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The Relationship Between Phonological Memory, Phonological Sensitivity, and Incidental Word Learning

Vijayachandra Ramachandra · Lynne E. Hewitt · Tim Brackenbury

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Abstract This study investigated the cognitive abilities needed to succeed at incidental word learning, specifically by examining the role of phonological memory and phonological sensitivity in novel word learning by 4-year-olds who were typically developing. Forty 4-year-olds were administered a test of nonword repetition (to investigate phonological memory), rhyming and phoneme alliteration tasks (to investigate phonological sensitivity), and an incidental word learning task (via a computer-based presentation of a cartoon story). A multiple regression analysis revealed that nonword repetition scores did not contribute significantly to incidental word learning. Phonological sensitivity scores were significant predictors of incidental word learning. These findings provide support for a model of lexical acquisition in which phonological knowledge plays an important role.

Keywords Fast mapping · Vocabulary development · Lexical memory · Phonological knowledge

Lexical acquisition forms an important aspect of language development. An average American or British high school graduate has a receptive vocabulary of about 60,000 words. In order to hit this mark by the age of 18, children have to learn 3,750 new words every year, or 10 words every day, or 1 word every waking 90 mins (Bloom 2000). Clearly children are outpacing even the best attempts by parents to teach them new words. This rapid acquisition of words can be attributed to a process called incidental word learning. In incidental word learning, children make connections between a novel word and its referent (and possibly some

V. Ramachandra (✉)
Department of Communication Sciences and Disorders, Marywood University, Scranton, PA 18509, USA
e-mail: vijay.chandra2002@gmail.com

L. E. Hewitt · T. Brackenbury
Department of Communication Disorders, Bowling Green State University, Bowling Green, OH 43403, USA
e-mail: lhewitt@bgsu.edu

T. Brackenbury
e-mail: tbracke@bgsu.edu

aspects of its meaning) after minimal exposure and no direct instruction. In other words, they are quite capable of learning at least some aspects of new words via the course of every-day life, and retain this information despite brief exposures. Incidental word learning begins with fast mapping (Carey and Bartlett 1978), in which an initial bare-bones representation is formed and placed in lexical-semantic memory. Over time, fast mapping gives way to slow mapping, in which the initial representations are elaborated and refined as the result of repeated exposures and experiences (e.g., Capone and McGregor 2005; Bloom 2000).

The process by which incidental word learning takes place has been investigated using both controlled and naturalistic word learning paradigms. In controlled word learning research, novel (usually nonce) words and their novel referents are presented to children along with familiar names and their referents. Children are tested at a later time to determine whether they can identify and/or label the referent by/with the nonce word. The findings from these studies have shown that children can readily fast map novel names with their novel referents, even after a single exposure. This brief exposure may be sufficient for performing well on comprehension tasks (identifying a novel object from an array), but is insufficient for performing well on word production tasks (Carey and Bartlett 1978; Dollaghan 1985, 1987).

Studies conducted in laboratory environments may suffer from poor ecological validity. Children in these studies are exposed to words in an environment quite different from the natural contexts in which they normally learn words. In order to understand how children learn words in more natural environments, the fast mapping literature has evolved over time, seeking ways to simulate a more natural word-learning context. This has lead to the introduction of a procedure known as-"quick incidental word learning" (QUIL). QUIL is similar to the fast mapping procedure, in that, both refer to the rapid and partial representations of novel word meanings, which forms the initial phase of lexical acquisition by children. It is however, different from the controlled word learning procedures, because of its emphasis on the 'incidental' nature of word learning, which requires making rapid word-referent connections without much contextual support and direct instructions from the examiner. QUIL procedures usually involve watching videos with story narratives containing novel words. The nonlinguistic referents, the novel words, and the familiar words are not isolated or emphasized. Finally, the positions of the novel words within the story passages are not always the same (Oetting et al. 1995). The findings of word learning studies using QUIL indicate that children are able to acquire novel words incidentally, following brief exposure. In addition, these studies indicate that children can learn various aspects of novel words and can also maintain these representations after a delay of at least 3–7 days (Oetting et al. 1995; Rice et al. 1990; Rice and Woodsmall 1988).

Incidental word learning is a complex process that encompasses phonological processing, memory for a novel word, and making a connection between the novel word and its referent. Recent work has investigated this process to attempt to uncover the underlying abilities needed to be successful in incidental word learning. Investigators have examined the influence of phonological memory and/or phonological sensitivity in experimental word learning paradigms (De Jong et al. 2000; Gathercole and Baddeley 1990a). Phonological memory has been of interest to investigators of word learning because of its key role in the temporary storage and manipulation of information for complex cognitive tasks, including speech and language. Phonological sensitivity has been investigated because this ability indexes phonological knowledge on a metalinguistic level. That is, success on tasks of phonological sensitivity is only possible when the child has sufficiently detailed phonological knowledge, along with the cognitive flexibility to use that knowledge in metalinguistic tasks. The present investigation extends this line of research by examining the role of phonological memory and phonological sensitivity in an incidental word learning procedure.

Phonological Memory

Phonological memory capacity is considered important for incidental word learning because it enables the temporary storage of information about a novel word in order to form a representation that can be transferred to long term memory (Gathercole et al. 1992). Nonword repetition tasks have been used to test the phonological memory capacity. Nonword repetition involves repeating nonsense words that have little or no correspondence with real English words. Baddeley and colleagues (e.g., Gathercole and Baddeley 1989, 1990b) have construed that nonword repetition involves the activation of pure phonological processes such as encoding, storage, and retrieval, independently from lexical knowledge (although others have challenged this assertion–see Snowling et al. 1991; Metsala 1999; Bowey 1996, 2001). Both nonword repetition and word learning are constrained by phonological memory. That is, the acts of learning novel words and repeating nonwords require encoding and processing of novel phonological codes and are constrained by phonological memory. Because of the common phonological memory shared by these two tasks, the existence of a direct relationship between phonological memory and word learning has been proposed (Gathercole 2006). There is some evidence showing a direct correlation between nonword repetition and vocabulary knowledge in children, and nonword repetition and novel word learning in children as well as adults (Gathercole et al. 1992; Gathercole and Baddeley 1989, 1990a; Vallar and Papagno 1993). This indicates that repetition of nonwords and learning word-nonword pairs may be constrained by a common underlying short-term phonological storage capacity. There is evidence that weakens the findings of a direct causal link between performance on nonword repetition (construed as a measure of phonological memory) and word learning. Beyond 5 years of age, the relationship between nonword repetition and vocabulary appears to flip, with vocabulary knowledge becoming a relatively strong predictor of performance on nonword repetition (Gathercole et al. 1992).

There are some studies in children with Specific Language Impairment (SLI), which provide credence to the lack of a direct link between nonword repetition and word learning. For example, Gray (2004) wanted to determine whether preschool children with SLI had problems at the lemma (representation of the semantic and syntactic aspects of a word) or the lexeme (phonological representation) level of learning a word. The findings revealed that both semantic knowledge (measured by PPVT-III) and phonological representation (measured by nonword repetition) contributed to variance in novel word learning. Gray (2005) investigated the effects of semantic and phonological cues in novel word learning by children with SLI. The findings revealed that the semantic cues helped children with SLI by strengthening their lemma-lexeme connections and in turn aided them in responding accurately to novel word comprehension tasks. On the other hand, phonological cues strengthened SLI children's phonological representations (lexeme) and therefore enhanced their performance on novel word productions. Gray (2006) found that neither nonword repetition nor the PPVT-III predicted performance on fast mapping tasks in children with SLI between the ages of 3 and 6. These investigations by Gray (2004, 2005, 2006) suggest that children with SLI have problems in learning both the semantic and phonological aspects of a novel word, and that both these cues help in novel word learning by these children.

Alt and Plante (2006) found that nonword repetition was highly correlated with both the lexical labeling (making connections between the word and its referent) and learning the semantic features (the nonlinguistic visual features associated with a novel word) in a fast mapping task by children with SLI. This indicates that nonword repetition is not a unique measure of phonological memory capacity. Horohov and Oetting (2004) found that nonword repetition had moderate correlations with children's scores on standardized vocabulary and semantic tests but, when all variables were partialled out, nonword repetition did not contribute to any unique variance in learning novel words presented via a story narrative. On the other hand, nonword repetition did have significant contributions to word learning when it was factored in with the other two language tests. These findings in children with SLI indicate that nonword repetition is not a pure measure of phonological memory, as suggested by Gathercole and Baddeley (1989, 1990b). Overall, the studies in children with SLI when combined with studies by Gathercole et al. (1992) in typically developing children beyond 5 years weaken the claims by Gathercole and colleagues for the existence of a direct link between phonological memory (measured by nonword repetition) and subsequent vocabulary acquisition.

Phonological Sensitivity

Metsala (1999) and Bowey (1996, 2001) offered an alternative view of the relationship between phonological memory and vocabulary size. They have suggested that increases in a child's vocabulary lead to increasingly detailed phonemic representations, which give rise to more efficient phonological processing. This would in turn lead to better performance on tasks such as nonword repetition. They contend that this is why Gathercole et al. found that vocabulary was a significant predictor of nonword repetition in children over the age of five. Further investigations by Metsala (1999) and Bowey (1996, 2001) have led to two main conclusions. First, phonological memory as measured by nonword repetition is not the only predictor of subsequent vocabulary size. Second, phonological sensitivity contributes significantly to variance in vocabulary after nonword repetition effects are controlled for, but not vice versa. The latter findings can be attributed to the more metaphonological nature of phonological sensitivity tasks relative to nonword repetition.

While there exists a fairly extensive literature investigating the influence of phonological memory on vocabulary development, relatively fewer investigations of the relation between phonological sensitivity and vocabulary size have been undertaken. Relatively little work has been done relating either of these measures of phonological skill with incidental word learning. This is an important area for investigation, because although vocabulary and incidental word learning are related concepts, performance on tasks related to them do not significantly correlate (e.g., Rice et al. 1990). In other words, children who do better on incidental word learning tasks do not have larger vocabularies than those who perform more poorly. To our knowledge, only two published studies have explored the role of phonological memory and sensitivity in a word-learning paradigm (Gathercole and Baddeley 1990a; De Jong et al. 2000). Gathercole and Baddeley (1990a) found a high correlation between scores on a task of nonword repetition and rate of word learning, which was a measure of the speed at which 5 and 6-year-olds learned the novel names of toys. This study used an unusual paradigm, however, in that proper names were used rather than common nouns. In addition, the nonword repetition stimuli used in this work, as in all of Gathercole and Baddeley's work in this area, contain several derivational morphemes. Thus the nonwords used were actually somewhat wordlike. Success at the task may therefore have been linked to sophisticated lexical knowledge, and not to phonological memory alone. De Jong et al. (2000) explored the interaction between phonological short-term memory (using a nonword repetition task), phonological sensitivity, and paired associate word learning in Dutch speaking 5-year-old children. Their findings contrast with those of Gathercole and Baddeley, in that they found a significant contribution of phonological sensitivity but a weak contribution of phonological short-term memory in paired associate word learning tasks. A follow-up study reported in the same article investigated the effect of training in phonological sensitivity on paired associate word learning, and revealed a performance improvement in word learning following a short two- week training. These findings suggest that enhanced phonological sensitivity (a measure hypothesized to indicate the presence of a richer phonemic representation) leads to enhancement in word learning skills. This literature accords with recent models of word learning showing a strong link between phonological and lexical development (see Storkel and Morrisette 2002 for a review of some of this work).

Present Investigation

It is not known whether the connections previously reported between semantic knowledge/skill (as measured by formal vocabulary tests and controlled word learning tasks), and phonological memory and sensitivity would hold for children learning words in a more naturalistic activity (such as an incidental word learning task). Incidental word learning draws on a wide variety of cognitive realms. These would include prior world knowledge and linguistic (syntactic, semantic, pragmatic, and phonological) knowledge. It requires the ability to attend to novel linguistic input in context, and extract relevant details for temporary storage and processing, so that linguistic and conceptual information can be transferred to memory tied to the novel phonological form. The nonword repetition task, which is a measure of phonological memory, is designed to eliminate most of this complexity, requiring only brief storage and processing of nonce forms (largely divorced from linguistic and world knowledge). In contrast, phonological sensitivity tasks depend on the ability to extract phonological information at a metalinguistic level, and this adds complexity to the task as well as requiring more sophistication in phonological knowledge representation. The phonological sensitivity tasks, which require complex storage and processing of previously learned phonological information, might show greater relationship to incidental word learning than nonword repetition. The current study explores the contributions of phonological memory and phonological sensitivity to initial stages of word learning of preschool children by using tasks of nonword repetition, phonological sensitivity and quick incidental word learning.

Method

Participants

Forty typically developing children (22 males, 18 females), between 48 to 60 months (M = 55 months), who were native speakers of English participated in this study. Four-year-olds were selected because at age 5, nonword repetition is influenced by children's lexical and phonotactic knowledge and some studies have shown that nonword repetition becomes relatively less significant predictor of vocabulary at this age (Gathercole et al. 1992; Laws and Gunn 2004). Children in this study had no history of speech, language, sensory, or cognitive impairments. In order to help rule out hearing and speech and language impairment, all participants passed a language screening, the Fluharty Preschool Speech and Language Screening Test (Fluharty 2001), and a hearing screening, using a portable audiometer at 20 dB HL (ASHA Panel on Audiologic Assessment 1997).

Procedures

Participants were administered a nonword repetition task, as a measure of phonological memory, a Quick Incidental Learning (QUIL) task, as a measure of incidental word learning, and alliteration awareness and rhyme awareness tasks, as measures of children's phonological sensitivity. Each is described below. The order of the tasks was not counterbalanced.

Nonword Repetition

Gathercole and Baddeley (1990a) and Gathercole et al. (1992) argued that nonword repetition is a purer measure of phonological working memory when compared with classic measures of phonologic memory such as the digit span because nonword repetition is less dependent on previous lexical knowledge. Dollaghan and Campbell (1998) used nonword repetition as a diagnostic tool to identify children with language impairment because they considered it to be a process-dependent measure independent of children's linguistic experience and socioeconomic background and was equal in familiarity to all the participants of the study (see also Engel et al. 2008). In the current study, we wanted to use a measure of phonological memory, which was dependent on a relatively complex set of cognitive processes and was less dependent on child's previous linguistic knowledge and socioeconomic background. Therefore we chose nonword repetition, a less knowledge dependent task, as a measure of phonological memory, rather than the more traditional digit span.

The nonword repetition stimuli developed by Dollaghan and Campbell (1998) were used, consisting of 16 nonwords of varying lengths (one, two, three, and four syllables). All nonwords began and ended with a consonant. The main rationale for choosing these nonword repetition stimuli was that the syllables (CV or CVC) in these nonwords have no correspondences with any real English words. That is, the nonwords developed by Dollaghan and Campbell (1998) are not "word-like" and so the child does not have an opportunity to make use of his or her lexical knowledge to encode, store and retrieve nonwords. This would help in tapping phonological memory independent of any influences by children's lexical knowledge. Administration and scoring procedures were those stipulated by Dollaghan and Campbell (1998). Participants were given audiotaped instructions (pre-recorded by a native speaker of English) "Now I will say some made up words. Say them after me exactly the way I say them". Following the instructions, the participants were presented with nonwords via headphones at comfortable listening levels. Children's responses were picked up by a microphone placed in close proximity to their mouths. Responses were recorded for analysis and scoring. The responses were scored for percentage of correct phonemes. To establish reliability of scoring, recordings of 20% of children were randomly selected and analyzed by a second trained clinician, who was a native speaker of English. The inter-rater reliability between the investigator and the second trained clinician was calculated by counting the total number of phonemes that were transcribed identically by both the raters and then dividing the result by the total number of phonemes (which was 96 phonemes). The inter-rater reliability of 91–99% was considered reliable for nonword repetition scoring.

Quick Incidental Learning

A modified Quick Incidental Learning (QUIL) procedure based on that used by Brackenbury and Fey (2003) was adopted for the current study. The aim was to obtain a more naturalistic measure of incidental word learning. The following six monosyllabic target words were selected for this task**:** *dap, gid, shan, zik, paz, puk*, selected on the basis that they have similar phonotactic probabilities and neighborhood densities. The target stimuli, and the information regarding their phonotactic probability and neighborhood densities, were taken from Psychonomic Society Archive of Norms, Stimuli and Data (Gupta et al. 2004). The QUIL procedure consisted of three stages: training and testing on blank comparison; exposure phase; and post-exposure comprehension testing.

Training and Testing on Blank-Comparison

In the blank-comparison procedure, children were conditioned to respond to a missing picture (when that picture is named) by selecting a black square. The black square represented the response "the correct picture is hidden behind this black square or none of the above". This procedure has been used in many word learning studies with children and adults with mental retardation (see for example, McIlvane et al. 1992; Saunders et al. 1997).

This has also been successfully used with 4-year-old children in the QUIL study by Brackenbury and Fey (2003). The Match to Sample Program (Version 11.0.1, Dube and Hiris 1997) was used to train children. In this procedure, children were presented with three familiar pictures, and one was named by the experimenter. At the beginning of the trials, a small black square partially covered one of the familiar pictures, and with the progress of trials, the size of the black square increased and eventually covered the entire picture. The children were asked to either select the picture hidden behind the black square (the picture name is missing from the screen) or select one of the uncovered pictures. There were 24 trials in this training and all the participants of this study successfully completed it. That is out of the 24 trails none of the children made more than 1 error.

Exposure Phase

The participants in this phase were exposed to two stories presented in the form of cartoon slide shows with pre-recorded audio narrative to go with them. The two stories had three target words each. The children had five exposures to each of these target words. During the exposure phase, the participants were instructed that they would be listening to a story, which had some new words in it. They were asked to pay attention to the story that they would hear. For example, the target novel word *dap* was introduced to the child using the following story passages accompanying pictures- "One day John was getting ready to go to school and his mother reminded him to take his *dap* to school. John's school bus arrived and he was in a hurry to get into the bus. He grabbed his bag and forgot to take his *dap*. When John reached school he saw Ted playing with the *dap*. John realized that he had forgotten his *dap* at home and began to cry. John's teacher saw this and asked him why he was crying. John told his teacher that he had forgotten his *dap* at home".

Post-Exposure Comprehension Testing

Following the exposure to each story, children completed post-exposure comprehension testing for the three novel words presented to them in that story. The order of presentation of novel words in the comprehension testing was the same as the order of presentation of words in the story. The post-exposure comprehension testing not only examined children's initial ability to make a connection between the novel word and the novel referent, but also the stability of retention of the newly learned word. This stability was tested in two generalization

1. Generalization item-Label mismatch

"Where is chiv"?

Target picture "dap"	Familiar picture "apple"
Familiar picture "table"	Blank comparison

2. Identification item: Target "dap"

"Show me dap"

Blank comparison	Target picture ("dap")
Unfamiliar picture 1	Familiar picture ("table")

3. Generalization item-Referent mismatch

"Find dap"

Unfamiliar picture 1	Familiar picture ("table")
Blank comparison	Unfamiliar picture 2

4. Identification item

"Point to dap"

Familiar picture ("table")	Blank comparison
Target "dap"	Unfamiliar picture 1

Fig. 1 Examples of the four trials on the post-exposure comprehension testing (for the word "dap"). Correct responses are shown in *gray*

procedures, the "generalization item-label mismatch" and the "generalization item-referent mismatch". In the "generalization item-label mismatch", children were asked to match a novel unfamiliar label with a picture from a choice of the target picture, two familiar pictures, and a blank comparison. In the "generalization item-referent mismatch", children were asked to match the target label with a picture from a choice of two unfamiliar pictures, a familiar picture, and a blank comparison (see example in Fig. 1). The stability of newly learned labels was determined by testing children's ability to reject associations between a completely novel, previously unheard, label and the target picture (label mismatch), and between the target label and a completely novel object, never before seen (referent mismatch). If children are able to perform at above chance levels on the generalization-items (if they select the blank-comparison on label-mismatch *and* referent mismatch trials), then it strengthens the interpretation of children's responses on identification trials. Specifically, it would mean that children's selection of the correct referent and rejection of the blank-comparison response on the identification trials was because they had learned the association between the target words and the target referents presented via the stories. The post-exposure comprehension testing for each novel picture consisted of four items (two identification items and two mismatch items). The identification items required children to select the just-labeled novel picture from a field that included a familiar picture, the target novel picture, an unfamiliar picture, and a blank comparison. The two identification items were identical except for the location of different pictures on the screen. One point was given for each item that was correctly identified on both the identification trials for each target word. In the label mismatch items, either the visual referent or the phonological form of the word was missing. That is, a previously unheard phonological form was requested while the visual referent for the target was observable (the label mismatch) or the target word's phonological form was requested when its visual referent was not included (the referent mismatch). As shown in Fig. 1, the order of the questions was the label mismatch, identification, referent mismatch, and identification. The mismatch questions and the order of all four question types were included to prevent the participants from fast mapping the target words to their referents without having used any information from the exposure stories (see Brackenbury and Fey 2003, for additional ways that these questions can be used). If an identification item had been presented first, for example, a child might have ruled out the familiar object and the blank comparison, leaving only a 50% chance of guessing the correct novel object. Remembering that same choice on the next identification question, she/he could pick the target picture again. As a result, this child would have been given credit for learning the target word and referent from the story, when she/he did not. By placing the label mismatch first, a child applying this strategy would fail because she/he would have mapped the wrong label to the target referent.

There were two identification trials for each word on the post-exposure comprehension testing, and children could get a maximum score of 1 for each word (if the child responded correctly on both the identification trials). So there were 6 new words and children were able to score a maximum of 6 points on the post-exposure comprehension testing.

Phonological Sensitivity

The phonological sensitivity tasks were based on the tasks used by Burt et al. (1999). They were selected because they were within the capabilities of preschool children in previous research while still showing variance indicating that children would not be likely to be at ceiling.

Alliteration Awareness Task

The experimenter and the child sat facing each other across a table. The experimenter then introduced the task by asking the child's name and telling the child 3 names that start with the same sound. The child was shown pictures of a leaf, a light, a lake, and a dog and explained how leaf, light, and lake were similar because they started with the same sound "l," and how the word "dog" was different because it started with the sound "d". The child was given a practice trial with feedback on the words head, house, bird, and hat. The practice trial was done without any pictures. The testing phase which followed the practice phase consisted of 12 trials during which no feedback was given to the child. No pictures were used and one repetition was allowed. A score of 1 was given for correctly identifying the odd-one-out.

Rhyme Awareness Task

The nursery rhyme "Humpty Dumpty" was recited by the experimenter along with pictures and the child's attention was drawn towards the rhyming words *wall* and *fall* in the nursery rhyme. The experimenter explained that *wall* and*fall* sound alike because both end with the sound—*all*. This was followed by a practice phase where the experimenter pointed to and named the pictures of *wall, fall, ball,* and *cat*. The experimenter then asked the child to point to the picture that sounded different. Feedback regarding why *wall, fall,* and *ball* sound similar and why *cat* sounds different was given to the child. The same procedure was repeated with the pictures *feet-meat-seat-key.* After these two trials, the child was asked to pick out the word, which “does not belong”, or “sounds different,” by just listening to those words and without any pictures. The words *sun-one-hat-gun,* were presented to the child during these trials. The testing phase, which followed the practice phase, consisted of 12 trials without feedback to the child. No pictures were used and one repetition was allowed. A score of 1 was given for correctly identifying the odd-one-out.

Results

Data Analysis

In order to investigate the potential interaction between phonological memory and phonological sensitivity in the incidental word learning of 4-year-old children who participated in this study, a bivariate correlation between the different variables of the study and a series of hierarchical multiple regression analyses were carried out. The independent variables in this study were nonword repetition (a measure of phonological memory), rhyming, and alliteration (measures of phonological sensitivity). A phonological sensitivity composite (combined scores on rhyming and alliteration) was also calculated. The dependent variable was consistent word identification (a measure of incidental word learning).

Results of Bivariate Correlation and Multiple Regressions

The means and standard deviations for incidental word learning, nonword repetition, alliteration, rhyming, and phonological sensitivity composite were 3.45 (SD = 1.43), 84.79 (SD = 11.85), 6.08 (SD = 3.09), 7.95 (SD = 2.01) and 14.03 (SD = 4.69) respectively. These descriptive results are depicted in Table 1. The results of the bivariate correlation, which are depicted in Table 2, reveal that the incidental word learning task was significantly correlated with rhyming ($r = 0.400$, $p < 0.05$), alliteration ($r = 0.462$, $p < 0.01$), and phonological sensitivity composite ($r = 0.475$, $p < 0.01$) (see Table 2). There was, however, no significant correlation between incidental word learning and nonword repetition ($r = 0.080$, $p > 0.05$). There was also a significant correlation between the different variables of phonological sensitivity measures but there was no correlation between the different phonological sensitivity measures and nonword repetition.

A series of hierarchical multiple regressions were run to further specify the influences of the phonological sensitivity and phonological memory on incidental word learning.

Table 1 Means and standard deviations for incidental word learning, nonword repetition, alliteration and rhyming

Task	Mean	SD	N
CI	3.45 (max = 6)	1.43	40
NWR	84.79 (max = 100)	11.85	40
ALI	6.08 (max = 12)	3.09	40
RHY	7.95 (max = 12)	2.01	40
PS compo	14.03 (max = 24)	4.69	40

CI consistent identification (a measure of incidental word learning), *NWR* nonword repetition, *ALI* alliteration, *RHY* rhyming, *PS compo* Phonological sensitivity composite (combined scores on alliteration and rhyming)

Table 2 Bivariate correlations between the different variables of the study

Variable	Incidental word learning	Rhyming	Alliteration	Phonological sensitivity composite	Nonword repetition
Incidental word learning	–	0.400*	0.462**	0.475**	0.080
Rhyming		–	0.677**	0.874**	0.151
Alliteration			–	0.949**	0.138
Phonological sensitivity composite				–	0.155
Nonword repetition					–

* Significant at $p < 0.05$ (2-tailed)
** Significant at $p < 0.01$ (2-tailed)

Table 3 Hierarchical regressions predicting incidental word learning from nonword repetition and phonological sensitivity tasks

Step variable entered	R^2 change	F change	Level of significance	f^2
Regression 1 ($N = 40$)				
Nonword repetition[a]	0.006	0.245	0.624	0.006
Alliteration[b]	0.207	9.730	0.004**	0.261
Regression 1a ($N = 40$)				
Alliteration[a]	0.213	10.285	0.003**	0.271
Nonword repetition[b]	0.000	0.013	0.910	0.000
Regression 2 ($N = 40$)				
Nonword repetition[a]	0.006	0.245	0.624	0.006
Rhyming[b]	0.154	6.776	0.013*	0.182
Regression 2a ($N = 40$)				
Rhyming[a]	0.160	7.227	0.011*	0.191
Nonword repetition[b]	0.000	0.017	0.896	0.000
Regression 3 ($N = 40$)				
Nonword repetition[a]	0.006	0.245	0.624	0.006
PS comp[b]	0.220	10.502	0.003**	0.282
Regression 3a ($N = 40$)				
PS comp[a]	0.226	11.097	0.002	0.292
Nonword repetition[b]	0.000	0.002	0.966	0.000

PS comp phonological sensitivity, f^2 effect size
* $p < 0.05$, ** $p < 0.005$
[a] Variable forced into the equation as step 1 of the regression
[b] Variable forced into the equation as step 2 of the regression

In each of the regressions, one or all of the sensitivity measures and the phonological memory measure were entered in opposing orders. As shown in Table 3, the sensitivity tasks (individually and as a group) were always found to be significant contributors to novel word learning, regardless of whether they were entered first or second. These measures accounted for 15–22% of the variance in incidental word learning performance. In contrast, phonological memory was not a significant contributor to any of the analyses (accounting for less than 1% of the variance in incidental word learning). The effect sizes for the contribution of nonword repetition in incidental word learning were extremely small ($f^2 = 0.006$). The effect sizes for the contribution of phonological sensitivity tasks in incidental word learning ranged between 0.191 and 0.292, which is between moderate and high ranges (Cohen and Cohen 1983).

Discussion

This study explored the role of phonological memory and phonological sensitivity in incidental word learning by 4-year-old typically developing children. Forty 4-year-old children were administered a test of nonword repetition (to investigate phonological memory), rhyming and alliteration tasks (to investigate phonological sensitivity), and an incidental word learning task. A hierarchical multiple regression analysis revealed that nonword repetition did not contribute to any significant variance in incidental word learning. On the other hand, each measure of phonological sensitivity (alliteration, rhyming, phonological sensitivity composite) contributed to significant variance in predicting incidental word learning.

The findings of the current study suggest that phonological memory, measured by nonword repetition, was not a significant contributor to variance in incidental word learning. These results suggest that while phonological memory may be a necessary component of a model of lexical acquisition, it is not sufficient in that some key abilities for word learning are not tapped by phonological memory tasks. A number of explanations are possible for the nonsignificant contribution of nonword repetition in predicting incidental word learning. The word learning tasks used in previous research by Baddeley and colleagues may have failed to capture significant processes in natural word learning. These studies have either used paired associate word learning (for example, Papagno and Vallar 1992) or controlled word learning procedures (Gathercole and Baddeley 1990a). Neither of these tasks mirrors natural word learning. In the paired associate word learning task, subjects were exposed to word-word and word-nonword pairs. Following the exposure, they were presented with the first word from the pair and subjects were required to say the second word/nonword associated with the word. A failure to say the nonwords in response to a word was considered as a failure to learn novel words. This task was more of a word recognition task rather than word learning, because it involved storing words and nonwords in the memory and then matching the spoken word with the stored set of nonwords and then repeating the nonword that exactly matched with the target word. This task did not capture the complexity involved in learning novel words. For example, it did not involve making associations between a word and its referent, which is one of the most important aspects of learning a new word.

The controlled word learning task used by Gathercole and Baddeley (1990a) involved making associations between a novel toy and a nonword. This task was more representative of word learning than the paired-associate task but lacked the complexity of word learning. In this controlled word learning task, children had to learn names of both familiar and unfamiliar toy names. The child had to repeat the name of each toy presented by the experimenter and this repetition continued until the child accurately repeated a toy's name. This exposure phase was followed by a learning trial where the child had to name each toy, which was presented in the exposure phase. Speed of learning was measured by calculating the time taken by a child to reach this learning criterion. These children were tested for comprehension and production of these toy names after a 24-h delay. Learning new names by children in a natural setting rarely involves direct exposure to objects and requests to repeat their names. It is a complex process requiring abilities such as attention, phonological processing, phonological memory, and sensitivity to statistical and socio-pragmatic cues. Neither of the word learning paradigms adopted by Baddeley and his colleagues captured these complex elements of word learning. The modified QUIL procedure used in the current study were different from the word learning procedures used in the previous studies in that, children in the present study were indirectly exposed to novel names and their referents through cartoon stories presented via a computer. This not only enhanced the naturalness and semantic richness of the word learning environment, it also examined children's initial ability to make a connection between the novel word and the novel referent, along with the stability of retention of the newly learned word.

Nonword repetition shares several cognitive and linguistic processes with paired associate and controlled word learning tasks used by Baddeley and colleagues. Therefore, research in the past showing significant association between nonword repetition and novel word learning could be attributed to the common phonological memory shared by them (Gathercole 2006). Moreover, the nonword repetition tasks used in these studies could have been influenced by previous lexical knowledge because of the presence of some word-like nonwords. For example, Gathercole (1995) found a strong correlation between nonwords rated low in wordlikeness and vocabulary learning relative to nonwords, which were high in wordlikeness ratings. On the other hand, the nonwords by Dollaghan and Campbell (1998) used in this study, which were low in wordlikeness, may be dependent on phonological processing skills that are less influenced by prior linguistic knowledge (Archibald and Gathercole 2006; Estes et al. 2007). A principal-components analysis by Thal et al. (2005) revealed that the nonword repetition test by Dollaghan and Campbell (1998) did not load on a factor containing language variables. This is quite contrary to the previous findings, which have linked nonword repetition with language skills because of the underlying phonological memory shared between them. Thal et al. (2005) suggested that the less wordlikeness of Dollaghan and Campbell's nonwords could have led to the weak relation between nonwords and language variables in their study. Therefore, given all these findings, the relationship between nonword repetition and word learning in previous studies by Baddeley and colleagues, which have utilized nonwords high in wordlikeness, cannot be generalized to the Dollaghan and Campbell's nonword repetition test used in the present study.

Another important difference between the study by Gathercole and Baddeley (1990a) and the current study is in the method of scoring. The study by Gathercole and Baddeley (1990a) used rate of word learning, which was a measure of the time taken by children to repeat the novel names accurately. The current study used consistent identification, which was a measure of correct response on both the identification trials of the post-exposure comprehension testing. The rate of word learning is a measure of how fast a child can form a phonological template of a novel lexical item and produce it in response to visual presentation of that item. The consistent identification is a measure of how well the child can map a novel name onto a novel object without multiple and direct exposures to words and their referents and with elaborate socio-pragmatic cues such as elicited imitation. In addition, Gathercole and Baddeley used explicit elicitation of labels to criterion, which differs from typical word learning situations, and from the naturalistic imitation of typical word learning environments used in this study. While it is unclear what the precise effect would be, it is also notable that they used proper names rather than ordinary lexical items in their study. The fast mapping literature has used ordinary, not proper, nouns.

The current findings are consistent with those reported by Metsala (1999) and Bowey (1996, 2001), with its critique of nonword repetition as uniquely related to word learning abilities. However, unlike the findings by Metsala (1999) and Bowey (1996, 2001), nonword repetition scores of the present study failed to predict word learning before controlling for phonological sensitivity effects. Vocabulary acquisition as indexed by estimates of size of lexicon (measured through tests such as British Picture Vocabulary Scale (BPVS)/Peabody Picture Vocabulary Test (PPVT) used in studies by Metsala (1999) and Bowey (1996, 2001) is a different construct from incidental word learning used in this study. Incidental word learning is dependent on several linguistic and cognitive skills. It would involve making novel connections between the lemma (the semantic and syntactic aspects of a word) and the lexeme (phonological representation of a word). On the other hand, in standardized measures such as BPVS/PPVT, a set of pictures are shown to the child and s/he has to choose the correct picture that goes with the word spoken by the examiner. In this case, the child is just extracting the image evoked upon hearing the word spoken by the examiner and then selecting a picture (from an array of pictures) that matches the evoked image. This image is extracted from the already established long-term mental representation of lexical items, which is the information (word-referent connections) stored based on multiple exposures to the word and the referent. The child does not have to attend to the contextual linguistic information and therefore it involves less use of cognitive resources. Also, unlike the incidental word learning task, standardized vocabulary tests do not require the formation of new lemma-lexeme connections. Therefore, although nonword repetition is a fairly complex task, which shares certain linguistic and cognitive processes with word learning, it appears not to be sufficient to assess the type of phonological knowledge needed to succeed at incidental word learning tasks used in the present study. The findings in this study are also in agreement with that of Sutherland and Gillon (2005) who found a moderate correlation between receptive vocabulary and receptive-based tasks such as phonological representation judgments (detecting mispronunciations of words) and nonword learning in children with speech impairment. There was however, a weak correlation between receptive vocabulary and performance on nonword repetition tasks. The authors argue that nonword repetition may require moving from sensory perception to articulatory output by circumventing higher-level phonological representations (as indicated by Dodd and McCormack's speech processing model).

The phonological sensitivity tasks used in this study required complex storage and processing of verbal information. For instance, the rhyme awareness task used in the current study (for example, the child had to pick the odd word amongst the words *feet, meat, seat, key*) requires speech perception, phonological representation (including both auditory and visual/motor representations of words), phonological memory, separating the onset (initial consonant or consonant blend of a word) from its rime (the vowel and any final consonants), matching words that have the same rime, picking the word that does not end with the same rime, and articulatory instructions. Therefore, a failure to perform well on a phonological sensitivity task such as rhyme awareness could be a result of a breakdown in any of these above-mentioned processes, and may reflect a system unable to simultaneously process and reflect on the abstract qualities of the phonological information provided to it.

The key abilities that underlie incidental word learning may be best characterized as constrained by general cognitive resources needed for the manipulation of complex information. Phonological sensitivity and incidental word learning are dependent on a complex set of storage and processing mechanisms, which in turn depend on a rich phonological knowledge base, and the ability to access this knowledge base metacognitively. Although nonword repetition, phonological sensitivity, and incidental word learning may draw resources from the same cognitive pool, phonological sensitivity and incidental word learning share a similar set of complex cognitive mechanisms, differing from those needed for nonword repetition (Bowey 2001; Hansson et al. 2004; Munson 2001; Munson et al. 2005). The notion of a general cognitive processing ability underlying all these three abilities is in line with the current thinking of several researchers (Gathercole 2006; Gupta 2006; Snowling 2006). For example, Gathercole (2006) has conceded that nonword repetition and word learning are multiply determined, and that phonological memory deficits alone are not sufficient in explaining language deficits in children. She agrees that one needs to combine phonological storage deficits with impairment in general cognitive processing while accounting for such deficits. Based on computational models, Gupta (2006) proposed that both phonological store and phonological sensitivity are important for word learning. He echoes Gathercole (2006) proposal that multiple factors underlie nonword repetition and word learning. Snowling (2006) proposed a developmental contingency model for language learning disorders in which nonword repetition, new word learning, and phonological awareness share common cognitive and biological mechanisms (see Snowling 2006, for a complete review of the model). Overall, the findings of the current study would tend to provide support for a view of cognitive processing of linguistic information where complex higher level knowledge, including meta-knowledge, plays a role in moment-by-moment processing of novel lexical items. The finding that nonword repetition alone did not contribute to incidental word learning undercuts the views of Gathercole and others that this measure is able to tap into an important aspect of word learning ability. Nonword repetition is a measure of a tiny slice of the totality of what is needed to learn words, one that is not privileged relative to any other. To get at the variance in word learning ability, measures of some complexity that tap parallel processing of multiple types of information are needed. Theories attempting to assign equal roles to nonword repetition and measures tapping more complex phonological processing abilities are maintaining a fractionated view of processing. Our present results do not support a fractionated view; instead, they support a model of word learning abilities as multiply determined, requiring processing of many elements simultaneously.

Conclusion

Results of this study support a view of word learning as a complex process requiring a range of cognitive abilities and attainments, among which are attention, phonological knowledge, and phonological processing. The word learning procedure used in this study was designed to mimic the relatively complex word learning that occurs in the child's natural environment. Although nonword repetition is a fairly complex task, which shares certain linguistic and cognitive processes with word learning, it appears insufficient as an assessment of the type of knowledge needed to succeed at real-world word learning tasks. Phonological sensitivity tasks, in contrast, entail some similar abilities, but also require other skills and knowledge, including metacognitive processing. It may be for this reason that they emerged as predictors of incidental word learning, when nonword repetition did not. Finally, the findings of the current study weaken support for a domain-specific, modular model of phonological and lexical processing. These results suggest that broader cognitive-linguistic processes and knowledge underlie incidental word learning abilities.

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