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Research Note

Nonword Repetition and Vocabulary Knowledge as Predictors of Children's Phonological and Semantic Word Learning

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Purpose: This study examined the unique and shared variance that nonword repetition and vocabulary knowledge contribute to children's ability to learn new words. Multiple measures of word learning were used to assess recall and recognition of phonological and semantic information.
Method: Fifty children, with a mean age of 8 years (range 5–12 years), completed experimental assessments of word learning and norm-referenced assessments of receptive and expressive vocabulary knowledge and nonword repetition skills. Hierarchical multiple regression analyses examined the variance in word learning that was explained by vocabulary knowledge and nonword repetition after controlling for chronological age.
Results: Together with chronological age, nonword repetition and vocabulary knowledge explained up to 44% of the variance in children's word learning. Nonword repetition was the stronger predictor of phonological recall, phonological recognition, and semantic recognition, whereas vocabulary knowledge was the stronger predictor of verbal semantic recall.
Conclusions: These findings extend the results of past studies indicating that both nonword repetition skill and existing vocabulary knowledge are important for new word learning, but the relative influence of each predictor depends on the way word learning is measured. Suggestions for further research involving typically developing children and children with language or reading impairments are discussed.

Vocabulary knowledge is an important indicator of language and literacy skills and overall academic success. Discourse comprehension requires an understanding of the majority of the included words. Measures of verbal intelligence as well as college entrance exams and career placement tests rely heavily on vocabulary items (Roid, 2003; Wechsler, 2008). Vocabulary deficits are characteristic of many children with language and reading difficulties, including specific language impairment (SLI) and poor reading comprehension (Cain & Oakhill, 2011; Catts, Adlof, & Ellis Weismer, 2006; Catts, Fey, Zhang, & Tomblin, 1999; McGregor, Oleson, Bahnsen, & Duff, 2013; Scarborough, 1990). In addition, young children's vocabulary size predicts their popularity among peers (Gertner, Rice, & Hadley, 1994). Thus, understanding factors that influence vocabulary development is important to inform efforts to affect change in children's language, academic, and social outcomes.

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At the most basic level, learning a new word involves forming a new phonological representation (i.e., a *form* representation), a new semantic representation (i.e., a *meaning* representation), and bidirectional links between them (Gupta & Tisdale, 2009). The functional independence (or partial independence) of these two classes of representations is underscored by models of lexical access in spoken language production (e.g., Caramazza, 1997). Further, as described in the lexical quality framework (Perfetti, 2007; Perfetti & Hart, 2002), word knowledge is not an all-or-none construct. During the process of learning a word, form and meaning representations may be specified to different degrees. For example, an individual might have a very specific phonological representation for a given word but only a vague sense of the word's meaning. A child who calls every four-legged house pet a "doggie" has created a stable form representation but lacks specification in her semantic representation. Conversely, a person may know very well what a word means but be unsure of the exact pronunciation. For example, many adults are unsure of the correct pronunciation of *nuclear*. Ultimately, words with high lexical quality have well-specified form and meaning representations and redundant links between them, such that activation of one leads to activation of the other.

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Because vocabulary acquisition depends largely on exposure, variations in the frequency and quality of word experiences are significant contributors to differences in lexical quality (Adlof, Frishkoff, Dandy, & Perfetti, 2016; Adlof & Perfetti, 2013). Studies indicate that the number of words young children hear from their parents predicts concurrent and subsequent vocabulary size as well as broader language and literacy skills (Hart & Risley, 1995; Goodman, Dale, & Li, 2008; Walker, Greenwood, Hart, & Carta, 1994). In addition, specific characteristics of the items to be learned affect their ease of learning. For example, the degree to which novel word forms are similar to other words in the lexicon and the degree to which referents are like other known objects have both been shown to influence word-learning performance (Hoover, Storkel, & Hogan, 2010; McKean, Letts, & Howard, 2013; Storkel & Adlof, 2009). However, individual differences in word learning persist even when word characteristics and word experiences are controlled (Gellert & Elbro, 2013; Kan & Windsor, 2010; Warmington, Hitch, & Gathercole, 2013). Thus, other factors must also affect the degree to which individuals are able to capitalize on even high-quality word exposures. The processes that underlie such individual differences in word-learning abilities are not well understood.

Numerous studies have shown an association between nonword repetition and vocabulary size (Gathercole & Baddely, 1989; Gathercole, Service, Hitch, Adams, & Martin, 1999; Hoff, Core, & Bridges, 2008; Melby-Lervåg et al., 2012) and between nonword repetition and novel word learning (Gathercole, Hitch, Service, & Martin, 1997; Gupta, 2003) in children and adults. Two interpretations of this association have received attention in the literature. On one account, nonword repetition serves as an indicator of phonological memory capacity (Gathercole & Baddely, 1989; Gathercole, 2006), whereas on another account it serves as an indicator of phonological sensitivity, which may itself be at least partially driven by vocabulary growth (Bowey, 2001; Edwards, Beckman, & Munson, 2004; Metsala, 1999; Snowling, Chiat, & Hulme, 1991). Under both accounts, it is believed that poor nonword repetition is indicative of problems with phonological processing, which may interfere with the ability to construct precise form representations or links between form and meaning representations.

The robustness of the existing semantic network may also influence word-learning abilities. For example, children with larger vocabularies tend to learn the meanings of new words from storybook exposure and direct instruction more easily than children with smaller vocabularies (Cain, Oakhill, & Lemmon, 2004; Ewers & Brownson, 1999). Although not directly studying word learning, some studies of children with SLI have implicated semantic deficits as sources of word retrieval difficulties during confrontation naming tasks. Lahey and Edwards (1999) examined errors made by 4- to 9-year-old children with SLI versus typical language development in a speeded naming task involving familiar items. Children with SLI made a significantly greater proportion of errors involving the production of words that were semantically associated with the target name (e.g., *key/lock*; *dust/broom*). Because there was little phonological overlap with the target, Lahey and Edwards concluded that such errors suggested incomplete or poorly organized semantic representations. McGregor, Newman, Reilly, and Capone (2002) similarly found that semantic errors were the most common naming errors exhibited by 4- to 8-year-old children with SLI. These errors were also associated with less specific definitional recall and poorer drawings of the target items, suggesting underspecified semantic representations. Note that low vocabulary scores were characteristic of most participants with SLI in both studies (Lahey & Edwards, 1999; McGregor et al., 2002). Taken together, these studies suggest that semantic deficits, which are associated with lower levels of existing vocabulary knowledge, may contribute to difficulties recalling form representations as well as acquiring meaning representations.

Predictors of Word Learning

Although many studies have established a correlation between nonword repetition skills and vocabulary size, relatively few studies have specifically examined their simultaneous contributions to children's ability to learn new words. In addition, individual studies have generally used a restricted set of measures to assess word learning (but see Gray, 2004; Nash & Donaldson, 2005). In one study, Gathercole and colleagues (1997) taught typically developing 5- to 6-year-old children brief verbal definitions for two nonwords and then measured word learning with a definition recall task (recall definition when provided a nonword) and a phonological recall task (recall the nonword when provided the definition). The results indicated that both nonword repetition and vocabulary knowledge were significantly correlated with performance on both tasks. Vocabulary knowledge explained significant unique variance in both tasks after controlling for age, nonverbal IQ, and nonword repetition, but nonword repetition was not a unique predictor of either definition recall or phonological recall after age, nonverbal IQ, and vocabulary knowledge were controlled.

Other studies have involved children with language and/or reading difficulties. In a combined sample of 4- to 5-year-old children with SLI and their typically developing peers, Gray (2004) found that vocabulary knowledge and nonword repetition each predicted different measures of word learning. Vocabulary knowledge was a significant predictor of semantic recognition (i.e., ability to find the correct object upon hearing its name) and phonological recall (i.e., ability to name an object) in the fast mapping phase (i.e., the earliest stage of word learning) and the number of words learned to criterion for semantic recall. Nonword repetition was a significant predictor of trials to criterion for phonological recall. Gray (2006) examined predictors of semantic recognition and phonological recall during fast mapping in separate samples of typically developing children and children with SLI, ages 3 to 6 years.

In typically developing children, only nonword repetition significantly predicted phonological recall, and neither nonword repetition nor vocabulary knowledge showed a significant relationship with semantic recognition. In the SLI sample, neither variable significantly predicted semantic recognition or phonological recall. Finally, Nation, Snowling, and Clarke (2007) examined predictors of word learning in a combined sample of children aged 8 to 9 years who either were "poor comprehenders" (i.e., who demonstrated age-appropriate word reading but poor reading comprehension) or had good reading skills. After controlling for nonverbal cognitive skills, a composite nonphonological language measure that included two vocabulary tests significantly predicted children's definition recall but not their phonological recall. Nonword repetition skills did not predict performance on any word-learning measure.

Study Purpose

Overall, it is clear that nonword repetition and vocabulary knowledge are correlated with new word learning, but it is unclear how each contributes to the phonological and semantic components of word learning. The studies reviewed above provide some evidence that nonword repetition contributes to the acquisition of phonological forms, whereas existing vocabulary knowledge may play a role in both phonological and semantic aspects of word learning. However, it is difficult to find a clear pattern across studies or draw strong conclusions. It is possible that differences in results across studies are attributable to methodological differences, including differences in the measures used to assess new phonological and semantic representations. Therefore, we aimed to explore the relationship between nonword repetition, vocabulary knowledge, and children's word-learning abilities and to examine the relative influence of each predictor on different assessments of word learning. Furthermore, in examining these relationships, we aimed to use a word-learning task that was ecologically valid with regard to the acquisition of new semantic information. Thus, we developed a word-learning paradigm that involved teaching elaborated descriptions, such as those used to define real words or describe real objects. This study represented an initial step in exploring relationships between nonword repetition, existing vocabulary knowledge, and new word learning with a diverse sample of school-aged children using this new paradigm. We hypothesized that nonword repetition and existing vocabulary knowledge would each explain unique variance in measures of children's word learning and that the strength of the relationships would vary depending on the task used to assess word learning (i.e., phonological vs. semantic, recall vs. recognition).

Method

Participants

Participants included 50 children (28 boys, 22 girls), aged 5–12 years (mean age = 7.95 years), who were recruited through community and school advertisements in Columbia, South Carolina, and surrounding areas. The sample was racially diverse (22 White, 24 African American, 4 not reported). Per parent report, none of the participants had diagnosed hearing loss, one participant had a diagnosis of attention-deficit/hyperactivity disorder, one had previously received school services for English as a second language, and nine had previously received some form of speech/language services. None of the participants had a motor disorder or other medical history that would interfere with their ability to complete the norm-referenced assessments or experimental tasks involved in this study.

General Procedure

Children completed an experimental battery of word-learning assessments (30–40 min) as well as norm-referenced measures of nonword repetition and vocabulary knowledge (30–40 min), administered by trained data collectors in a quiet room of their school or in the research lab. All experimental word-learning tasks were completed in a single session. Some participants completed the norm-referenced assessments in the same session immediately after the word-learning tasks, whereas others completed them in a separate session, according to scheduling limitations and participant stamina. Unless otherwise noted, all tasks were video and audio recorded and double-scored offline from the recordings by trained research assistants to ensure reliability.

Because some children had a history of speech/language services, it was important to ensure that scores on production tasks (i.e., nonword repetition, phonological recall, and phonological recognition tasks described below) did not reflect possible articulation errors. Therefore, a certified and experienced speech-language pathologist (CCC-SLP) who was also a trained research assistant listened to recorded conversational samples from all participants with a history of speech-language services and three additional participants who had been flagged by assessors for possible articulation issues. The CCC-SLP also listened and verified scoring for the nonword repetition and word-learning tasks for all of these children. None of the errors noted in conversational speech samples (e.g., w/r, d/voiced /th/, s/z distortions and cluster reduction) involved any of the sounds in the word-learning stimuli, and no word-learning or nonword repetition item scores were related to articulation errors.

Norm-Referenced Assessments

Nonword Repetition

Nonword repetition skills were measured using the Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999). Eighteen recorded nonwords were played over a CD player, and children repeated them back to an examiner. The test manual reports acceptable reliability for this task (coefficient $\alpha = .78$).

Vocabulary

Receptive vocabulary knowledge was measured using the Peabody Picture Vocabulary Test–4 (PPVT-4; Dunn &

Dunn, 2007). On each item, children selected, from a field of four, the picture that best matched a word spoken by the examiner. Expressive vocabulary knowledge was measured using the Expressive Vocabulary Test–2 (EVT-2; Williams, 2007). For each item, children viewed a picture and responded to questions or statements from the examiner, such as "What is this animal?" or "Tell me another word for *father*." Both the PPVT-4 and the EVT-2 manuals report high levels of reliability (PPVT-4: $\alpha = .97$; EVT-2: $\alpha = .96$). Scores on the PPVT-4 and EVT-2 were highly correlated in our sample ($r = .77$; $p < .001$). To preserve degrees of freedom in further analyses, a composite vocabulary score was created by averaging the two scores. Two participants were missing data from the EVT-2 because of scheduling limitations and examiner error; for these two students, the PPVT-4 score was used.

Word-Learning Procedures

Stimuli

Participants' word-learning abilities were assessed with computerized training and testing tasks in which children were taught six pairs of novel names and unfamiliar object referents. Our objective in designing the word-learning task was to promote acquisition of new semantic representations. Thus, target pictures depicted objects the average American child would not know. In addition, the objects were selected to be complex, engaging, and ecologically valid: They had identifiable semantic features (e.g., body or machine parts) that are familiar to children and can be used to classify objects as real, or plausible, instances of known categories (i.e., birds, fish, trees, fruits, machines, vehicles). Two additional pictured objects served as foils in the finding task described later; these were pictures of a unique, handmade stringed musical instrument and an obscure weevil. Pilot testing with a separate group of similar-aged children confirmed that the categories were familiar but the specific items were not. Pictures of these objects were obtained from stock photo websites and Google Images and modified using Adobe Photoshop such that the items were all approximately the same size and displayed on a white background. The novel word stimuli consisted of six, two-syllable CVCVC pseudowords selected from the Irvine Phonotactic Online Dictionary (Vaden, Halpin, & Hickok, 2009), which had medium phonotactic probability and neighborhood density relative to all two-syllable real words within the database. All items had three phonological neighbors, biphone probability ranging from .003 to .005, and positional segment probability ranging from .048 to .057. The six nonword stimuli and sample picture stimuli are provided in Appendix A.

Training

The training task was programmed using E-Prime 2.0 stimulus presentation software (Psychology Software Tools, Sharpsburg, PA). Children were instructed that they would be helping an astronaut learn about life on an alien planet before she traveled there. A recorded script introduced names for object referents, the category they belonged to, two features that were visible in the pictures, and one feature that was not visible. These script elements were repeated three times, with the order of script elements varied in the second and third presentation to encourage attention (see Appendix B). Within each teaching block, the order of presentation of the target words was randomized. From the complete training session, the children received 21 exposures to the spoken word form, three opportunities to practice saying the name of each object, and three opportunities to identify the correct object from an array of eight pictures that included the five other target objects and two unfamiliar objects that were not in the teaching set. Participants received automated feedback on the accuracy of their responses during the training session.

Assessments of Word Learning

Five measures were programmed in E-Prime 2.0 to assess children's recall and recognition of phonological and semantic information provided during training. Although all five assessments required some knowledge of both phonological and semantic information, following the logic of Nash and Donaldson (2005) we classified the assessment as phonological or semantic on the basis of to the kind of information that children were asked to supply in their responses. The order of measures was fixed, as follows, but the order of items within each measure was randomized across participants. Participants did not receive any feedback regarding the accuracy of their responses in these tasks.

Naming (Phonological Recall)

Children were shown a picture of a novel object and asked to recall its name. Responses were transcribed from audio recordings and scored dichotomously as correct or incorrect.

Listening (Phonological Recognition)

Children viewed a picture of a novel object and heard four novel words, including the correct word, a phonological foil, a semantic foil, and a combined phonological/semantic foil. Phonological foils were mispronunciations of the target word that differed on the medial consonant; the medial consonant in the foil had the same manner and voicing but a different place of articulation than the medial consonant in the target word. For example, the phonological foil for the target word /nædəm/ was /nægəm/. Semantic foils were correct productions of other target words, and combined foils were mispronunciations of the semantic foils. Thus, for each item, participants heard two correctly produced target words and two mispronounced target words, of which only one was the correct name of the picture. The order of presentation of the correct answer was randomized across trials. After listening to the four options, children were asked to say the correct word for the displayed object. Responses were transcribed from audio recordings and scored dichotomously as correct or incorrect.

Drawing (Nonverbal Semantic Recall)

Children heard a novel word and were asked to draw a picture of the corresponding object. Drawings were scored on a partial credit scale that gave higher credit to more specific drawings of the objects. A drawing received zero points if the child drew nothing about the target item correctly and at least one point if it the scorer could discern that the child was drawing the correct item. Drawings that included most of the correct features were awarded two points, and drawings that included all of the important features were awarded three points. Appendix C provides sample scored drawings.

Describing (Verbal Semantic Recall)

The child heard a novel word and was asked to describe everything he or she could remember about it. Responses were transcribed from audio recordings and scored according to the amount of information recalled, with up to four points possible per item. One point was awarded for recalling the correct category, and up to three points were awarded for recall of features.

Finding (Semantic Recognition)

The child heard a novel word and was asked to choose the correct object from an array of eight pictures, including the six taught objects and two additional unfamiliar objects. Responses were scored automatically by the computer program.

Results

Descriptive Statistics

Means and standard deviations for all norm-referenced measures and experimental word-learning tasks are displayed in Table 1. Scores on the norm-referenced measures were approximately normally distributed within our sample. However, similar to previous studies, floor and ceiling effects were observed in some of the experimental measures of word learning. We observed a floor effect for the naming task, in which 17 participants (34%) were unable to name any items correctly. In contrast, a ceiling effect was observed for the finding task, in which 20 participants (40%) correctly identified all target objects.[1] More variability was observed in the other three word-learning assessments in which no more than six participants (12%, in the describing task) scored at floor and no more than nine participants (18%, in the listening task) scored at ceiling. These results suggest that across participants, the different types of word-learning assessments have varying levels of difficulty.

[1]Although chronological age was significantly correlated with performance on most word-learning tasks, the ceiling and floor effects observed were not fully explained by age. To illustrate this, we divided the sample into younger (< 8 years) and older (> 8 years) groups. The effects were present in both groups: 32% of younger group and 36% of older group scored at floor on the naming task and 39% of younger group and 41% of older group scored at ceiling on the finding task.

Table 1. Descriptive statistics.

Measure	*M*	*SD*	Range
Chronological age (months)	95.42	19.47	60–151
CTOPP nonword repetition SS	7.88	2.05	3–13
PPVT-4 SS	104.78	12.65	72–138
EVT-2 SS	103.71	11.23	74–132
Naming accuracy (max = 6)	1.72	1.68	0–6
Listening accuracy (max = 6)	3.78	1.63	1–6
Drawing rating (max = 18)	7.98	5.45	0–18
Describing score (max = 24)	8.82	5.93	0–20
Finding accuracy (max = 6)	4.24	1.78	0–6

Note. CTOPP = Comprehensive Test of Phonological Processing; SS = Standard Score; PPVT-4 = Peabody Picture Vocabulary Test–4; EVT-2 = Expressive Vocabulary Test–2.

Correlational Analysis

Table 2 presents correlations for the variables of interest. Spearman correlations are reported for all comparisons that included experimental word-learning measures. Pearson correlations are reported for intercorrelations between norm-referenced measures and chronological age. As expected, significant positive correlations were observed between the various assessments of word learning. Overall, these were in the moderate to large range but, importantly, no two measures showed complete overlap. Correlations between the predictor variables (age, nonword repetition, and existing vocabulary knowledge) and word-learning measures ranged from small to moderate. Chronological age was significantly correlated with performance on the listening, drawing, and describing tasks. Nonword repetition was significantly correlated with performance in the naming, listening, and finding tasks. Finally, vocabulary was significantly correlated with performance on the describing task.

Table 2. Correlations.

Measure	1	2	3	4	5	6	7
1. CA							
2. CTOPP NWR	**–.13**						
3. Vocab Comp.	**–.07**	**.29***					
4. Naming	.17	.35*	.28*				
5. Listening	.33*	.34*	.29*	.55***			
6. Drawing	.52***	.12	.23	.54***	.70***		
7. Describing	.40*	.26	.44**	.58***	.70***	.84***	
8. Finding	.21	.37*	.27	.63***	.73***	.66***	.73***

Note. Pearson correlations are reported for boldface pairs, including only CA, CTOPP NWR, Vocabulary Composite. Spearman correlations are reported for all other comparisons involving word-learning measures. Correlations were not adjusted for multiple comparisons; however, applying a Bonferroni adjustment to maintain a familywise error rate < 5% would result in a critical *p* value of .002 to determine statistical significance. CA = chronological age; CTOPP NWR = Nonword Recognition subtest of the Comprehensive Test of Phonological Processing.

**p* < .05. ***p* < .01. ****p* < .001.

Regression Models

Hierarchical linear regression models were used to determine the amount of unique and shared variance contributed to each measure of word learning by vocabulary knowledge and nonword repetition after controlling for chronological age.[2] For each measure of word learning, we ran two regression models. Chronological age was entered in the first step for both models. To isolate the effect of existing vocabulary knowledge, nonword repetition was entered in the second step, followed by the vocabulary composite in the third step. To isolate the effect of phonological working memory, Steps 2 and 3 were reversed. Table 3 reports the results of each regression model for each word-learning measure.

Phonological Recall (Naming)

The full model containing chronological age, vocabulary, and nonword repetition accounted for 25% of the variance in the naming task. Nonword repetition accounted for 9% unique variance in naming after controlling for chronological age and existing vocabulary knowledge, but existing vocabulary knowledge did not explain significant unique variance after controlling for chronological age and nonword repetition.

Phonological Recognition (Listening)

The full model containing chronological age, vocabulary, and nonword repetition accounted for 29% of the variance in the listening task. Nonword repetition accounted for 8% unique variance in the listening task after controlling for chronological age and existing vocabulary knowledge, but existing vocabulary knowledge did not explain significant unique variance when entered last in the model.

Semantic Recall (Drawing, Describing)

The full model with all three predictors explained 41% of the variance in scores on the drawing task, which assessed nonverbal semantic recall. Neither vocabulary nor nonword repetition accounted for significant unique variance when entered last in models containing three predictors. Vocabulary knowledge accounted for 5% after controlling for age alone, whereas nonword repetition was not a significant predictor after controlling for age.

The describing task assessed verbal semantic recall. The full model containing chronological age, vocabulary, and nonword repetition accounted for 44% of the variance in controlling for chronological age and existing vocabulary knowledge. Nonword repetition did not explain significant unique variance when entered last in the model, but existing vocabulary knowledge accounted for 11% unique variance after controlling for chronological age and nonword repetition. Taken together, these results suggest that existing vocabulary knowledge plays a unique role in explaining individual differences in verbal semantic recall, whereas its contribution to nonverbal semantic recall is not statistically independent from nonword repetition.

Semantic Recognition (Finding)

The finding task assessed semantic recognition. The full model, with all three predictors, explained 18% of the variance in scores on the finding task. Nonword repetition was the only significant predictor of finding performance, explaining 13% unique variance after controlling for chronological age and vocabulary knowledge.

Discussion

In this study we examined the influence of nonword repetition and existing vocabulary knowledge on children's ability to learn new words. The results indicated that, together with chronological age, nonword repetition and existing vocabulary knowledge explained up to 44% of the variance in children's word learning. However, the relative influence of each predictor varied across assessment tasks. Nonword repetition was the stronger predictor of phonological recall, phonological recognition, and semantic recognition, whereas vocabulary knowledge was the stronger predictor of verbal semantic recall.

These results are consistent with theoretical models of word learning and lexical quality (e.g., Gupta & Tisdale, 2009; Perfetti, 2007) and converge with previous studies to highlight the importance of existing phonological skills and semantic knowledge on new word learning (e.g., Gathercole et al., 1997; Gray, 2004, 2006; Nation et al., 2007). The results further extend previous findings by illustrating how these knowledge sources differentially contribute to measures of lexical quality. In this study, both assessments of phonological word learning provided participants with visual semantic information (the picture of the target object) and asked them to produce the correct phonological form. The tasks differed on whether the participants had to retrieve the phonological representation from memory or recognize it and repeat it when given four choices. We found that nonword repetition uniquely predicted performance on both phonological assessments, suggesting its relationship with phonological aspects of word learning was similar across tasks.

The pattern for semantic tasks was less consistent. Vocabulary predicted significant unique variance after age and nonword repetition in the verbal semantic recall (describing) task. The unique contributions of vocabulary and nonword repetition were nonsignificant and approximately equal in size for the nonverbal semantic recall (drawing) task; however, we note that vocabulary, but not nonword repetition, was a significant predictor after controlling for age alone. In this study, the novel objects were designed to be new members of real categories that children were already familiar with—a design feature intended to approximate real word learning for school-aged children,

[2]Linear regression assumes a linear relationship between predictors and outcome variables and a normal distribution of residuals. Scatter plots of predictor and outcome variables and histograms of saved standardized residuals from each regression model were inspected to confirm that these assumptions were met.

Table 3. Hierarchical linear regression models.

Task	Step	Variable	R^2	$R^2\Delta$	*F*Δ	*df*	*p*
Naming (phonological recall)	1	Chronological age	.10	.10	5.13	(1, 48)	.028
	2	Vocabulary composite	.16	.06	3.24	(1, 47)	.078
	3	CTOPP NWR	.25	.09	5.75	(1, 46)	.021
	2	CTOPP NWR	.23	.13	8.01	(1, 47)	.007
	3	Vocabulary composite	.25	.02	1.27	(1, 46)	.266
Listening (phonological recognition)	1	Chronological age	.13	.13	7.29	(1, 48)	.010
	2	Vocabulary Composite	.21	.08	4.54	(1, 47)	.038
	3	CTOPP NWR	.29	.08	4.91	(1, 46)	.032
	2	CTOPP NWR	.25	.12	7.41	(1, 47)	.009
	3	Vocabulary Composite	.29	.04	2.23	(1, 46)	.142
Drawing (nonverbal semantic recall)	1	Chronological age	.34	.34	24.94	(1, 48)	<.001
	2	Vocabulary Composite	.40	.05	4.10	(1, 47)	.049
	3	CTOPP NWR	.41	.02	1.21	(1, 46)	.277
	2	CTOPP NWR	.38	.03	2.58	(1, 47)	.115
	3	Vocabulary Composite	.41	.03	2.66	(1, 46)	.110
Describing (verbal semantic recall)	1	Chronological age	.23	.23	14.68	(1, 48)	<.001
	2	Vocabulary Composite	.40	.16	12.65	(1, 47)	.001
	3	CTOPP NWR	.44	.04	3.15	(1, 46)	.082
	2	CTOPP NWR	.33	.09	6.43	(1, 47)	.015
	3	Vocabulary Composite	.44	.11	8.88	(1, 46)	.005
Finding (semantic recognition)	1	Chronological age	.06	.06	3.27	(1, 48)	.077
	2	Vocabulary Composite	.09	.03	1.54	(1, 47)	.220
	3	CTOPP NWR	.18	.09	4.89	(1, 46)	.032
	2	CTOPP NWR	.17	.11	6.28	(1, 47)	.016
	3	Vocabulary Composite	.18	.01	0.37	(1, 46)	.546

Note. For readers interested in whether the combination of vocabulary and nonword repetition, entered together in the second step, significantly improved the prediction of word learning after controlling for age, results were as follows: naming, $F = 4.66$, $p = .014$; listening, $F = 4.92$, $p = .012$; drawing, $F = 2.66$, $p = .08$; describing, $F = 8.19$, $p < .001$; finding, $F = 3.28$, $p = .047$. CTOPP NWR = Nonword Recognition subtest of the Comprehensive Test of Phonological Processing.

at least for concrete nouns. Children were provided both visual and verbal semantic information during instruction, including the picture and descriptions of both visible and nonvisible features. However, although retrieval of verbal semantic information may have enhanced performance, it was not essential to the accurate completion of the drawing task. Therefore, it is possible that children could rely on existing categorical knowledge to complete the drawing task. In contrast, to accurately complete the describing task, children had to retrieve specific verbal information about each object from memory, some of which was not visible on the basis of the picture. For example, one cannot tell by looking at a fruit whether it will taste sour or sweet. This may explain why existing vocabulary knowledge was a more important contributor to the verbal semantic recall task than to the nonverbal semantic recall task.

We were somewhat surprised that nonword repetition was a unique predictor of performance on the semantic recognition task, whereas existing vocabulary knowledge was not. The strong ceiling effects observed in this task may have limited the ability to detect individual differences overall. In this task, both phonological and semantic information were available, such that low-quality representations would suffice to complete the task accurately, provided that participants had correctly linked the two. Our results suggest that the phonological processing skills, as measured by nonword repetition, had a greater influence on this task than existing vocabulary knowledge. This may reflect the fact that participants had to hold the provided phonological form in memory while searching for the correct picture. We note that, in this study, there was only one target item from each category, which therefore limits the amount of semantic analysis required to successfully complete the task. Although replication is needed to confirm the present pattern of results, a question for future studies is whether a different pattern is observed when more than one member of each category is represented in the stimulus items. In such cases, a more specific semantic representation will be needed to distinguish between members of a category. We hypothesize that existing vocabulary knowledge may have more influence in such cases.

Conclusions about the relationships between word-learning predictors and outcomes are strengthened when word knowledge is assessed in varying domains and at different levels of complexity. In this study, following controlled instruction, a floor effect was observed in the naming task, whereas a ceiling effect was observed in the finding task. Fast mapping studies have shown a similar pattern of better performance on finding than naming tasks after minimal exposure to new words (Carey & Bartlett, 1978; Dollaghan, 1987). In addition, these two tasks were the most commonly used assessments of word learning among studies in Kan and Windsor's (2010) meta-analysis, with word-learning differences between SLI and typically developing groups being significantly smaller for naming tasks than for finding tasks. A common interpretation has been that comprehension of newly learned words is easier than production. However, when considering these findings, it is important to note that these tasks vary in at least two dimensions: the primary domain of assessment (phonology vs. semantics) and the modality of the task (recall vs. recognition). An advantage of the present study was that there was more than one task in each modality and in each domain, and our results support a somewhat different interpretation. Across both domains of assessment, we noted that performance was higher in recognition tasks than in recall tasks. Participants averaged 63% and 71% of points possible for phonological and semantic recognition, respectively, and 29%, 37%, and 44% for phonological recall, verbal semantic recall, and nonverbal semantic recall, respectively. With regard to the lexical quality framework, lower quality representations may be sufficient to support performance in recognition tasks, whereas higher quality representations may be necessary for accurate performance in recall tasks.

Although not a question explored in this study, the results may have implications for the assessment of word learning in special populations, who show differential profiles of strength and weakness in phonological and semantic skills, including children with dyslexia, poor comprehenders, and SLI. Word-learning difficulties have been documented in each of these groups, and it appears that the specific nature of the word-learning difficulties may differ between groups; however, to date, no studies have directly compared them (see Adlof & Perfetti, 2013, for a review). The current study demonstrated how different results might be obtained when word learning is assessed by different measures, varying in domain of word knowledge (phonological vs. semantic) or task demand (recall vs. recognition). Such tasks may be useful for determining the locus of potential word-learning difficulties in individual children and across subgroups.

Strengths of this study include the use of ecologically valid novel word and object stimuli and multiple measures to assess word learning at various levels in school-aged children. Several limitations and considerations for future research should also be noted. First, there was a wide age range in the participant sample (5–12 years). Our analyses controlled for chronological-age differences by entering chronological age first in regression models and by using standard scores as indicators of nonword repetition and vocabulary knowledge. However, it is possible that the effects of nonword repetition skill and vocabulary knowledge on word learning change across development, especially with the development of literacy. This is an important question to be addressed by future studies with a larger sample of children across each age. In addition, this study did not control for the potential effects of nonverbal cognitive skills on children's word learning. Thus, it is not possible to determine the degree to which the effects of nonword repetition and vocabulary knowledge are specific to phonological and/or semantic skills versus indicative of general cognitive abilities. It is also possible that some measures of word learning, such as the drawing task, would be more impacted by nonverbal skills than other tasks. Last, we examined phonological and semantic recall and recognition immediately after word instruction. However, after words are taught, some information is forgotten while other information is retained during the process of memory consolidation (Dumay & Gaskell, 2007; Vlach & Sandhofer, 2012). Recent studies indicate that some factors, such as the phonotactic properties of words to be learned, have differing effects depending on the stage of word learning being examined (Storkel, Bontempo, & Pak, 2014; Storkel & Lee, 2011). It remains to be determined whether and how the specific relationships observed in this study would change if word learning were reassessed after a delay. These issues represent important areas for future research.

Conclusion

Theories of word learning have implicated both nonword repetition skill and existing vocabulary knowledge as important foundations for new word learning. This study demonstrated the utility of using multiple assessments of word learning to measure the quality of newly acquired phonological and semantic representations. The results indicate that the relative contributions of nonword repetition skill and existing vocabulary knowledge vary across different assessments of word learning. Future studies should examine these relationships at early and later stages of word learning; across developmental time; and in populations with language and/or reading impairments, who are known to struggle with word learning.

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Appendix A

Word-Learning Stimuli

Novel word	Novel object category	Visible feature 1	Visible feature 2	Invisible feature
/jumʌt/	Bird	Dark feathers	Horn on top of beak	Can travel very long distances
/tinɪk/	Fish	Doesn't have scales	Flat body	Lives in deep water
/fonɪk/	Fruit	Yellow skin	Green pulp inside	Tastes sour
/nædʌm/	Machine	Round keyboard	Paper-holder underneath	Types at very fast speeds
/meɪkʌdʒ/	Vehicle	Big back wheel	Small front wheel	Runs on electricity
/gɔmɪk/	Tree	Few leaves	Huge trunk	Trunk stores lots of water

Sample Object Images:

Appendix B

Sample Teaching Script for Target Word /gɔmɪk/

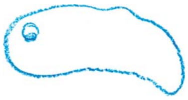
Block	Script
1	This is a /gɔmɪk/. A /gɔmɪk/ is a type of tree. A /gɔmɪk/ has only a few leaves. It has a huge trunk. The trunk of the /gɔmɪk/ stores lots of water. Can you find the /gɔmɪk/? Yes, that's the /gɔmɪk/. OR Not quite, here's the /gɔmɪk/. What's this called? You say it. Right, it's a /gɔmɪk/. OR It's a /gɔmɪk/.
2	What's this called? You say it. Right, it's a /gɔmɪk/. OR It's a /gɔmɪk/. A /gɔmɪk/ is a type of tree. A /gɔmɪk/ has only a few leaves. It has a huge trunk. The trunk of the /gɔmɪk/ stores lots of water. Can you find the /gɔmɪk/? Yes, that's the /gɔmɪk/. OR Not quite, here's the /gɔmɪk/.
3	Can you find the /gɔmɪk/? Right, that's the /gɔmɪk/. OR Not quite, here's the /gɔmɪk/. A /gɔmɪk/ is a type of tree. A /gɔmɪk/ has only a few leaves. It has a huge trunk. The trunk of the /gɔmɪk/ stores lots of water. What's this called? You say it. Yes, it's a /gɔmɪk/. OR It's a /gɔmɪk/.

Appendix C

Sample Drawings at Each Level of the Rating Scale

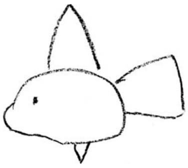
Score = 0

Not discernible as target object



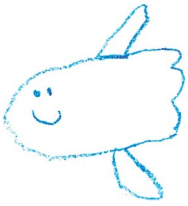
Score = 1

Discernible as a fish, but no specific features



Score = 2

Discernible as a fish, includes fins and tail



Score = 3

Discernible as a fish, includes fins and tail of correct size and shape