INTRODUCTION

Spatial neglect is a neurocognitive disorder, affecting perception, representation, and/or motor planning. Neglect dyslexia in spatial neglect after right hemisphere damage (RHD) may co-occur with, or be dissociated from, other spatial neglect signs (Arduino, Daini, & Silveri, 2005; Lee et al., 2009; Vallar, Burani, & Arduino, 2010). Previous neglect dyslexia research focused on word-level stimuli and reading errors, primarily identifying letter omissions and substitutions to the left of the word midpoint (Ellis, Flude, & Young, 1987). However, functional materials may be more challenging to read (greater spatial extent of sentences and paragraphs, versus words). Although experimental studies that focus on reading at the single-word level may ask interesting theoretical questions regarding the sources of errors in the reading stages and systems, it is not often in the real-world that people read single words in isolation.

We hypothesized that assessment materials with ecological validity such as reading a menu and reading an article would be more reflective of the degree to which reading errors and neglect dyslexia was detected in individuals with RHD than assessments that contained only single words or short phrases, which are rarely read in isolation in everyday life.

Methods

Participants

Sixty-seven patients (21 female, 46 male) who had sustained either an infarction or an intracerebral hemorrhage, as documented in their medical charts, within two months of admission to an inpatient rehabilitation facility participated in the study. Table 1 summarizes their demographic and baseline characteristics.

Tests for Spatial Neglect

All participants were administered a spatial neglect test battery that consisted of the Behavior Inattention Test (BIT) (Wilson, Cockburn, & Halligan, 1987) and the Catherine Bergego Scale (CBS) (Azouvi et al., 1996) via the Kessler Foundation Neglect Assessment Process (KF-NAP) (Chen, Hreha, Fortis, Goedert, & Barrett, 2012).

Tests for Neglect Dyslexia

Participants read 72 single-words, 20 two-word phrases, a 4-column menu (2 columns per page), and a 3-column article.

Words. Two words lists were alternately administered to participants. Words consisted of 4, 6, or 8 letters and 1-4 syllables, and word lists did not differ in frequency.

Two-word Phrases. Two phrase lists from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) (Kay, Lesser, & Coltheart, 1992) were alternately administered to participants.

Article. The two articles from the optional additional Article subtest of the BIT were alternately administered to participants.

Menu. The two menus from the optional additional Menu subtest of the BIT were alternately administered to participants. The menu contained left and right letter-sized pages, opening like a book.

Procedures

Two examiners were present for testing.

Words and Phrases. Each trial started with one PowerPoint slide with a colored dot, followed with a slide with a word or a phrase, and immediately a blank slide once the participant initiated vocalization of the word or phrase, then a colored dot, followed with a word or phrase, followed immediately by a blank slide. As soon as the participant began production of the color/word/phrase, Examiner 1 immediately clicked the mouse so the participant did not have time to rethink his/her response. Examiner 2 wrote down what the participant said and scored the participant as correct or incorrect on the scoring sheet.

Article and Menu.

The article and the menu were each placed in midline on the desk in front of the participant. Examiner 1 was seated behind the participant and had a copy of the testing material. Examiner 1 scored the material as the participant read aloud.

Test Scoring

Percent correct and percent neglect-related error scores were determined.

Results

Statistical analysis was performed fitting mixed-effects logistic regression to performance accuracy. We started building the level-1 model by adding the task type variable (Article task as a reference level) to the null model, which improved the model fit ($\chi^2(3) = 33.49$, $p < 0.001$). Building the subject-level model, we included MMSE as a covariate to control for the general cognitive impairment; given its relevance, MMSE was the only variable that was kept in the model regardless of its statistical significance. The CBS-BIT combined measure, as an index of neglect severity (see Table 2), improved the model fit ($\chi^2(1) = 52.79$, $p < 0.001$), but not its interaction with task type ($\chi^2(3) = 0.24$, $p = 0.97$), indicating that the effect of the type of task on performance accuracy was not moderated by neglect severity. The effects and interactions of other potentially relevant covariates were also tested: age, education, days post-stroke, and gender. None of these effects improved the model fit. The model that was selected as final is shown in Table 3.

In sum, based on the final model (Table 3), both task type and neglect severity (CBS-BIT) have a significant effect on performance accuracy. The estimated percentage accuracy for the Article task is 52%. Predicted accuracy for Menu, Phrase, and Word are 70%, 93%, and 89% respectively (Figure 1). A pre-planned contrast was run to test the directional hypothesis that, on average, performance on the Menu and Article tasks would be significantly poorer than performance on the Phrase and Word tasks. Table 4 shows that this contrast is highly significant and that our hypothesis has strong support.

Neglect severity, as indicated by the CBS-BIT variable, resulted to have an overall highly significant effect on performance accuracy, but, as previously mentioned, did not moderate the effect of task type on the outcome. For example, a point increase in CBS-BIT score, from 0 to 1 (+1.1 SD), produced .35 (65%) estimated drop in accuracy for Article; .38 (54%) decrease in accuracy for Menu; .19 (20%) decrease in accuracy for Phrase; .26 (29%) decrease in accuracy for the Word task (Figure 2).

Hierarchical regression analysis

To further investigate the relationship between neglect severity and task type we conducted a hierarchical regression analysis with CBS-BIT as the dependent variable. After controlling for general cognitive impairment, we entered variables in a theoretically constrained order: first we entered Article and Menu, which we predicted to be a better indicator of the neglect severity for its close-to-everyday-life face value; then, we entered the more widely used measures Phrase and Word. This way it was possible to identify tasks that are able to make independent and significant contributions to the model. Results of the hierarchical regression analysis (see Stage-1 in Table 5) showed that Menu and Article predicted a large (53%) and significant proportion of the variance of neglect severity above the variance explained by the covariate MMSE. R squared change in step 3, where Phrase and Word were collectively entered into the equation, was not statistically significant.

Discussion

These findings provide evidence for a strong relationship between Menu and Article and neglect severity. Phrase and Word did not explain a significant amount of variance over and above that explained by Menu and Article. Therefore, in comparison to single words or two-word phrases, texts with ecological value such as multi-columned menus and articles present a significant difficulty to persons with spatial neglect. The current result provides strong evidence that spatial neglect is disabling in everyday reading behavior, which may in turn have substantial negative consequences in patients' leisure activities, social interaction, and overall well-being. Future studies should evaluate whether treatment, as well as assessment, would be more functionally effective when using spatially extensive stimuli.

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Table 1. Descriptive statistics (N = 67).

	Mean(SD)	Min	Max
Age in years	66.87(12.97)	28	90
MMSE	23.66(4)	11	30
Education in years	13.93(3.2)	5	21
Days post-stroke	18.66(9.59)	2	48
BIT	77.94(43.95)	8	143
CBS	15.57(8.57)	0	29
CBS-BIT	0(0.94)	-1.6	1.51
Article	0.51(0.38)	0	1
Menu	0.63(0.34)	0	1
Phrase	0.87(0.25)	0.1	1
Word	0.82(0.28)	0.04	1

Note. MMSE = Mini Mental Status Examination; BIT = Behavior Inattention Test; CBS = Catherine Bergego Scale; CBS-BIT = mean of CBS standardized z-scores and additive inverse of BIT standardized z-scores; Phrase, Word, Menu, and Article = see text for description.

Table 2. Correspondence between CBS-BIT scores and estimated BIT and CBS scores (95% CI in square brackets). Estimated scores were obtained regressing BIT and CBS on the combined CBS-BIT variable. The two variables were combined because of their strong linear correlation ($r = -.75$, $p < .001$).

Variable	MIN	-1 SD	Mean	+1 SD	MAX
CBS-BIT	-1.6	-0.94	0	0.94	1.51
BIT	[140.4, 155.3]	[113.7, 124.4]	[74.2, 81.71]	[31.51, 42.21]	[4.78, 19.12]
CBS	[0.47, 3.39]	[6.51, 8.6]	[14.83, 16.3]	[22.54, 24.62]	[27.04, 29.84]

Note. BIT = Behavior Inattention Test; CBS = Catherine Bergego Scale; CBS-BIT = mean of CBS standardized z-scores and additive inverse of BIT standardized z-scores. For both the regression of BIT on CBS-BIT and CBS on CBS-BIT: N = 67, $R^2 = .87$, $F(1,65) = 449.5$, $p < .001$.

Table 3. Summary of generalized mixed-effects final model for performance Accuracy.

Fixed effects	Estimate	Std. Error	*z*	*p*
Intercept	0.12	0.31	0.388	0.698
MMSE	0.06	0.046	1.266	0.206
Menu	0.751	0.443	1.696	0.09
Phrase	2.609	0.536	4.869	<.001
Word	2.08	0.496	4.196	<.001
CBS-BIT	-1.614	0.252	-6.408	<.001
Random effects	Variance	Std. Dev.		
Intercept	0	0		

Note. MMSE = Mini Mental Status Examination (grand mean centered); CBS-BIT = mean of CBS standardized z-scores and additive inverse of BIT standardized z-scores. Participants included as random effects.

Table 4. Post-hoc analyses for performance accuracy.

	Estimate	Std. Error	*z*	*p*
Contrast				
Phr.Word – Art.Menu <= 0	3.939	0.74	5.322	< 0.001
Comparison[a]				
Menu – Article = 0	0.751	0.443	1.69	0.324
Phrase – Article = 0	2.609	0.536	4.869	< 0.001
Word – Article = 0	2.08	0.496	4.196	< 0.001
Phrase – Menu = 0	1.858	0.519	3.58	0.002
Word – Menu = 0	1.33	0.481	2.77	0.029
Word – Phrase = 0	-0.528	0.539	-0.98	0.76

Note. [a]Tukey-HSD tests.

Table 5. Summary of hierarchical multiple regression analysis predicting neglect severity (CBS-BIT) scores.

STAGE-1

	Step 1		Step 2		Step 3	
Variable	Coef.(SE)	Beta	Coef.(SE)	Beta	Coef.(SE)	Beta
Intercept	0(.11)		1.29(.15)		1.29(.26)	
MMSE	-.09(.03)	-.4**	-.02(.02)	-.09	-.02(.02)	-.09
Menu			-1.48(.35)	-.54***	-1.54(.4)	-.56***
Article			-.69(.31)	-.28*	-.73(.32)	-.3*
Phrase					-.3(.6)	-.08
Word					.4(.63)	.12
R^2 (R^2 change)	.157(.157)		.683(.526)		.685(.002)	
F for R^2 change	12.07 ($p < .001$)		52.2 ($p < .001$)		0.19 ($p = .83$)	

STAGE-2

	Step 1		Step 2		Step 3	
Variable	Coef.(SE)	Beta	Coef.(SE)	Beta	Coef.(SE)	Beta
Intercept	0(.11)		1.32(.35)		1.29(.26)	
MMSE	-.09(.03)	-.4**	-.05(.02)	-.21*	-.02(.02)	-.09
Menu					-1.54(.4)	-.56***
Article					-.73(.32)	-.3*
Phrase			.61(.78)	.16	-.3(.6)	-.08
Word			-2.26(.7)	-.67**	.4(.63)	.12
R^2 (R^2 change)	.157(.157)		.411(.254)		.684(.274)	
F for R^2 change	12.07 ($p < .001$)		13.61($p < .001$)		26.44($p < .001$)	

Note. MMSE = Mini Mental Status Examination (grand mean centered). *$p < .05$, **$p < .01$, ***$p < .001$.

Figure 1. Predicted and observed performance accuracy by task type.

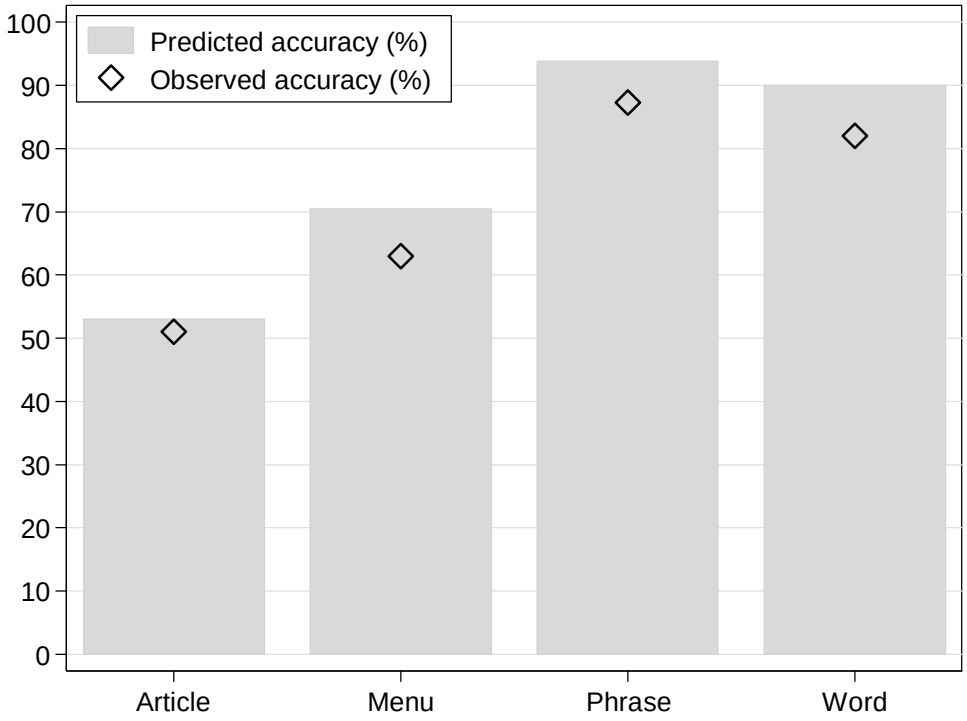

Figure 2. Predicted performance accuracy by task type and neglect severity (CBS-BIT) for average degree of general cognitive impairment (MMSE = 23.7).