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Breadth over depth in the semantic representations of adults with nonverbal learning disabilities

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ABSTRACT

Oral language in individuals with nonverbal learning disabilities (NLD) has been described as empty of meaning, despite apparently average word knowledge. The present study explored the hypothesis that depth but not breadth of semantic representations would be reduced in NLD, and that depth but not breadth would be related to nonverbal gestalt perception. A cross-sectional design compared breadth and depth of vocabulary in 50 adults with or without a diagnosis of NLD. Vocabulary results were also compared with a visual closure test. Participants with NLD had reduced vocabulary depth in comparison with controls. The NLD group also had lower scores for gestalt perception, the ability to perceive a meaningful whole from unrelated parts. Across the sample, this measure predicted scores for vocabulary depth, but not breadth. The NLD group was also less able than the Control group to estimate the size of unknown, physical features of everyday objects. Results supported clinical observations that semantic representations are unconventional and imprecise in individuals with NLD, and suggested specific cognitive underpinnings for such difficulties. Results were also compatible with separate theories of embodied and lateralized semantics. A proposal uniting these theories in a DESIGNATION OVER ELABORATION model is presented.

KEYWORDS: nonverbal learning disabilities, semantic representations, collocations, gestalt perception.

1. Introduction

Nonverbal learning disabilities (NLD) are learning disorders characterized by deficits in visual, spatial, and gestalt perception; perceptual reasoning; spatial working memory; social, self, and tactile perception; and fine and

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gross motor skills (Gross-Tsur, Shalev, Manor, & Amir, 1995; Mammarella & Cornoldi, 2014; Myklebust, 1975; Rourke, 1989; Semrud-Clikeman, Walkowiak, Wilkinson, & Christopher, 2010; Stothers & Klein, 2010). As this list suggests, NLD is most easily understood as a disorder of perceptual organization, cognitive processes that are usually measured without also measuring language. Verbal abilities in both children and adults are stronger in comparison, either intra-individually, or as compared to the population in general (Rourke & Tsatsanis, 1996; Stothers & Oram Cardy, 2016). In children with NLD, early facility with word learning and oral expression may be so exceptional as to mask the presence of a learning disorder (Stein, Klin, & Miller, 2004; Yalof, 2006). Overall, however, oral language is more variable in NLD than a simple contrast between weak nonverbal and strong verbal abilities might suggest.

1.1. WORD KNOWLEDGE IN NLD

Few empirical studies have addressed language in NLD, but evidence of uneven capabilities is available. A small, qualitative study of adults with NLD characterized oral language production as monologic, disorganized, and rehearsed (Gregg & Jackson, 1989). For example, participants solved interpersonal problems by repeating elaborate stories with unclear references to people, and to events. This kind of repetitive and ambiguous speech in clinical accounts of children with NLD has been termed COCKTAIL PARTY SYNDROME (CPS; Rourke, Ahmad, Collins, Hayman-Abello, Hayman-Abello, & Warriner, 2002; Rourke, Del Dotto, Rourke, & Casey, 1990; also cited in Davis & Broitman, 2011; Lajiness-O'Neill & Beaulieu, 2002; Rissman, 2011; Scheeringa, 2001). Early descriptions of CPS included "the use of many clichés and quotes, phrases out of context, and words without appropriate referents" (Horn, Lorch, Lorch, & Culatta, 1985, p. 713). Reports have also described fluent but tangential and irrelevant speech (Culatta & Young, 1992); the use of abstract terms without comprehension (Culatta & Young, 1992; Tew, 1979); and grammatically correct utterances in combination with better verbal than performance IQ (Horn et al., 1985).

The term CPS has been applied to children with NLD, but its use has been neither supported nor discounted by experimental research. Observations in a recent study (Stothers & Oram Cardy, 2016) included responses by participants with a diagnosis of NLD that typify CPS, including *a way to calculate objects*; *to enjoy our leisurely time*; and *the plutonic family dream*. The same individuals also correctly used words that occur less frequently in everyday conversation. A participant who said that an object *omits a sound* also used *predator* and *disciple* accurately. Another described words in sentences as being arranged from right to left, but used *ersatz* appropriately; another used *vestuble* [sic] to mean container,

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but correctly used *metamorphose* in context. CPS may be an apt way to characterize the use of incorrect words and phrases, but it does not also encompass the appropriate use of less-familiar words. A plausible account of these contrasting but contemporaneous qualities has yet to be proposed.

1.2. WHY MIGHT SEMANTIC REPRESENTATIONS DIFFER IN NLD?

Semantic representations are mental entries for spoken or written words that consist of meanings derived from multiple contexts. Qualities such as colour, odour, size, shape, texture, space, and weight, add depth to our semantic representations for objects and events, as does affordance information, or information about the ways in which objects may be used (Andrews, Vigliocco, & Vinson, 2009; Corrigan, 2008; Gupta & Tisdale, 2009; Ross, 2010; Schmitt, 2012). For example, a host of new terms may be linked with a single experience of information-seeking: *Is this thing alive, quiet, soft, heavy, slippery, edible, colourful, round, or dry*; *can I move it, open it, hear it*, and more. Semantic representations are built in part through exploration of objects and places, as individuals acquire details and connect these instantiations to existing representations. By this route, words develop through perception, or the organization and interpretation of sensory experience. In writing about NLD as a perceptual level disorder, Myklebust (1975) asserted that "[t]he meaning of verbal concepts is derived from nonverbal experience" (p.100). Thus, motor, tactile, and perceptual organizational weaknesses are hypothesized to disrupt exploration of the environment and the subsequent formation of semantic representations (Myklebust, 1975; Rourke, 1989; reviewed in Volden, 2004).

Studies that explore the effects on oral language of differences in perceptual organization in children with NLD support the hypothesis. In one study, children with NLD were asked to form mental representations of places by listening to descriptions of them (Mammarella, Meneghetti, Pazzaglia, Gitti, Gomez, & Cornoldi, 2009). Places were described either from a survey or a route perspective. Children with NLD had more difficulty verifying the descriptions based on an overhead view of spatial layouts (survey) than with descriptions based on the linear organization of landmarks (route), highlighting their difficulties with spatial over sequential reasoning in a linguistic task. In another study, children with NLD less frequently made inferences about spatial relationships implied in short vignettes than did typically developing controls (Worling, Humphries, & Tannock, 1999). Because participants had first demonstrated their understanding of spatial words on a receptive vocabulary test, the authors proposed that children with NLD struggled to integrate individual story elements. In a related study of story retelling, children with NLD correctly answered questions about the factual content of stories they heard, but

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made more errors than controls in judging the veracity of statements that were not explicitly stated in the stories (Humphries, Oram Cardy, & Worling, 2004). The authors suggested that perceptual organizational weaknesses in the NLD group impaired the ability to construct mental models of text, linking perceptual experience and semantic representations.

These results suggest a second source of difference in semantic representations for individuals with NLD. The creation of semantic representations is constructive, or integrative, regardless of the modality in which the input to be combined is encountered (Booth, Burman, Meyer, Gitelman, Parrish, & Mesulam, 2002; Coulson, 2006; Fauconnier & Turner, 1998). Cognitive processes used to make sense of information through integration, binding, or blending (Coulson, 2006; Dien, 2009; Fauconnier & Turner, 1998; van der Helm, 2012) appear to be impaired in NLD (Denckla, 1983; Grodzinsky, Forbes, & Holmes Bernstein, 2010; Gross-Tsur et al., 1995; Humphries et al., 2004; Rourke, 1989; Semrud-Clikeman & Hynd, 1990; Stothers & Klein, 2010; Stothers & Oram Cardy, 2016; Weintraub & Mesulam, 1983). In our study of adults with NLD, scores for tests of perceptual organization better predicted reading comprehension results than did breadth of vocabulary or tests of phonology (Stothers & Klein, 2010). We interpreted difficulties in the NLD group with arranging blocks and resolving incomplete figures as signs of an underlying weakness with the organization and integration of mental representations. This difficulty with integration, extending from nonverbal perceptual reasoning to forming semantic representations, is proposed here to be a source of reduced depth of vocabulary in individuals with NLD.

As noted, however, vocabulary breadth appears to be unaffected. It has been proposed that new vocabulary is neither consolidated nor integrated with other content as it is initially stored. Meanings are said to emerge through multiple exposures, as they are interwoven with other representations (Davis & Gaskell, 2009). It is possible that adults with NLD store novel words without these rich connections, using average or better lexical memory to compensate for the effects of perceptual organizational and integrative weaknesses on the depth of their vocabularies. Relying on memory to compensate for difficulties with integrating new experiences with existing semantic representations, however, suggests that, in these adults, words may remain as relatively constrained labels rather than fully articulated semantic representations.

Labels may simply be definitions that are limited in scope, or they may be COLLOCATIONS, a type of formulaic language consisting of pre-learned, predictable combinations of words that are retrieved as wholes from long-term memory (Molinaro & Carreiras, 2010). Adult post-secondary students diagnosed as having NLD have been found to use slightly altered

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formulaic expressions such as *freedom for expression* or *without impunity* (Stothers & Oram Cardy, 2016). Imprecise uses of collocations also suggest a reliance on memorization over comprehension. Once established, imprecise collocations may be less likely to be corrected in adults than in children, given social norms concerning polite conversation. In this way, the proposal that semantic representations differ in NLD can be reasonably extended to adults, as investigated in the current study.

It is proposed here that over time, the compounding of weaker perceptual reasoning, difficulty with conceptual blending, and memorization of words and phrases without full comprehension lead to the speech characterized as CPS. A reliance on word definitions would develop in conjunction with, and as a method of, compensating for nonverbal weaknesses. In turn, average, better than average, or even extraordinary breadth of representations would result from a preference for mediating the environment through language. Also, the combination of fewer opportunities for adding to semantic depth through exploration, and a reduced ability to integrate new semantic representations with previously existing ones, would result in reduced depth and imprecise, sometimes odd, semantic representations.

1.3. HOW MIGHT SEMANTIC REPRESENTATIONS DIFFER?

1.3.1. *Depth*

The first direct consequence of the hypothesis described above is that semantic representations in individuals who have perceptual organizational weaknesses will encompass fewer associations, synonyms, and related concepts as compared to those without such difficulties. Words with more than one meaning, or polysemous words, were used to determine whether participants with NLD would produce fewer discrete definitions than would participants without a learning disability.

1.3.2. *Collocations*

A second atypicality is suggested by the clichés and quotes characteristic of oral language production marked by CPS (Horn et al., 1985), and the observation of an ability to repeat conversations and prose verbatim in NLD (Rourke & Tsatsanis, 1996). Collocations may be used in familiar contexts with varying degrees of awareness or intent, as recognition of the word string appears to happen before meaning is accessed (Molinaro, Canal, Vespignani, Pesciarelli, & Cacciari, 2013). Here, any use of a collocation was probed to determine what the participant meant by the phrase. The frequency of collocations without precise or adequate semantic representations was also tallied.

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1.3.3 *Word stress*

Individuals with NLD are said to have difficulty with prosodic features of speech such as pitch, rhythm, and intonation (Gross-Tsur et al., 1995; Ris et al., 2007; Rourke et al., 1990). These difficulties include matching WORD STRESS HOMOGRAPHS to the contexts in which they appear (Stothers, 2016). Word stress homographs are words for which meaning depends on which syllable is stressed more heavily (Small, Simon, & Goldberg, 1988), for example: *The artist was known to appropriate comic strips in her paintings*, versus *The artist was happy to accept an appropriate offer for her comic strip paintings*. Disruptions to prosody, however, have rarely been the topic of research in NLD (cf. Weintraub & Mesulam, 1983). An exploratory, single word stress item was included as a potential source of reduced semantic depth.

1.3.4. *Perceptual experience*

Children with NLD in Myklebust's (1975) case studies struggled with estimating time, distance, weight, and other quantities (see also Gross-Tsur et al., 1995; Semrud-Clikeman & Hynd, 1990), suggesting difficulty with expressing physical experiences in words. A study of word knowledge in adults with NLD (Stothers & Oram Cardy, 2016) found that participants named shapes incorrectly, and were sometimes unable to articulate their understanding of affordances. Errors for word definitions that involved quantity and direction were also observed. Errors in this type of semantic representation appear to be a direct consequence of perceptual difficulties in NLD. In the present study, a verbal measure of cognitive estimation that included size, weight, and other material qualities was used to link perceptual experiences with semantic representations of the physical relationships between objects.

1.4. HYPOTHESES

In summary, the proposal that depth of semantic representations is reduced by perceptual organizational impairments was explored. Hypotheses included:

1. Adults with NLD have equal breadth of vocabulary in combination with less rich semantic representations in comparison with typical adults, demonstrated by (a) average standardized vocabulary, (b) fewer meanings for polysemous words, (c) more frequent use of imprecise collocations, (d) less frequent identification of two meanings of the same printed word that depend on varying word stress, and (e) lower scores for a verbal test of estimation.

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2. Despite a shared demand for defining words, scores for Homographs (polysemous word definitions) are predicted as well or better by tests that require perceptual reasoning than by Vocabulary (non-polysemous word definitions) in the entire sample.

2. Method

2.1. PARTICIPANTS

Fifty adults (30 females) participated (Table 1). They were between 18 and 52 years of age, had finished secondary school, and had completed or were engaged in some form of post-secondary training or education. The participants' education ranged from one term of a college course to completed Master's degrees. A portion of the sample (n = 30; NLD group = 16, Control group = 14) had completed the tasks as part of an earlier study (unpublished data, Stothers, 2005). Additional participants (n = 20; NLD group = 11, Control group = 9) were recruited from the same college and university sources and through word of mouth, according to the requirements of the ethics boards at the two educational institutions.

Participants in the group with NLD (n = 27) reported (a) a community diagnosis of NLD, and (b) accommodation use either in school or at work. Participants in the Control group (n = 23) reported never having been diagnosed with a developmental disorder, and never having used accommodation or services for a disability. Exclusion criteria for both groups were a diagnosis of autism spectrum disorder, brain injury, sensory impairment, or medical conditions such as seizure disorder. Participants whose first language was not English were also excluded. There were three participants with an additional diagnosis of ADHD in the NLD group, and four others who had a history of clinical depression. No other psychiatric conditions were reported. None of these participants were taking stimulant or anti-depressant medications at the time that data were collected. The majority of the sample was Caucasian.

TABLE 1. *Sample characteristics, N = 50*

	Controls (n = 23)	NLD (n = 27)
Sex	12F, 11M	18F, 9M
Age (s.d.)	25.83 (1.41)	27.96 (10.17)
Education (s.d.)	3.80 (1.42)	3.15 (1.63)
Block Design (s.d.)	12.65 (1.70)	8.33 (1.62)
ADHD	0	3

NOTE: Block Design mean is for scaled scores, with M = 10 and SD = 3; Education = years of post-secondary education completed at the time of data collection.

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2.2. MATERIALS

The participants completed five measures. Word definition tests were (a) a five item Homograph test, the dependent variable and a measure of the depth of semantic representations, and (b) the Vocabulary subtest of the Wechsler Adult Intelligence Scale, third edition (WAIS III), a baseline test of word knowledge against which potential differences in the dependent measure could be compared.[1] Variables examined for their ability to predict scores on Homographs and Vocabulary were (a) Gestalt Closure, a nonverbal perceptual closure test, and (b) Estimation, a test of the ability to quantify and express physical characteristics of everyday objects. Block Design, a perceptual organizational subtest of the WAIS III, was used to support diagnoses of NLD. Participants whose data were collected more recently completed the same measures, except that the two WAIS III subtests were drawn from the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). Correlations between the two versions of Vocabulary and Block Design are reported as .88 and .83 respectively (Wechsler, 1999).

2.2.1. *Homographs*

Participants read five homographs, that is, words that have more than one meaning but for which spelling does not vary, and were asked to generate as many different meanings for each word as they could. No time limit was imposed. The first dependent variable, Homographs total, was the number of meanings produced in response to *fair*, *bank*, *diamond*, *object*, and *point*. These words had similar, high familiarity ratings (fair = 573; bank = 573; diamond = 512; object = 586; point = 538) according to the MRC Psycholinguistic database, in which a maximum familiarity rating of 657, a mean of 488, and a standard deviation of 99, have been reported. A second outcome for the Homographs variable was the frequency of inaccurate or empty collocations, when their use suggested retrieval without full understanding. A third outcome was the question of whether the NLD group would less frequently identify a meaning for the word stress Homograph item, *object* (thing, part of speech, goal) that relied on stressing its second syllable, *object* (to disagree).

[1] Some of the items in this version of Vocabulary are polysemous, as they can be defined either as nouns or verbs. Because only one meaning is required in a standardized administration, and providing both meanings do not result in additional points, the test is considered to be a measure of single word meanings.

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2.2.2. *Vocabulary*

Vocabulary, an untimed expressive measure that permits responses of any length, was used as a baseline measure of word knowledge. Reliability coefficients for Vocabulary range from .92 to .94 in adults (Wechsler, 1997).

2.2.3. *Gestalt Closure*

Gestalt Closure (Kaufman & Kaufman, 1994) is a visual closure test. Stimuli are images from which interior and silhouette details have been removed. The dependent variable is the number of correctly identified pictures out of a total of 25. This type of task cannot be solved simply by joining item fragments; that is, the objects to be identified are made up of more than the parts that appear on the page. Thus, Gestalt Closure is a test of gestalt perception. The version used here has been found to be difficult for individuals with NLD (Gross-Tsur et al., 1995; Stothers & Klein, 2010). The technical manual for the battery of tests from which Gestalt Closure was taken reported split-half reliability coefficients from .82 to .87 for adults (Kaufman & Kaufman, 1994).

2.2.4. *Estimation*

Participants were asked to estimate size, length, distance, weight, and other measurements, where estimation is the process of arriving at an unknown amount by combining available data (Bisbing et al., 2015; Wagner, MacPherson, Parente, & Trentini, 2011). For example, "How long is the average metered parking space downtown?" requires relating the mental image of the size of a car to the experience of how much space is required to manoeuvre a car between two others. Participants could use either metric or imperial units. Eight items were taken from a study of children with cognitive impairment secondary to prenatal alcohol exposure (Kopera-Frye, Dehaene, & Streissguth, 1996), with two items from Shallice and Evans (1978) and an additional five items devised by the author. Control ranges for all items were calculated by adding and subtracting a consistent percentage of actual amounts obtained through Internet searches. This procedure gave similar control ranges to those provided by Kopera-Frye et al. (1996), but avoided the inclusion of outlying scores that occasional control participants provided in Kopera-Frye et al. (see Della Sala, MacPherson, Phillips, Sacco, & Spinnler, 2004; Shallice & Evans, 1978, for discussion).

2.2.5. *Block Design*

Block Design relies on spatial visualization, nonverbal concept formation, and a combination of analysis and synthesis of part–whole relationships

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(Wechsler, 1999). Split-half reliability coefficients provided by the Wechsler technical manual for Block Design were over .88 for adults.

2.2.6 *Education*

The number of years of college or university education that each participant had completed was also recorded and included as a variable in these analyses. Increases in years of education have been found to increase scores for tests of verbal IQ (Salthouse, 2004). Education was included because it was unknown whether this factor would affect breadth and depth of semantic representation equivalently, or at all, across the sample or differently by group.

2.3. ANALYSES

For the first hypothesis, potential group mean differences in scores for Vocabulary and Homographs total were analyzed with independent sample *t*-tests (Table 2). Effect size calculations used the pooled standard deviation of the total sample rather than the standard deviation of the Control group, as is recommended when variances for populations represented by groups

TABLE 2. *Dependent and predictor variable group mean comparisons*

	Group		Comparison	Effect
Variable	Control M (s.d.)	NLD M (s.d.)	*t* (mean diff.) CI (lower, upper)	*d*
Vocabulary	14.61 (2.43)	12.33 (2.96)	2.94 (2.28) (0.72, 3.83), $p = .005$	0.84
Homographs (total)	15.83 (2.08)	11.26 (2.30)	7.31 (4.57) (3.31, 5.82), $p < .001$	2.08
Homographs (collocations)*	1 : 364	26 : 304	0.001, $p < .001$	
Homographs (word stress)*	2 / 23	14 / 27	0.002, $p = .004$	
Gestalt Closure	12.65 (2.59)	7.52 (2.19)	7.60 (5.13) (3.78, 6.49), $p < .001$	2.14
Block Design	12.65 (1.70)	8.33 (1.62)	9.21 (4.32) (3.38, 5.26), $p < .001$	2.60
Estimation	23.51 (3.79)	16.44 (4.74)	5.76 (7.08) (4.61, 9.55), $p < .001$	1.65
Education	3.80 (1.42)	3.15 (1.63)	2.35 (0.5, 1.90), $p = .23$	0.67

NOTES: $df = 48$; CI (l, u) = 95th%ile Confidence Interval (lower, upper); Vocabulary and Gestalt Closure scores are scaled scores with $M = 10$ and $SD = 3$; Homographs and Estimation are raw scores. Education = years of post-secondary education completed at the time of data collection. [*] refers to ratio of errors to attempts, where errors are as defined in the text, for this variable; statistics are for Fisher's exact *t*.

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are unlikely to be equal (Ives, 2003). No differences between adults with NLD and controls were expected for Vocabulary. Mean scores for the number of meanings produced for Homographs were expected to be lower for the NLD group. For the latter variable, collocation errors and word stress identification were also analyzed, with more frequent use of collocations and less frequent identification of two meanings for a word stress item expected for the participants with NLD. Collocations were noted in the original data collection, but without audio-recordings that would have allowed a determination of whether formulaic phrases were used correctly. For this reason, collocation performance was reported for 20 participants, 12 in the NLD group and 8 in the Control group. A Fisher's exact *t* was used for both the collocation counts and the word stress item. Scores for Estimation were also analyzed with *t*-tests.

For the second hypothesis, that scores for tests of perceptual reasoning contribute as much or more to polysemy as does word knowledge, regression analyses separately examined the contribution of group and predictor variables to scores for Homographs and for Vocabulary (Table 3). The null hypothesis was based on the assumption that if the same cognitive processes were underlying both measures, regression analysis models would not be different. Instead, it was expected that Homographs scores would be significantly predicted by Gestalt Closure and Estimation, but that these variables would not contribute to a model for Vocabulary. Similarly, it was expected that group status would significantly predict Homographs but not Vocabulary scores, if the two groups had equivalent word knowledge but differed in the depth of their semantic representations. The potential influence of years of Education on Homographs and Vocabulary scores was explored by comparing correlations between Education, Vocabulary, and Homographs by group (Table 4).

TABLE 3. *Goodness of fit statistics for regression analyses*

Variable	Vocabulary *β*, *t*, *p*		Homographs total *β*, *t*, *p*
Homographs total	0.62, 3.31, $p = .002$	Vocabulary	0.32, 3.31, $p = .002$
Group	–0.06, –0.30, n.s.	Group	0.33, 2.36, $p = .023$
Gestalt Closure	–0.34, –1.84, n.s.	Gestalt Closure	0.46, 3.80, $p < .001$
Estimation	0.28, 1.9, n.s.	Estimation	–0.13, –1.19, n.s.
Education	0.24, 1.96, n.s.	Education	0.04, 0.38, n.s.
Model	$R = .67$, R^2 adj = .38, $F = 7.09$, $p < .001$	Model	$R = .84$, R^2 adj = .71, $F = 19.75$, $p < .001$

NOTES: Education = years of post-secondary education completed at the time of data collection; *β* = beta weight

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TABLE 4. *Correlations between predictor and dependent variables by group*

	NLD group (top rows), Control group (bottom rows)					
Variable	1	2	3	4	5	6
1. Vocabulary	1	0.60**	0.16	0.41*	0.04	0.25
2. Homograph total	0.07	1	0.42*	–0.02	0.19	0.11
3. Gestalt Closure	–0.27	0.48*	1	0.13	0.42*	0.07
4. Estimation	0.18	–0.05	–0.19	1	–0.02	0.10
5. Block Design	0.14	0.38	0.43*	0.22	1	0.13
6. Education	0.57**	0.37	0.06	0.33	0.43*	1

NOTES: * $p < .05$ (two-tailed test), ** $p < .01$ (two-tailed test); Vocabulary, Gestalt Closure, and Block Design correlations were calculated on scaled scores, with a mean of 10 and a standard deviation of 3; Degrees of freedom for Control group = 22; for NLD group = 26.

3. Results

3.1. GROUP ASSIGNMENT

Scores for Block Design were significantly different [$t(48) = 9.21$, $p < .001$]. A very large between-groups effect size (Cohen, 1992) emerged [$d = 2.60$]. The 95th percentile confidence intervals around the means did not overlap (Table 2). This result supported participants' reports of NLD diagnoses and thus their assignment to the clinical group.

3.2. HYPOTHESIS 1: GROUP DIFFERENCES IN DEPTH OF SEMANTIC REPRESENTATIONS

3.2.1. *Homographs total*

The Control group had significantly higher Homograph total scores than the NLD group [$t(48) = 7.31$, $p < .001$, $d = 2.08$] (Table 2). Similar statistical differences were seen in all other variables, including an unexpected group difference in Vocabulary [$t(48) = 2.94$, $p = .005$, $d = 0.84$]. Consequently, Vocabulary was used as a covariate in a univariate analysis of Homographs total, with significant group differences emerging for the corrected model [$F(2) = 35.41$, $p < .001$, $d = 1.26$]. Estimated marginal means for Homographs total were 15.43 for the Control group (95% CI = 14.54–16.33) and 11.59 (95% CI = 10.77–12.42) for the NLD group, demonstrating non-overlapping confidence intervals for Homographs without the influence of Vocabulary. However, because the two groups could not be randomly assigned, and differed from each other on all variables, removing the influence of Vocabulary would not be expected to alter the difference in Homograph totals between groups. This caveat to analysis of covariance is called SPECIFICATION ERROR (Miller & Chapman, 2001).

Consequently, two alternatives were considered to further explore the impact of the group difference in Vocabulary scores. In one, following Mervis

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and Robinson (2005), participants with the highest scores for Vocabulary were removed from analysis until the null hypothesis, that groups were not different on Vocabulary, could be accepted with reasonable confidence. Without eight control participants whose scores were at or above the 98th percentile, mean Vocabulary scores no longer differed by group [$t(40) = 1.23$, $p = .25$, $d = 0.42$]. Without these participants, however, the statistically significant difference and large effect size between group means remained for Homographs totals [$t(40) = 6.85$, $p < .001$, $d = 2.26$]. In the second alternative, a numerical estimate of the influence of Vocabulary and of group status independent of each other on Homograph scores was obtained via regression analysis. This was also a planned analysis to examine the influence of Gestalt Closure and Estimation on the verbal outcome measures.

3.2.2. *Collocation errors*

Results are reported for 20 participants whose responses to Homographs were recorded. The Fisher's exact *t*-test for collocation errors [$t(20) = 0.003$] was significant [$p < .001$]. The 12 member NLD group demonstrated 26 inaccurate or incomplete semantic representations for familiar words and phrases. One of the 8 control participants made a single collocation error, defining *fair-haired* as *having fine or weak hair.* The same participant also found only one meaning for object. A between-groups comparison of ratios for errors per attempt, 26:304 for the NLD and 1:364 for the Control groups, respectively, was also significant at $p < .001$.

3.2.3. *Word stress*

A Fisher's exact test for overt identification of the word stress homograph [$t(20) = 0.002$], also was significant [$p < .001$] in the expected direction. Two of the 23 member Control group did not find meanings for both *object* and *object*, in comparison to 14 of 27 participants with NLD.

3.2.4. *Perceptual experience*

The Control group had significantly higher scores for Estimation than the NLD group [$t(48) = 5.76$, $p < .001$, $d = 1.65$] (Table 2).

3.3. HYPOTHESIS 2: STATISTICAL CONTRIBUTIONS TO VOCABULARY AND HOMOGRAPHS SCORES

On regression analyses, models for Homographs and Vocabulary were not interchangeable (Table 3). For Homographs, Vocabulary was entered before

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group, producing a statistic for the correlation between group and Homographs without the statistical influence of Vocabulary. The other predictor variables, Gestalt Closure, Estimation, and Education, were entered next. The total for the model was $R^2 = .71$. Group status accounted for approximately 3.7% [$r = 0.192$] of the variability in Homographs scores for the sample, Gestalt Closure accounted for 9.5% [$r = 0.309$] and Vocabulary for 7.2% [$r = 0.269$]; all of these contributions were statistically significant. Neither Education nor Estimation explained independent variance in Homographs. In contrast, variance accounted for by almost the same predictor variables in the model for Vocabulary was lower, $R^2 = .45$, and there were no effects for Gestalt Closure, Estimation, or Education. Variance accounted for by Group status was very small, .001 % [$r = –0.03$]. Only Homographs, the other word definition task, made a statistically significant contribution, accounting for approximately 14% [$r = 0.371$] of the variance in scores.

There were differences between groups in the correlations between Education and both word definition measures. Scores for Education and Vocabulary were positively correlated in the Control group [$r(23) = 0.57$, $p = .05$], but this relationship did not hold for Education and Homographs [$r(23) = 0.37$, n.s.]. In the NLD group, correlations for Education and all other variables ranged from almost zero to small, and not statistically significant, correlations between Education and Vocabulary, and Education and Homographs (Table 4). Homographs score correlations differed as well. The Homographs score in the Control group was significantly related only to Gestalt Closure [$r(23) = 0.48$, $p = .02$], and not to Vocabulary [$r(23) = 0.07$, n.s.]. In the NLD group, Homographs was significantly correlated with both Gestalt Closure and Vocabulary.

4. Discussion

Oral language in individuals with NLD has been described as empty, repetitive, and formulaic, despite average word knowledge. Here, participants with NLD had average scores for a standardized test of vocabulary. At the same time, the NLD group provided significantly fewer separate meanings for polysemous words than did the Control group, and more frequently used collocations without apparent understanding of their meanings. Differences were interpreted as a demonstration of reduced vocabulary depth in comparison with semantic breadth, as hypothesized. The prediction that perceptual reasoning would better predict depth of vocabulary than would general word knowledge was also supported. Results were consistent with other research that finds concurrent weaknesses in visual–spatial and language skills (Humphries et al., 2004; Mammarella et al., 2009; Stothers & Klein, 2010; Worling et al., 1999). Results supported the hypothesis that weaknesses in perceptual

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organization extend to the formation of semantic representations, and are compounded by difficulties with the integration of discrete pieces of information. This interpretation is discussed as it relates to the dependent variables and the cognitive processes proposed to be involved. Theoretical support and clinical implications are then considered.

4.1. REDUCED VOCABULARY DEPTH

4.1.1. *Homographs total*

The hypothesis that semantic representations lack depth in individuals with NLD was supported. These participants generated fewer meanings for polysemous words, despite having a mean standard score for Vocabulary at the upper end of the average range in the general population. Below average Vocabulary results would have predicted lower total Homograph scores, but results were inconsistent with restricted word knowledge. All participants provided at least one accurate definition for each of the Homographs items, but only the adults with NLD found fewer than eleven distinct meanings for five items – that is, only the NLD group showed a disparity between breadth and depth. The effect size for the group difference in total Homographs score was very large (Cohen, 1992).

Correlation patterns also showed a difference between the Control and NLD groups. Vocabulary and Homographs total were unrelated for Control participants when all other potential correlations were taken into account, suggesting that for typical adults the deepening of word knowledge is a separate process from acquiring single word definitions. For the NLD group, Vocabulary was positively and significantly related to the Homographs total score, and to Estimation, suggesting a relationship based in a shared test stimuli format rather than some other cognitive process common to Vocabulary, Homographs, and Estimation.

The significant difference in group mean scores for Vocabulary raised the question of whether the difference in Homograph total scores was driven by word knowledge. This appeared not to be the case. The Control group had an unusually high scaled score for Vocabulary, close to the superior range of function. The mean score for the NLD group was at the high end of the average range, and consequently could not be considered to be impaired. At a minimum, this suggested that limited word knowledge is unlikely a meaningful difference between Control and NLD groups in general, at least in adults (Stothers & Klein, 2010; Stothers & Oram Cardy, 2016). Additionally, the technique that resulted in accepting the null hypothesis that the groups did not differ in Vocabulary (Mervis & Robinson, 2005) did not also affect the statistically significant group differences seen for Homographs. Analysis for the reduced sample found a small effect between groups for Vocabulary,

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but the effect size for Homographs remained very large. Future studies could include other comparison groups whose word knowledge would be expected to be lower than those with NLD to further clarify this issue.[2]

4.1.2. *Collocation errors*

Instances of ill-defined collocations appeared significantly more frequently for the clinical group, as expected. Collocations are used to communicate complex ideas quickly, to communicate social intentions, to complete routine interactions with others, and for other communicative functions (Biber, 2009; Schmitt, 2012). The finding supported the hypothesis that adults with NLD rely on long-term memory for word definitions to compensate for a lack of understanding. An example from the present data, a misconstrual of *fair weather* to mean a *cloudy* day, was only apparent from a shared experience of the weather during data collection. Such an error might not be detected in writing, or when conversational partners are separated. The result also suggests a potentially causal relationship between under-constituted and imprecise semantic representations and pragmatic weaknesses, or difficulties with the use of language in social settings, which have been reported in NLD (e.g., Davis & Broitman, 2011; Palombo, 2006; Ris et al., 2007). This outcome could be investigated directly. If replicated, the result suggests that adults with NLD may benefit socially from instruction in polysemous vocabulary.

4.1.3. *Word stress*

Producing separate meanings for object based on syllable emphasis was seen less frequently in the NLD group, as hypothesized. Object was chosen as the word stress item because it has more than one common meaning. Very few participants in either group responded with *goal* or *a part of speech*, however, suggesting that *to disagree* is more familiar than either of these options. Although familiarity assists word retrieval (McNamara, 2005), and participants were aware that each item had more than one meaning, half of those in the NLD group could not provide more than one meaning for object. In contrast,

[2] Data were available for a smaller group of adults with dyslexia (n = 13) but were not included because phonological impairments could not be ruled out for participants whose data were added. These 13 adults had scaled scores for Vocabulary that were comparable (m = 10.92) to the present NLD group (m = 12.33), but their mean Homographs score was 14.08, in comparison with the NLD mean of 11.26 and the Control mean of 15.83 in the present sample. Critical to the hypothesis being tested here, the 13 adults with dyslexia also had average to above average scaled scores for Block Design and Gestalt Closure.

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almost all of the participants without learning disabilities were able to access both pronunciations of the written word without context. As a one-item measure, no conclusions could be drawn. Confusions about the influence of spelling on pronunciation, shallow semantic representations, separately stored semantic representations, lack of contextual cues, or some or all of these in combination, could not be differentiated. Instead, it was proposed that researching word-stress homographs and other forms of prosody in NLD may hold promise for delineating diagnostic characteristics, as well as for intervention.

4.2. Potential sources of the difference between Vocabulary breadth and depth

4.2.1. *Years of education*

Education was approximately equally correlated with Vocabulary and with Homographs in the NLD group, with neither relationship being significant. This finding rules out years of post-secondary education as the critical factor in the disparity between breadth and depth of vocabulary in individuals with NLD. Instead, the result suggested that education may contribute less to vocabulary development in individuals with NLD than in peers without learning disabilities, consistent with a general supposition in learning disabilities research known as a Matthew effect (Stanovich, 1986; Vellutino, Fletcher, Snowling, & Scanlon, 2004). This phenomenon is an adaptation of the rich get richer and the poor get poorer aphorism to literacy. That is, proficient readers read more, increasing the size of their vocabularies and the likelihood of reading more, thus increasing their proficiency further. Poor readers read less. They encounter fewer opportunities to increase vocabulary, making reading less likely and continuing the cycle of impoverished vocabulary.

4.2.2. *Cognitive processes related to estimation*

Scores for Estimation did not contribute to statistical models that predicted scores for either Homographs or Vocabulary. Given that Estimation was a measure of verbalized perceptual experience, it was expected that performance on Estimation would also contribute to Homograph total scores, if perceptual differences influence depth and flexibility of semantic representations. However, a relationship between Estimation and Homographs may have been too indirect to be visible in a sample of adults, perhaps mediated by crystallized knowledge (Wagner et al., 2011) and interests, as much as it was expected to be mediated by perceptual experience. That items on this measure were not matched to recent research also may have been a factor. Estimation studies have been conducted in relative isolation in

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diverse fields such as education, cognitive psychology, and neuropsychology (Hogan & Brezinski, 2003), resulting in varying kinds of tasks, not all of which were examined here.

Although Estimation scores did not contribute statistically to results for Homographs, a more general relationship to differences in semantic representations was expressed by the content of responses by participants with NLD. Some of these responses indicated indistinct representations of amount, most notably in unit errors that controls did not make. Three participants with NLD had difficulty finding an appropriate unit in which to express an estimate of the circumference of the largest tree in the world, answering in degrees rather than metres or feet. These participants were relating their knowledge that there are 360 degrees in a circle with the fact that circumference is a measurement that encircles an object, demonstrating that their representation of each concept was incomplete or unclear. None of the control participants used degrees as a unit of measurement for this item. Overall, Estimation results were consistent with Myklebust's (1975) documentation of confusions in children with NLD about the physical properties of objects and environments. As such, the results suggested that Estimation was at the very least a marker of NLD diagnostic status.

4.2.3. *Gestalt perception*

Scores for Gestalt Closure in the NLD group were lower than the Control group, and the low end of the group's range of scores fell in the borderline range. A divide between vocabulary breadth and depth also occurred only in the NLD group, pointing to gestalt perception as the predominant influence on semantic depth, rather than breadth of vocabulary, years of education, or intelligence in general – the NLD group had scores in the average range for both IQ subtests. This interpretation was supported by two other results. Regression analysis models for Vocabulary and Homographs diverged with respect to Gestalt Closure. The model for Homographs that included Gestalt Closure, as well as predictors that more conventionally would contribute to a model for a word definition task, explained close to three-quarters of the variance in scores. In contrast, Gestalt Closure did not contribute to the linear regression model for Vocabulary scores, and the same predictors explained less total variance. That is, Gestalt Closure results contributed significantly to the scores for Homographs, but not for Vocabulary. Also, there were positive correlations between Homographs and Gestalt Closure, but not between Vocabulary and Gestalt Closure in both groups.

Adding multiple meanings to representations requires a relational process of updating and storing elaborated meanings when new uses are encountered. To illustrate, the practice item given for the Homograph test was *down*, which

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may refer to a direction, a sad mood, or a feather lining. More recently, down has been used to mean being *alright* or *in agreement with* a suggestion, as in the collocation *I'm down with that*. Adding the last meaning for *down* requires that a listener consider that familiar meanings are not suitable, and then reinterpret its use by combining prosodic cues, facial expressions, and other contextual factors to create a novel interpretation. More than one exposure to the new use may be required. In contrast, once a semantic representation for a non-polysemous word has become familiar and well-learned, gestalt processes in maintaining semantic representations are proposed to be diminished, consistent with the lack of correlation between Gestalt Closure and Vocabulary in both groups.

4.3. THEORETICAL SUPPORT

The embodied view of cognition (Barsalou, 2008; Chwilla, Kolk, & Vissers, 2007; Gibbs, 2013; Wilson, 2002; Zwaan, 2014) is particularly applicable to the present hypotheses. A second theory, the Bilateral Activation, Integration, and Selection model (BAIS; Jung-Beeman, 2005), is also relevant to a connection between weaknesses in perceptual organization and atypical semantic representations.

4.3.1. *Embodied semantics*

Embodiment holds that cognition is rooted in physical interactions with the environment, and that abstract mental representations emerge from lived experience. A key feature of grounded or embodied cognition is that it opposes the assertion that abstract thought exists AMODALLY, or separately from perceptions and actions, in semantic memory (Barsalou, 2008; Casasanto, 2011; van Dam, van Dijk, Bekkering, & Rueschmeyer, 2012). Wilson (2002) explores embodiment as an updated view of the Piagetian view that the maturation of cognitive abilities can be traced in sensorimotor development. Piaget's theory was a source of Rourke's (1989) contention that children with NLD have impoverished semantic representations as a consequence of sensorimotor deficits and limited exploration of their environments.

Gibbs (2013) presents a detailed account of the contribution of embodiment to language, reviewing brain imaging studies that find activation in appropriate motor and somatosensory brain regions on the presentation of action and sensory words; this is known as SEMANTIC SOMATOTOPY. For example, using fMRI, neural correlates of leg movements in a cortical area known as the pre-motor cortex were seen to be active with written presentations of *kicking a ball* and *kicking a habit* (Boulenger, Hauk, & Pulvermüller, 2009). The finding supports the embodied account of semantics at a neural level of

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explanation. If individuals with NLD have less rich interactions with the environment, as supported here by lower scores for Estimation tests, they may also have less modally detailed semantic representations. Lack of premotor cortex activation for idioms such as *bite the bullet* or *kick the bucket* has also been found, perhaps because collocations may be accessed directly (Aziz-Zadeh & Damasio, 2008). Applied here, these results support the proposal that individuals with NLD compensate for so-called impoverished representations with long-term memory for word definitions.

4.3.2. *BAIS model*

A second theory that is applicable here was also developed from research that has investigated neural correlates of language. The BAIS model (Jung-Beeman, 2005) describes lateralized differences in the brain's response to linguistic stimuli (see also Beeman, 1998; Diaz, Barrett, & Hogstrom, 2011; Kounios & Beeman, 2014; Seger, Desmond, Glover, & Gabrieli, 2000), regardless of the imageability of the input. The cognitive processes for which the current sample showed weaknesses have been repeatedly characterized as being right hemisphere dominated, although this is an oversimplification; cognition requires the simultaneous function of disparate parts of the brain (Dien, 2009; Hugdahl & Westerhausen, 2010). Also, the sample was not tested on low-level perceptual measures in comparison with participants with known brain damage. Nonetheless, there may be some advantage in describing processes as predominantly or preferentially right or left hemisphere biased in a group of individuals whose behavioural responses differentiate them from peers, as was the case with the current sample.

In the BAIS model, the left hemisphere is hypothesized to briefly activate closely associated representations in response to a stimulus word, and to quickly select the most familiar meaning, allowing further processing. Competing meanings are inhibited if they are determined to be irrelevant to the context. To the same stimulus, the right hemisphere activates meanings, features, associations, and shades of meaning more weakly, but for a slightly longer period (Diaz et al., 2011; Kounios & Beeman, 2014; Seger et al., 2000). The field of activation in the left hemisphere is characterized as small and focused, containing closely associated representations; thus, the semantic field in this hemisphere is described as 'fine'. A 'coarse' semantic field refers to larger, more diffuse, and weaker activation of semantic representations in the right hemisphere. The larger size of coarse semantic fields and a weaker but lengthier period of activation allows for more overlap between semantically distant associations. Overlap is thought to facilitate the integration of meanings that are less frequently combined (Faust & Kenett, 2014; Jung-Beeman, 2005). Fluent on-line language comprehension relies on efficient word selection,

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but the addition of coarse coding would provide unfamiliar meanings when the dominant meaning is ill-suited to the context, or when words are presented in isolation, as in the Homographs task.

If both perceptual organizational and coarse semantic coding processes are right hemisphere biased, one would expect that the measures proposed to reflect these processes would be positively correlated, as was the case in the current results. Thus, the BAIS model provides a mechanism to support the positive relationship between Gestalt Closure and Homographs. The BAIS model's use in the present context is also consistent with the strong positive correlations between Homographs and the theoretically right hemisphere biased nonverbal measures.

Embodied semantics and hemisphere based differences in semantic coding are not mutually exclusive. Their functions as applied to the present data would work in concert. Putative right hemisphere deficits in perceptual reasoning, as demonstrated here by weaker Block Design and Gestalt Closure scores, would in theory have been present throughout development and have had a negative influence on physical exploration of the environment. According to embodied semantics, less exploration would result in less elaborated semantic representations. In the BAIS model, if representations are impoverished, coarse field activation would produce fewer distantly related terms, limiting the number of meanings available for selection in a polysemous word definition task. The results here were compatible with both accounts. It is proposed here that the combination of these mechanisms lead to the development of a preference for designation over elaboration.

4.4. CLINICAL IMPLICATIONS: SEMANTIC DEPTH AND CPS

Children with NLD have been said to demonstrate CPS. Some features of CPS were seen in the present sample, including higher Vocabulary than Block Design scaled scores, and the finding that collocations (clichés and quotes, stereotypic language) without adequate semantic representations (using words without comprehension) were more common in the NLD than Control group. Therefore, the overall pattern of formulaic but fluent speech in which a speaker has (a) inadequate semantic representations of his or her own words, and (b) weaker perceptual reasoning, was applicable in part to the present sample. However, CPS does not capture all aspects of oral language in NLD. The present group of adults made errors occasionally rather than continually, with instances of unfamiliar words used correctly in context. The full picture seen in the present study, therefore, was one of vocabulary breadth in combination with imprecision and a lack of depth. For weaknesses in oral language production, alternative terms such as INCOMPLETE SEMANTIC REPRESENTATION or COLLOCATION WITHOUT REPRESENTATION

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would emphasize the contribution of semantic representations to collocation errors, rather than highlighting their use in social situations. The capacity for accurate representations should be emphasized as well. DESIGNATION OVER ELABORATION captures both breadth and lack of depth by suggesting a preference or tendency rather than a simple inability.

4.5. LIMITATIONS

The current sample was unlikely to be representative of the larger population of adults with NLD. There were only three participants who were not recent graduates or not currently enrolled in post-secondary education, and only these participants had scores for Block Design or Gestalt Closure in the below average or borderline range. Adults who have more severe perceptual organizational impairments appear not be well represented in more educated samples, as in the present study. Nonetheless, there are more adults with learning disabilities in post-secondary school than ever before, so the information is of use to educators and service providers. Participants with other neurodevelopmental disorders such as dyslexia, autism spectrum disorders, and specific language impairment should be included in replications, with additional measures of semantic depth. Additional tests of perceptual organization should specifically include gestalt perception.

5. Conclusion

Individuals with NLD are not incapable of gestalt perception or integrating new information with existing semantic representations, but the present results support clinical assertions that they make novel links between unlike parts less frequently or easily (Grodzinsky et al., 2010; Rourke, 1989). The proposal that their weaknesses in perceptual organization affect the depth of their semantic representations assumes that cognitive integration or blending is a fundamental process that results in novel concepts independent of test stimuli format (Coulson, 2006; Fauconnier & Turner, 1998), but does not overlook the fact that cognition involves both sequential and holistic approaches that work in concert (Dien, 2009). A preference or increased capability for the former over the latter apparently affects depth, but not breadth of vocabulary. All participants had some post-secondary education, again pointing to semantic memory as a successful compensation strategy.

Taken together, the results of the current study suggested that relying on long-term memory for immutable word definitions, described here as designation over elaboration, may be both an effective compensation strategy and a source of difficulty for adults with NLD. It is plausible that differences in the depth and quality of semantic representations are not as salient in

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ordinary conversation as are differences in breadth, given the ubiquity of collocational speech (Biber, 2009; Schmitt, 2012) and the subtle nature of some errors that were made for the Homographs definitions. Collocation without representation appeared to be common in this group of participants, and more participants in the NLD group than the Control group did not identify two meanings for the word-stress item. The latter results were exploratory, but did suggest the possibility of an additional underlying explanation for pragmatic errors described in NLD.

Lack of research into these questions has been a barrier to the development of interventions. Instruction in polysemous and less familiar vocabulary, in the meanings of formulaic expressions, and potentially in aspects of prosody, may be beneficial, even for adults. If replicated, the contrast between Homographs and Vocabulary could be used clinically as a more sensitive measure of impairment than Vocabulary alone. The former test was easily and quickly administered, and the latter test is often used in diagnostic assessment of NLD. Similarly, Estimation may have potential as a method of evaluating perceptual differences in NLD in a verbal format. More generally, the present study is a first step towards quantifying and better understanding semantic differences in adults with NLD.

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Appendix

Estimation items

1. How many slices of bread are there in an average-sized loaf of bread? [a, b]
2. On average, how many children are there in an Ontario public school classroom? [a]
3. How fast do race horses run? [a, b]
4. How long does it take to cook a fish? [b]
5. How heavy is the heaviest dog on earth? [b]
6. What is the length of an average adult male's spine? [a, b]
7. How long does it take an astronaut to fly to the moon? [a]
8. How long does it take to drive from Vancouver to Halifax? [b]
9. How long do you think it took Columbus to sail across the Atlantic Ocean? [b]
10. What is the circumference of the trunk of the largest tree in the world? [b]
11. Approximately how much is this University's annual budget? [c]
12. How much does a compact car weigh? [c]
13. About how long does it take an Olympic athlete to run a marathon? [c]
14. What is the length of the average metered parking space in the downtown core? [c]
15. How long would it take to swim across Lake Ontario from Toronto to New York state? [c]

NOTES: [a] Shallice & Evans, 1978; [b] Kopera-Frye et al., 1996, [c] Stothers, 2005.

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