Ellis Weismer, S., Tomblin, B., Zhang, X., Buckwalter, P., Chynoweth, J., & Jones, M. (2000). Nonword repetition performance in school-age children with and without language impairment. *Journal of Speech, Language, and Hearing Research, 43*, 865–878.
Evans, J., Viele, Kass, R., & Tang, F. (2002). Grammatical morphology and perception of synthetic and natural speech in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 45*, 494–504.
Gathercole, S. E. (2006). Nonword repetition and word learning: The nature of the relationship [Keynote]. *Applied Psycholinguistics, 27*, 513–543.
Gathercole, S. E., & Baddeley, A. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29*, 336–360.
Gray, S. (2004). Word learning by preschoolers with specific language impairment: Predictors and poor learners. *Journal of Speech, Language and Hearing Research, 47*, 1117–1132.
Horohov, J., & Oetting, J. (2004). Effects of input manipulations on the word learning abilities of children with and without specific language impairment. *Applied Psycholinguistics, 25*, 43–65.
Kail, R., & Leonard, L. (1986). Word-finding abilities in language-impaired children [Monograph]. *ASHA Monographs,* No. 25.
Marton, K., & Schwartz, R. (2003). Working memory capacity and language processes in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 46*, 1138–1153.
Montgomery, J. (1995). Examination of phonological working memory in specifically language impaired children. *Applied Psycholinguistics, 16*, 355–378.
Montgomery, J. (2000). Verbal working memory and sentence comprehension in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 43*, 293–308.
Munson, B. (2001). Phonological pattern frequency and speech production in adults and children. *Journal of Speech, Language and Hearing Research, 44*, 778–792.
Munson, B., Edwards, J., & Beckman, M. (2005). Relationships between nonword repetition accuracy and other measures of linguistic development in children with specific language impairment. *Journal of Speech, Language and Hearing Research, 48*, 61–78.
Munson, B., Kurtz, B., & Windsor, J. (2005). The influence of vocabulary size, phonotactic probability, and wordlikeness on nonword repetitions of children with and without specific language impairment. *Journal of Speech, Language and Hearing Research, 48*, 1033–1047.
Tallal, P., Stark, R., & Mellits, D. (1985). Identification of language-impaired children on the basis of rapid perception and production skills. *Brain and Language, 25*, 314–322.

James Montgomery
Ohio University

Julia Evans
San Diego State University

DOI: 10.1017.S0142716406060474

Nonword repetition and levels of abstraction in phonological knowledge

Susan Gathercole's Keynote Article (2006) is an impressive summary of the literature on nonword repetition and its relationship to word learning and vocabulary size. When considering research by Mary Beckman, Jan Edwards, and myself, Gathercole speculates that our finding of a stronger relationship between vocabulary measures and repetition accuracy for low-frequency sequences than for high-frequency sequences is due to differences in the range of the two measures. In our work on diphone repetition (e.g., Edwards, Beckman, & Munson, 2004; Munson, Edwards, & Beckman, 2005) we tried to increase the range in our dependent measures by coding errors on a finer grained scale than simple correct/incorrect scoring would allow. Moreover, restriction of range does not appear to be the driving factor in the relationship between vocabulary size and the difference between high- and low-frequency sequence repetition accuracy (what we call the *frequency effect*) in at least one of our studies (Munson et al., 2005). When the children with the 50 lowest mean accuracy scores for high-frequency sequences were examined, vocabulary size accounted for 10.5% of the variance in the frequency effect beyond what was accounted for by chronological age. When the 50 children with the highest mean accuracy scores for high-frequency sequences were examined (a group in which the range of high-frequency accuracy scores was more compressed, arguably reflecting ceiling effects), an estimate of vocabulary size accounted for only 6.9% of the frequency effect beyond chronological age. The associated β coefficient was significant only at the $\alpha < 0.08$ level. This is the opposite pattern than Gathercole's argument would predict.

Nonetheless, I concede that ceiling effects may be a complicating factor in any study of nonword repetition accuracy. One could argue that the Length $\times$ Group (specific language impairment [SLI] vs. typically developing) interactions that are observed in many studies (although not in Munson, Kurtz, & Windsor, 2005) themselves may be due to restrictions in the range of performance on shorter items. One collective challenge that we face as a community of scientists is to construct nonword repetition tasks and dependent measures that elicit a range of performance, so that no group is at ceiling- or floor-level performance. In the meantime, one manipulation that we should all be using to increase the range of performance is rationalized arcsine transformations of our dependent measures, a transformation that we should be making to meet the normality assumptions required to calculate parametric statistics. For example, rationalized arcsine transformation diphone repetition scores on the Munson et al. (2005) data exhibit an appreciably larger range of data than nontransformed scores.

Although there are many different perspectives on the factors that drive nonword repetition performance, we can all agree that the relationship between nonword repetition and word learning is due to the association of these constructs with phonological representations. The relevant question to ask, then, concerns the nature of phonological representations themselves. What are they? Textbook descriptions of these generally posit that they look something like the strings of symbols that we are taught to transcribe in phonetics classes. However, phonetic transcriptions, even narrow ones, are abstractions of the signals that are being transcribed. The level of detail that they code is ultimately related more to the perceptual abilities of the listener, the degrees of freedom in the symbol system, and a priori assumptions about the quantity of detail that is relevant for transcription than to the signal being transcribed and its associated phonological representation.

What, then, do "real" phonological representations encompass? What is being represented? The answer to that is anyone's best guess. Representations themselves are latent variables. We can never see them, we can only posit them as explanations for the sensitivity that people have to variation and consistency in the speech signal in different tasks. To what aspects of the speech signal, then, are people sensitive? Classic research showed that speech perception appears sometimes to reference a relatively coarse-grained signal, suggesting that representations were themselves rather coarse-grained, abstract, symbolic entities, analogous to phonemic transcriptions of words. In contrast, a growing body of literature suggests that people encode, remember, and use a great deal of fine phonetic detail in speech (e.g., Johnson, 1997). We refer to these as *specific* speech encodings. Evidence for the existence of specific encodings comes from a variety of sources. Work in the emerging field of sociophonetics shows that individuals have acute sensitivity to fine phonetic detail when making judgments about a range of social categories like talker gender and sexual orientation, among others. Moreover, individuals' knowledge of systematic fine phonetic detail in speech influences their performance on phonological processing tasks that do not explicitly draw their attention to this variation (e.g., Goldinger & Azuma, 2004; Strand, 2000). These findings suggest that representations in memory consist of far more detail, perhaps in the form of detailed memories of individual perceptual "episodes," than classic models would suggest. At the same time, there is clear motivation to posit abstract units. These are needed, for example, to explain individuals' sensitivity to type frequency in the lexicon, such as the phonotactic probability effects noted Frisch, Large, and Pisoni (2000). The net result is that phonological representations in memory likely consist of two parallel representations: a specific encoding and an abstract encoding.

How do dual-level phonological representations arise? Are they learned simultaneously, or is one learned advance of another? Pierrehumbert (2003) argues that abstract representations are learned in development as progressive abstractions over specific perceptual episodes held in long-term memory. At the outset, language learners encode as much acoustic–perceptual detail in the speech signal as their perceptual mechanism will allow. These specific encodings will not be random, but they will reflect the phonological category structure of the ambient language. Learners then use domain-general statistical learning processes to infer the abstract phonological categories of the ambient language, based on the distribution of observed values along different acoustic–perceptual parameters.

Put simply, phonological category learning involves encoding the input and inferring the underlying structure. As Fisher, Hunt, Chambers and Church (2001) put it, "representations must be abstract enough to encompass variability due to voice, intonation, and linguistic context [but] also include enough phonetically relevant detail . . . to permit the child to learn about the various systematic sources of variability." Although this learning process has been studied exclusively as it relates to phonological categories (e.g., Maye, Werker, & Gerken, 2002), one can imagine that learners also make progressive generalizations over specific encodings to infer the abstract social–indexical categories that are invoked in sociophonetics experiments.

If phonological representations are comprised of both abstract and specific encodings, and development involves learning each of these levels of abstraction, we must ask ourselves whether nonword repetition is indeed the best tool measure a child's ability to create phonological representations. The wealth of published evidence suggests that it has considerable potential. The level of phonological knowledge tapped in nonword repetition experiments appears to be coarse grained and abstract, as shown, for example, by the influence of type frequency on repetition accuracy and latency.

How, then, do we measure a child's ability to create specific representations? In my laboratory, we have been examining an alternative method for assessing the ability to create *both* abstract and specific phonological representations using a single task. The task is long-term repetition priming, which we sometimes abbreviate *implicit phonological priming*. This task is comprised of two phases. In the *study* phase, children are presented with a string of nonwords without a referent. After a distracter task, children engage in a *test* phase that measures some aspect of their implicit "learning" of the nonwords that they were presented in the study phase. In the simplest version of this paradigm, this knowledge is gauged by measuring repetition accuracy. Previous research by Fisher et al. (2001) found that children repeat "studied" nonwords (stimuli identical to those played in the study phase) less accurately than completely novel stimuli.

Crucially, the implicit phonological priming paradigm allows for the systematic examination of the level of abstraction of the representations learned in the study phase. This can be accomplished by creating test-phase nonwords that have some characteristics in common with stimuli from the study phase but differ in other ways. For example, a study-phase stimulus might be a nonword like [mæfnaʊb], which contains the heterosyllabic sequence [aʊb]; this sequence is not attested in any monomorphemic words of English. In the test phase, the child might be asked to repeat nonwords like [maʊbfɪt]. A finding that the child repeated the [aʊb] sequence more accurately than another unstudied, unattested sequence (such as [aɪtʃ]) would be evidence that exposure to this sequence was sufficient to create a robust enough perceptual representation to support its repetition in an unstudied phonetic frame. The same paradigm can be used to examine specific encodings. For example, the study phase and test phase stimuli might vary in their fine phonetic detail, allowing for the systematic examination of the level of specific encoding that occurs during exposure to speech in the study phase.

My students and I believe that this paradigm holds significant promise in measuring the abilities of children with different speech and language impairments to learn both specific and abstract phonological representations. We are particularly enthusiastic about this methodology because it melds the established, well-supported nonword repetition task with an implicit learning task. We feel that study phase of the implicit learning task has a measure of ecological validity beyond traditional nonword repetition, in that it mirrors the way that children are exposed to new lexical items in real-world language development.

ACKNOWLEDGMENTS

Preparation of this manuscript was supported by NIH Grant R03 DC005702 to the author. Readers are advised that the views and opinions expressed in this commentary do not necessarily represent the views and opinions of my collaborators.

REFERENCES

Edwards, J., Beckman, M. E., & Munson, B. (2004). The interaction between vocabulary size and phonotactic probability effects on children's production accuracy and fluency in nonword repetition. *Journal of Speech, Language, and Hearing Research, 47*, 421–436.

Fisher, C., Hunt, C., Chambers, K., & Church, B. (2001). Abstraction and specificity in preschoolers' representations of novel spoken words. *Journal of Memory and Language, 45*, 665–687.
Frisch, S. A., Large, N. R., & Pisoni, D. B. (2000). Perception of wordlikeness: Effects of segment probability and length on processing of non-word sound patterns. *Journal of Memory and Language, 42*, 481–496.
Gathercole, S. E. (2006). Nonword repetition and word learning: The nature of the relationship [Keynote]. *Applied Psycholinguistics, 27*, 513–543.
Goldinger, S. A., & Azuma, T. (2004). Episodic memory reflected in printed word naming. *Psychonomic Bulletin and Review, 11*, 716–722.
Johnson, K. (1997). Speech perception without speaker normalization: an exemplar model. In K. Johnson & J. Mullenix (Eds.), *Talker variability in speech processing* (pp. 145–166). New York: Academic Press.
Maye, J., Werker, J. F., & Gerken, L. (2002). Infant sensitivity to distributional information can affect phonetic discrimination. *Cognition, 82*, B101–B111.
Munson, B., Edwards, J., & Beckman, M. E. (2005). Relationships between nonword repetition accuracy and other measures of linguistic development in children with phonological disorders. *Journal of Speech, Language, and Hearing Research, 48*, 61–78.
Munson, B., Kurtz, B. A., & Windsor, J. (2005). The influence of vocabulary size, phonotactic probability, and wordlikeness on nonword repetitions of children with and without specific language impairment. *Journal of Speech, Language, and Hearing, 48*, 1033–1047.
Pierrehumbert, J. B. (2003). Phonetic diversity, statistical learning, and acquisition of phonology. *Language and Speech, 46*, 115–154.
Strand, E. (2000). *Gender stereotype effects in speech processing*. PhD Dissertation, Ohio State University, Department of Linguistics.

Benjamin Munson
University of Minnesota, Twin Cities

DOI: 10.1017.S0142716406060486

Phonological networks and new word learning

The first report of a connection between vocabulary learning and phonological short-term memory was published in 1988 (Baddeley, Papagno, & Vallar, 1988). At that time, both Susan Gathercole and I were involved in longitudinal studies, investigating the relation between nonword repetition and language learning. We both found a connection. Now, almost 20 years later, in her Keynote Gathercole (2006) reviews a multitude of data bearing on the interpretation of this often replicated connection. Her main conclusions are three. First, both nonword repetition and word learning are constrained by the quality of temporary storage. She sees this storage as multiply determined, that is, affected by factors like perceptual analysis, phonological awareness (ability to identify and reflect on the speech sounds that make up words). Second, both nonword repetition and word learning are also affected by sensory, cognitive, and motor processes. Third, an impairment of phonological storage is typically associated with specific language impairment (SLI) but this may not be a sole causal factor.

The conclusions are closely related to the hypothesis of the phonological store in the Baddeley and Hitch framework as a language-learning device (Baddeley, Gathercole, & Papagno, 1998). According to this hypothesis, temporary storage in the phonological loop determines how well new material can be permanently