average MMSE score obtained in our sample was less than one standard deviation below MMSE's maximum score). Furthermore, no floor effects for subjects suffering from moderate dementia could be detected as these participants still reached an average score of 22. Thus, the BDST allows for testing over a wide range of performance levels of both weakly and strongly impaired individuals, which advises its use in geriatric patients. Furthermore, administration of the BDST does not require investigators to ask very basic questions about spatial and temporal orientation, which might be experienced as humiliating and stressful by patients suffering from dementia (Milian et al., 2012).

No effect of gender, but a weak – albeit statistically significant – correlation of educational level and age with BDST performance could be found. In theory, a screening measure should be independent of age and education (Borson et al., 2000). However, age and educational level are well documented "risk factors" for cognitive decline. Thus, the more sensitive a measure is for the development of dementia, the higher is its risk of being affected by these two factors. To figure out, whether age and education are predictors of BDST performance independent from cognitive status, we conducted a stepwise regression analysis with CERAD scores as well as gender, age and education as possible predictors of BDST test scores. As expected, BDST scores were solely predicted by cognitive status, which indicates that BDST performance is determined by cognitive factors more than by demographic parameters. This matches the claims for a screening instrument.

One limitation of the present study is that the overall sample size – at least for evaluating the diagnostic accuracy of the BDST – might have been too small, especially regarding the number of cognitively healthy control subjects. This was due to our objectives to thoroughly screen all potential control subjects by using an extensive cognitive screening battery and to recruit only an inpatient clinical control sample. Often, family members or hospital staff members were only screened very briefly and recruited as controls subjects. Nevertheless, future investigations should include larger control samples. Ideally, our results regarding the diagnostic accuracy of the BDST in mild dementia and mild cognitive impairment should be replicated in an independent dataset, using the cut-off scores determined in our present study.

Another not finally answered question is whether cognitive profiles can be extracted on the basis of BDST subscores. For example, patients suffering from frontotemporal dementia tend to be impaired in cognitive planning and/or speech production while showing only minor memory deficits in early stages of illness (Pachana, Boone, Miller, Cummings & Berman, 1996). As the results of the factor analysis have provided evidence that the BDST covers multiple independent cognitive dimensions, future studies could investigate, whether the patients with frontotemporal dementia might be discriminated from patients suffering from Alzheimer's disease by profiles based on their BDST scores. Unfortunately, our subsample of mild dementia patients was too small to conduct such analyses. This issue is particularly important because the use of variable but routine groupings of single tests for different types of patients in a flexible and adaptive manner has become increasingly popular among neuropsychologists (Sweet, Nelson & Moberg, 2006; Sweet, Meyer, Nelson & Moberg, 2011). For the differential diagnosis of depression versus dementia Jahn et al. (2004) could show that such a "flexible battery approach" (Sweet, Moberg & Suchy, 2000) is superior to the CERAD test battery. Even single BDST Subtests might therefore be potential candidates for future integration into small test batteries than can be flexibly administered to dementia patients.

Our analyses point to different qualifications of the BDST subtests to differentiate between the degrees of severity of dementia. This aspect has already been considered in the development of an "MCI-score", considering only subtests that differentiate best between MCI patients and unimpaired control patients. Moreover, the semantic and verbal memory tasks seem to differentiate best between mild and moderate dementia. Future versions of the BDST could therefore provide different cut-off scores for differential diagnoses between various diagnostic groups of dementia. Treatment regimens suggested by current guidelines differ substantially for mild and moderate forms of dementia. Once dementia has been diagnosed, maybe an even briefer version of the test might be sufficient to evaluate progression from mild to moderate conditions in the course of illness.

In sum, this study yields first, but strong evidence that "true bedside" measures like the BDST that are well applicable to geriatric patients may qualify as valid and reliable screening measures for the diagnosis of dementia. At the moment, since positive evidence is still too preliminary, the BDST should not be used alone in primary care or geriatric settings. However, the results presented above indicate that administration of the BDST in addition to standard or screening neuropsychological test batteries may reveal valuable information, especially in cases, where it is difficult to administer standard screening measures for dementia.

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