ORIGINAL ARTICLE

Psychometric Evaluation of Neglect Assessment Reveals Motor-Exploratory Predictor of Functional Disability in Acute-Stage Spatial Neglect

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ABSTRACT. Goedert KM, Chen P, Botticello A, Masmela JR, Adler U, Barrett AM. Psychometric evaluation of neglect assessment reveals motor-exploratory predictor of functional disability in acute-stage spatial neglect. Arch Phys Med Rehabil 2012;93:137-42.

Objective: To determine the psychometric properties of 2 neglect measures, the Behavioral Inattention Test (BIT)-conventional and the Catherine Bergego Scale (CBS), in acute spatial neglect. Spatial neglect is a failure or slowness to respond, orient, or initiate action toward contralesional stimuli, associated with functional disability that impedes stroke recovery. Early identification of specific neglect deficits may identify patients likely to experience chronic disability. However, psychometric evaluation of assessments has focused on subacute/chronic populations.

Design: Correlational/psychometric study.

Setting: Inpatient rehabilitation hospital.

Participants: Screening identified 51 consecutive patients with a right-hemisphere stroke with left neglect (BIT score <129 or CBS score >11) tested an average of 22.3 days poststroke.

Interventions: Not applicable.

Main Outcome Measures: We obtained BIT, CBS, and Barthel Index assessments for each participant and clinical and laboratory measures of perceptual-attentional and motor-intentional deficits.

Results: The BIT showed good reliability and loaded onto a single factor. Consistent with our theoretical prediction, principal components analysis of the CBS identified 2 underlying factors: Where perceptual-attentional items (CBS-PA) and embodied, motor-exploratory items (CBS-ME). The CBS-ME uniquely predicted deficits in activities of daily living (ADLs) assessed by using the Barthel Index, but did not predict clinical and laboratory assessments of motor-intentional bias. More severe neglect on the CBS-PA correlated with greater Where perceptual-attentional bias on clinical and laboratory tests, but did not uniquely predict deficits in ADLs.

Conclusions: Our results indicate that assessments of spatial neglect may be used to detect specific motor-exploratory deficits in spatial neglect. Obtaining CBS-ME scores routinely might improve the detection of acute-stage patients with spatial action deficits requiring increased assistance that may persist to the chronic stage.

Key Words: Assessment; Neglect; Psychometrics; Rehabilitation; Stroke.

SPATIAL NEGLECT, a functionally disabling failure or slowness to respond, orient, or initiate action toward contralesional stimuli,[1,2] impairs stroke rehabilitation and recovery.[3] In patients with acute stroke, neglect may better predict the extent of right-brain stroke damage than the National Institutes of Health Stroke Scale.[4] Acute-stage neglect detection and intervention may improve the recovery prospects of affected patients,[3,5] potentially saving hundreds of thousands of dollars in acute-care costs annually.[6] Unfortunately, neglect is underidentified and underassessed acutely.[7]

Two tests appear appropriate for reliable and valid neglect assessment. The Behavioral Inattention Test (BIT)-conventional[8] is a 6-item paper-and-pencil test with established test-retest reliability in subacute patients (2–18mo postevent).[9] The test has validly discriminated among controls and patients with left- and right-brain damage and is related to performance of activities of daily living (ADLs).[9] In addition, it proved unidimensional (ie, assessing a single factor) in a sample of subacute and chronic patients.[10] Recent psychometric assessment of the BIT using dichotomized versions of the subtest scores showed inadequate reliability[11] in an acute sample (<2mo postevent). However, a shortened version proved reliable and unidimensional.

The Catherine Bergego Scale (CBS)[12] is a 10-item instrument typically completed by a therapist after observing a

List of Abbreviations

ADL	activity of daily living
BIT	Behavioral Inattention Test-conventional
CBS	Catherine Bergego Scale
CBS-ME	Catherine Bergego Scale Motor-Exploratory subscale
CBS-PA	Catherine Bergego Scale Perceptual-Attentional subscale
DSS	double simultaneous stimulation
LMP	lateralized motor performance
PCA	principal components analysis

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patient perform common activities, such as grooming and eating (eg, patients with left neglect may fail to groom the left side of the face). Psychometric assessments of the CBS in patients with subacute and chronic right-brain damage showed good internal consistency, validity (ie, predictive of ADLs),[12] and unidimensionality.[13]

Both the BIT and CBS can be used to detect neglect. However, the brain-behavior dysfunction responsible for spatial errors may occur at more than 1 stage of cognitive processing: classically, patients are expected to experience selective disability in perceptual-attentional "Where" systems, showing profound difficulty perceiving and attending to contralesional stimuli. However, patients also may make motor-intentional "Aiming" spatial errors, showing difficulty initiating actions toward or in the contralesional side of space.[1,14-16] Some research suggested that a motor-intentional component may underlie chronic disability in neglect.[17]

PRESENT STUDY

Although the psychometric properties of the BIT and CBS were established for subacute and chronic populations,[9-13] their properties at the acute stage of poststroke recovery are still largely undetermined. These tests may not show the same properties at the acute stage. In particular, if the BIT or CBS allowed the examiner to assess distinct perceptual Where or motor-intentional Aiming components of spatial errors at the acute stage, it might help identify patients most likely to have persistent disability[17] and help triage patients for targeted treatment plans.[18]

We explored the factor structure of the BIT and CBS in an acute (<2mo poststroke) left-neglect population. Additionally, we considered that BIT and CBS items might assess similar latent constructs and thus performed combined principal components analysis (PCA) of the 2 tests. Finally, to determine the validity of any identified components, we assessed relations among the BIT, CBS, and clinical assessments of perceptual-attentional (double simultaneous stimulation [DSS]) and motor-intentional dysfunction (lateralized motor performance), as well as their relation to a laboratory line bisection task used to decouple Where and Aiming errors.[2,14]

METHODS

This research was approved by the institutional review board. A consecutive sample of 57 patients with acute right-hemisphere stroke from inpatient rehabilitation facilities met the inclusion criteria, gave informed consent, and completed left-neglect screening. Eligible patients were premorbidly right-handed,[19] had no previous neurologic damage or psychiatric conditions, and were not currently using psychiatric medication. Screening identified 51 participants (27 women) with left neglect (BIT score <129 or CBS score >11) who were retained for analysis (see table 1 for participant characteristics). All participants were assessed on the CBS and BIT. Subsets of participants received additional testing.

Behavioral Inattention Test (N=51)

The BIT[8] consists of 6 subtests: line crossing, letter cancellation, star cancellation, figure/shape copying, line bisection, and representational drawing (see Halligan et al[9] for description). Higher scores on the BIT indicate better functioning (range, 0–146).

Catherine Bergego Scale (N=51)

The CBS[12] is a 10-item scale reflecting therapists' ratings of participants' performance for stimuli and actions to the left (for complete text of items, see Azouvi et al[12]). Items are scored on a 0 to 3 scale of severity, with 0 indicating no neglect and 3 indicating severe neglect. Lower scores on the CBS indicate better functioning (range, 0–30).

Table 1: Participant Characteristics

Measure	Mean ± SD	Range
Days poststroke	22.3±10.9	9 to 61
Age (y)	66.9±15.9	28 to 90
Education (y)	13.2±3.2	6 to 20
BIT	66.2±44.8	11 to 137
CBS	19.3±6.7	2 to 30
CBS-PA	1.7±0.8	0.17 to 3.0
CBS-ME	2.3±0.7	0 to 3.0
Barthel Index	26.1±24.1	0 to 95
DSS-total	5.9±4.8	0 to 15
DSS-visual	1.6±2.0	0 to 5
DSS-auditory	2.30±2.2	0 to 5
DSS-tactile	2.0±2.1	0 to 5
LMP	0.01±0.11	−0.23 to 0.28
Where bias	5.8±24.1	−35.35 to 78.16
Aiming bias	2.5±15.1	−14.67 to 56.66

Barthel Index (N=49)

The Barthel Index, completed by participants' nurses and therapists, assesses participants' independence in ADLs. Higher scores indicate greater independence (range, 0–100).

Lateralized Motor Performance (N=29)

We created an assessment of hemispatial hypokinesia based on a previously-used motor-intentional assessment.[20] Participants used the right hand to click a golf counter as many times as possible in 30 seconds in both left and right space. Lateralized motor performance (LMP) was calculated as follows:

$$\mathrm{LMP} = \left(\frac{\text{Right Clicks}}{\text{Total Clicks}}\right) - \left(\frac{\text{Left Clicks}}{\text{Total Clicks}}\right) \quad (1)$$

Scores range from −1.0 to 1.0 (positive values indicate rightward bias, negative values indicate leftward bias).

Double Simultaneous Stimulation (N=47)

Extinction to DSS was tested in 3 modalities: vision, auditory, and tactile. For vision, the examiner stood centered at the participant's body midline with both hands raised. Across 15 trials, the examiner raised right, left, or both index fingers. While looking at the examiner's nose, the participant indicated which fingers moved. For auditory DSS, the examiner sat behind the participant and snapped her fingers near the participant's ears. For tactile DSS, the examiner touched the participant's hands while the participant's eyes were closed. In each modality, 5 trials of each type (left, right, bilateral) were performed and the number of correct bilateral detections was summed.

Fractionated Where and Aiming Measures (N=23)

Participants sat at a computer monitor and bisected horizontal lines (subtending 23.6° visual angle) under both normal and reversed viewing conditions.[2] In both conditions, lines appeared 1 at a time and participants clicked on the line's apparent center by using a wireless mouse held in the right hand. Participants' vision of the hand was occluded by a wooden shelf. In the normal viewing condition, the cursor moved in the

same direction as the mouse. Under reversed conditions, visual feedback was left-right reversed such that rightward movements of the mouse resulted in leftward movements of the cursor and vice versa. We fractionated each participant's line bisection error into its Where and Aiming components by using the following equations:

$$\text{Normal Viewing Error} = \text{Where} + \text{Aiming} \quad (2)$$

$$\text{Reversed Viewing Error} = \text{Aiming} - \text{Where} \quad (3)$$

In the computerized line bisection task, rightward errors may be related to either perceptual-attentional Where unawareness, motor-intentional Aiming spatial bias, or some combination of both problems. Under normal viewing conditions, visually perceived right and left are aligned with right and left movement. Thus, the effects of Where and Aiming bias are additive (as in equation 2). However, when visual feedback of the cursor movement is right-left reversed (relative to the participant's actual movement in the workspace), Where perceptual-attentional feedback is reversed. As a result, participants show a reversal of the visual-feedback–dependent Where perceptual-attentional errors (hence the subtraction in equation 3). By solving for Where and Aiming spatial bias using equations 2 and 3, we can separately quantify the perceptual-attentional Where and motor-intentional Aiming contributions to line bisection bias.

Analysis Plan

Our analysis goals were 3-fold.

Goal 1. First, we wished to determine the reliability and factor structure of the BIT and CBS in an acute sample. We assessed the reliability of the BIT and CBS with coefficient α. Because BIT items are measured on different scales, the items were standardized based on this sample's mean and SD values before the reliability analysis. The factor structure of both scales was assessed by using PCA with varimax (ie, orthogonal) rotation using PASW 18.0.[a] We retained as factors components with eigenvalues greater than 1.0. When the analysis identified more than 1 factor, items were assigned to the factor on which they loaded most strongly, given that factor loading was at least .40.[21] Because CBS items are ordinal rather than interval-level data, we conducted a Rasch analysis using Winsteps 3.70.0.2[b] to confirm the dimensionality of the CBS as identified by using PCA. Rasch analysis yields a single interval-level measure from ordinal-level raw data, with difficulty scores for each item and ability scores for each participant. However, Rasch analysis assumes that the items form a unidimensional scale.[22] We tested this assumption within the Rasch analysis by performing PCA of the residual variability unaccounted for by the Rasch measure. Any systematic factors in the residuals would suggest multidimensionality in the CBS scale. We did not apply Rasch analyses to the BIT: some BIT items are already interval measures and therefore are not appropriate for use under the Rasch model.

Goal 2. We wished to determine whether the BIT and CBS assess the same underlying constructs. We performed a single PCA as described for goal 1, but included items from both tests. We reverse-coded the CBS items so that higher scores indicated better function on both scales. The use of PCA to address goal 2 was contingent on Rasch confirmation of the CBS PCA identified under goal 1. Such confirmation would suggest that the PCA was appropriate for use with CBS items.

Goal 3. We wished to validate the BIT and CBS (or any identified subscales) by assessing their relation to laboratory and clinical assessments of perceptual-attentional and motor-intentional bias, as well as their relation to functional activities (Barthel Index). We performed partial correlations among the assessments controlling for age and days poststroke. In addition, we performed stepwise regression with BIT and CBS (or their subscales) as predictors and the Barthel Index as the outcome.

Table 2: PCA of the BIT

Item	Factor Loading	Communality
Letter cancellation	.93	.87
Star cancellation	.93	.86
Line crossing	.91	.82
Copying	.85	.73
Representational drawing	.84	.70
Line bisection	.73	.54

Hypotheses for Relations Among Neglect Measures

Visual and auditory DSS may be primarily perceptual-attentional tasks and thus correlated with the Where spatial bias component. With its lateralized motor demands, the LMP was expected to correlate with Aiming bias. Because tactile DSS may be associated with somesthetic-motor function, it may be related to both Where and Aiming bias components.[1,18,23] If we identified perceptual-attentional or motor-intentional components of the BIT or CBS, we expected these to correlate with Where and Aiming spatial biases, respectively.

RESULTS

Behavioral Inattention Test

The scale had good reliability (α=.93), which improved further with removal of the line bisection item (α=.94). PCA yielded a single factor accounting for 75.3% of the variance (table 2). The line bisection item had very poor communality (.54) compared with other items on the scale (≥.70).

Catherine Bergego Scale

The CBS showed good reliability (α=.90) among the 10 scale items. PCA identified 2 factors (table 3). The first factor accounted for 52.8% of the variance and consisted of items assessing perceptual-attentional deficits. The second factor ac-

Table 3: PCA of the CBS

Factor	Factor 1 Loading	Factor 2 Loading
Factor 1: PA items		
Finding belongings	.84	.12
Eating food	.77	.41
Cleaning mouth after eating	.77	.12
Attending to noise or people addressing from left	.75	.30
Spontaneously looking	.69	.08
Grooming face	.65	.39
Factor 2: ME items		
Collides with people or objects	.22	.85
Adjusting sleeve/slipper/pant leg	.20	.84
Forgets parts of body	.07	.79
Finding way on left when traveling in familiar places	.40	.76

Table 4: Rasch Statistics and PCA of Standardized Residuals

Item	Difficulty (logits)	Infit Mnsq	Outfit Mnsq	Pt Bis Correlation	PCA of Residuals: Loading on 1st Contrast
Grooming face	1.56	0.95	0.91	.79	−.19
Cleaning mouth	1.19	1.11	1.05	.71	−.55
Attending to noise or people	0.66	0.80	0.78	.78	−.40
Eating food	0.75	0.56	0.56	.80	−.51
Finding belongings	−0.34	1.25	1.29	.61	−.52
Spontaneously looking	−0.43	1.19	1.08	.63	−.19
Forgets to use parts of body	−0.85	1.36	1.30	.57	.45
Finding way on left	−0.76	0.84	0.68	.67	.59
Collides with people or objects	−0.86	1.06	1.08	.59	.78
Adjusting sleeve/slipper/pants	−0.93	0.86	0.86	.66	.51

Abbreviations: Mnsq, means square; Pt Bis, point biserial correlation of the item with the Rasch measure.

counted for 14.4% of the variance and consisted of items potentially assessing embodied motor-exploratory deficits.

Rasch analysis confirmed the multidimensionality of the CBS scale (see table 4 for Rasch item statistics). Although the Rasch measure accounted for 56.0% of the variance in the raw CBS item scores, PCA of the unexplained variance identified 1 contrast that accounted for an additional 10.9%. In this residual contrast, embodied motor-exploratory items had positive factor loadings of .40 or greater, whereas the remaining perceptual-attentional items loaded negatively (see right-most column of table 4). This pattern of factor loadings confirms the existence of 2 distinct underlying constructs, potentially corresponding to perceptual-attentional and motor-exploratory components.

Combined PCA of the CBS

This PCA showed a 3-factor solution identical to the factor solutions arrived at through separate PCAs of the scales. The BIT emerged as the first factor, accounting for 47.6% of the variance. The CBS perceptual-attentional (CBS-PA) items emerged as the second factor, accounting for 14.4% of the variance, and the CBS motor-exploratory (CBS-ME) items emerged as the third factor, accounting for 9.2% of the variance.

Associations Between Neglect Measures and Behavioral Tests

We created perceptual-attentional (CBS-PA) and motor-exploratory (CBS-ME) CBS subscores by taking the average of the 6 perceptual-attentional and 4 motor-exploratory items. As listed in table 5, better performance on the BIT was associated with better detection on visual and tactile DSS, but the BIT was not related to other assessments.

We found support for our suggestion that CBS-PA items assess perceptual-attentional deficits. These scores predicted performance on perceptual-attentional behavioral tests: more severe CBS-PA was associated with poorer detection performance on the visual and tactile DSS and more rightward Where bias. However, the CBS-ME was not related to Aiming or other motor-intentional bias assessments, although it was predictive of tactile DSS.

Table 5: Partial Correlations Among Measures, Controlling for Age and Days Poststroke

Variable	BIT	CBS-PA	CBS-ME
DSS-visual	.46*	−.44*	−.15
DSS-auditory	−.05	−.13	−.07
DSS-tactile	.35†	−.49*	−.40*
LMP	.11	−.24	−.16
Where	−.09	.45†	.23
Aiming	.08	−.11	−.11
Barthel Index	.40‡	−.33†	−.43*

NOTE. Higher scores on the BIT, DSS, and Barthel Index indicate better performance. For all others, lower scores indicate either better performance or less rightward bias.
*$P<.001$; †$P<.05$; ‡$P<.01$.

Predictors of ADLs (Barthel Index)

We assessed the relation between neglect tests and scores on the Barthel Index, controlling for age and number of days postevent. The CBS-ME was related strongly to Barthel Index scores, as was the BIT and, to a lesser extent, the CBS-PA (see table 5). To test how each uniquely predicted ADLs, we performed stepwise multiple regression. Both the BIT ($\beta=.563$; $P<.001$) and the CBS-ME ($\beta=-.347$; $P=.010$), but not the CBS-PA ($\beta=-.041$; $P=.780$), emerged as significant predictors of Barthel Index scores ($R^2=.41$; $F_{2,46}=15.9$; $P<.001$), with the BIT accounting for 31.7% of the variance. The CBS-ME uniquely accounted for an additional 9.2% of the variance.

DISCUSSION

In an acute sample of patients with left neglect, we showed that the CBS, a functional neglect assessment, potentially includes 2 distinct underlying constructs: 1 perceptual-attentional (CBS-PA) and 1 associated with embodied motor-exploratory bias (CBS-ME). This result is consistent with multiple spatial cognitive systems[1,14,16] potentially producing neglect symptoms. Previous research suggested that identifying the mechanisms of spatial dysfunction in acute patients may help identify patients likely to experience chronic disability and need of increased caregiver assistance.[17] The CBS-PA and -ME also might assist in triaging patients for targeted treatment programs.[18]

Previous studies identified a single CBS factor,[11,12] but this psychometric research did not include acute patients, for whom stroke care costs are greatest[6] and standardized assessment and intervention[5] are feasible in our present system of care. Others suggested review of individual CBS items as a method for stratifying patients.[24] However, in the absence of evidence regarding item-construct relationships, obtaining CBS-PA and CBS-ME subscores may be more valid. In addition, we found that motor-exploratory deficits uniquely

predicted functional disability. Because motor deficits may be associated with chronic persistence of neglect,[17] the CBS-ME may improve the detection of individuals most likely to require increased assistance (eg, long-term nursing care). Clinicians assessing visual-spatial attention and awareness, apparently measured by the BIT and CBS-PA items, may not be able to detect embodied motor-exploratory spatial deficits, potentially salient to care, recovery, and response to rehabilitation treatments.

Perhaps surprisingly, scores on the CBS-ME were not related to other behavioral motor-intentional measures (lateralized motor performance or rightward Aiming bias on computerized line bisection). However, there may be multiple spatial motor output systems.[16] Aiming line bisection bias, assessing directional hypokinesia, and LMP, assessing movement in left versus right hemispace, may both measure propensity to move in peripersonal action space. In contrast, CBS-ME items may measure the integrity of a whole-body egocentric reference frame that supports continuous computation and awareness of body center relative to the environment.[25,26] These spatial motor representations (peripersonal action-space and whole body) are dissociable in healthy individuals[26] and may dissociate in the performance of neglect patients. Consistent with this idea, better performance on the CBS-ME was associated with better performance on the DSS-tactile: Recent research showed tactile representations to be partially dependent on whole-body postural representations.[23]

Although our results challenge the unidimensionality of the CBS in acute neglect, we replicated previous work that reported the BIT to be unidimensional.[10,11] Although we do not know why the line bisection item of the BIT had poor communality, patients bisect several lines on 1 page, perhaps inducing perseveration. Future work in a larger sample of acute patients should assess the appropriateness of inclusion of the line bisection item on the BIT. Finally, simultaneous PCA of the BIT and CBS showed that they assess distinct underlying constructs, suggesting the value of retention and use of both scales to accurately identify neglect subcomponents. Although the BIT no doubt recruits both perceptual and spatial-cognitive motor systems, the CBS subscales may assess unique aspects of perceptual and motor dysfunction. Furthermore, the CBS subscales provide separate quantification of these aspects of neglect.

Study Limitations

The present study identified a distinctive motor-exploratory component to the CBS, and the work of others suggested that persistence to the chronic stage of neglect may be associated with spatial motor deficits.[17] However, the present study did not directly show that the CBS-ME subscale is predictive of persistence to the chronic stage. Prospective research is needed to determine whether deficits of embodied motor exploration may be predictive of chronic disability. Furthermore, future research could further assess the validity of the ME component of the CBS by including measures of whole-body spatial bias (eg, postural measures). Last, it will be important to replicate the factor solution of the CBS-PA and CBS-ME in large populations broadly representative of stroke survivors, as well as explore the effects of potential moderating variables on the stability of that factor structure.

CONCLUSIONS

We propose that an ME subscale of the CBS may characterize spatial neglect after acute stroke and optimally identify functional dependence. Future work needs to explore the extent to which this dimension of motor-exploratory bias may predict chronic neglect and disability, as well as its ability to predict treatment response.[18] Despite a paucity of research on acute-stage interventions, recent work suggested that they hold promise,[5] and given the high cost of acute-stage care,[6] reducing the acute-care burden is of vital importance.

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Suppliers

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