Journal of Communication Disorders 83 (2020) 105946

Contents lists available at ScienceDirect

Journal of Communication Disorders

journal homepage: www.elsevier.com/locate/jcomdis

Discussion

An alternative to the procedural ~ declarative memory account of developmental language disorder

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We appreciate Dr. Kamhi's review of the Procedural ~ Declarative (P ~ D) dichotomy (this issue) and how it might apply to assessment and intervention for children with developmental language disorder (DLD; also known as specific language impairment). We fully agree that viewing language learning as composed of distinct mechanisms should profoundly influence assessment and intervention practices, though we differ in what we view as the substance of this influence. In this reply, we raise two considerations: one concerning some problems with the P ~ D dichotomy as it applies to learning in human infants and some non-humans, and the other concerning the specificity and content of the procedural deficit that has been identified in children with DLD. We end by suggesting an alternative to the P ~ D dichotomy that we have been developing. This alternative relies on developmental findings in which infants show sensitivity to sequences that can be described by a rule but not to those that are more associative in nature. Our proposal that children with DLD have a relatively intact associatively organized lexicon is compatible with those of Ullman and colleagues (Ullman & Pierpont, 2005; Ullman & Pullman, 2015; Ullman, Earle, Walenski, & Janacsek, 2019) and McGregor, Gordon, Eden, Arbisi-Kelm, and Oleson (2017), in which it is argued that many aspects of word learning and word knowledge are not affected in children with DLD. In this view, specific domains of language—such as encoding of sound and syllable patterns—are especially implicated in DLD. Such pattern learning undergirds the comprehension and production of phonology and grammar—two key areas of deficit in children with DLD.

As noted in Kamhi's target article, the P ~ D dichotomy is one of several dual process theories of cognition (e.g., Barbey & Sloman, 2007; Dienes & Perner, 1999; Evans & Stanovich, 2013; Reber, 1993). The P ~ D dichotomy focuses on the notion that there are two memory systems, a consciously accessed declarative system that stores information about facts and events, and an unconscious procedural system that stores information about how to do things. In addition to being consciously accessed, the declarative system is described as relatively fast, while the procedural system, in addition to being unconscious, is slow and requires practice. According to the Ullman model reviewed in the target article (Ullman, 2016), the P ~ D dichotomy applies to language because the regularly patterned aspects of language are best suited to being stored in procedural memory, and it is the procedural system that is weak in children with DLD.

One problem with the fast-conscious vs. slow-unconscious characterization of the declarative vs. procedural systems, respectively, is that this characterization does not appear to apply well to the initial language learning we see in infants. Twenty years of research have shown that infants are able to learn language-like patterns in the laboratory in a matter of minutes or seconds. For example, 11-month-olds have been shown to learn a rule in which CVCV words either must have two voiced consonants (e.g., *dova*) or two unvoiced consonants (e.g., *pota*) from receiving input of just four words, 2 examples of each type (Gerken & Knight, 2015). Similarly, 17-month-old English-learning infants are able to infer the correct morphological endings for a set of Russian nouns after hearing a subset of nouns that each occurred with two different endings (Gerken, Wilson, & Lewis, 2005). This kind of linguistic pattern completion, in which a brief exposure to part of a pattern allows the implicit inference of another part of the pattern, seems to be exactly what the procedural system should be responsible for in Ullman's P ~ D model of language learning. Yet, this learning occurs remarkably quickly (supposedly a property of the declarative system) and unconsciously (supposedly a property of the procedural

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https://doi.org/10.1016/j.jcomdis.2019.105946
Received 1 October 2019; Accepted 6 October 2019
Available online 15 October 2019
0021-9924/

system).

Thus, the characterization of the two memory systems does not appear to be well-suited to describing early language development or, as we suggest in the following sections, deficit and strength profiles observed in children with DLD. Below we consider a somewhat different dual process model that combines rapid sequential pattern learning and associatively organized stored forms (e.g., words), the regularities of which emerge over time as more and more forms are stored. We think the rapid sequence learning vs. slowly emerging associative organization better accounts for infant-adult differences that we have observed (Gerken, Quam, & Goffman, 2019) as well as providing a new way of thinking about the strengths and weaknesses observed in children with DLD.

As pointed out by Kamhi, the P ~ D dichotomy has been particularly provocative as applied to the profile of deficits and of relative strengths observed in children with DLD. The procedural deficit hypothesis, initially proposed by Ullman and Pierpont in 2005 (see also Ullman et al., 2019), has spurred much research. However, it has become apparent that there are limitations to this very general view of procedural and declarative deficits. For example, there is now evidence that several aspects of procedural learning–such as pursuit rotor (Hsu & Bishop, 2014) and metronomic timing (Vuolo, Goffman, & Zelaznik, 2017; Zelaznik & Goffman, 2010) tasks–are unaffected in children with DLD. However, impairments are observed in oral language and manual tasks that require complex sequencing and coordination, such as the serial reaction time task (Hsu & Bishop, 2014; Tomblin, Maniela-Arnold, & Zhang, 2007), rhythmic bimanual clapping (Vuolo et al., 2017), and the organization of syllable sequences in novel word production (Benham, Goffman, & Schweickert, 2018) and of prosodically complex articulatory sequences (Goffman, 1999, 2004). Only components of procedural learning related to sequencing and coordination seem affected. While encoding of word forms and perhaps aspects of categorization may be impaired, semantic real world knowledge is generally not an area of deficit in children with DLD (McGregor et al., 2017; Ullman et al., 2019).

A critical point accentuated by Kamhi is that the profile of weaknesses and strengths associated with DLD forms the basis for the development of efficacious assessment and intervention paradigms. Kamhi suggests that one approach to intervention is to integrate "routinized language structures that serve a variety of communicative functions." That is, it is recommended that clinicians focus on rote structures in intervention, and incorporate them into varying communicative contexts. Two sets of results speak to this issue. First, in reference to routinized language structures, we have reported, using measures of articulatory variability, that for children with DLD, practicing a simple sentence results in levels of articulatory variability that are similar to those of their age matched peers (Saletta, Goffman, Ward, & Oleson, 2018). We argue that rote practice indeed results in increased automaticity and stability, but at the same time shifts these productions from obligating sequential organization to behaving more like words. That is, these forms become rote wholes—and may no longer invoke sequential (a component of procedural) processes. When children with DLD are required to generate more complex sentences or prosodic sequences, their articulatory variability increases, and more so than their typical peers. Thus, we make the opposite argument of Kamhi; reduced articulatory variability (perhaps behaviorally instantiated as decreased mazes) does not tap the core sequencing deficit documented in children with DLD.

Kamhi suggests that context variability may serve as an approach to tapping into procedural learning. This is an avenue well worth pursuing empirically. Capitalizing on findings from the infant literature (e.g., Gomez & Gerken, 1999), Plante et al. (2014) have demonstrated that a particular (relatively high) level of lexical variability in sentence frames facilitates the acquisition of grammatical morphemes in children with DLD. The incorporation of highly variable object exemplars improves word learning (Aguilar, Plante, & Sandoval, 2018). Kamhi argues for contextual variability. This form of variability may indeed enhance learning. However, it may be that only manipulation of input related to sequence patterns influences learning.

To summarize, there are reasons to believe that some kind of dual process model is needed to account for the strengths and weaknesses in children with DLD. However, we question Kamhi's characterization of the two processes and implications for treatment in the following three ways. First, the slow/unconscious and fast/conscious dichotomy does not appear to be well suited to what we know about infant language learning. Indeed, there is growing evidence that humans and some non-humans have two learning systems: a relatively faster system that learns single feature categories or rules and a relatively slower system that learns associations among sets of features. Importantly for the current discussion, earlier work with humans equated rule-learning with "explicit" or "verbalizable" - much like the way declarative memory is currently characterized in the P ~ D dichotomy. In contrast with the older view of rule learning as an explicit process, and in keeping with the infant research reviewed above, new research shows an advantage in learning speed for rule-based categories in species that cannot explicitly state the generalization that they have learned (e.g., macaques; Smith et al., 2012). Furthermore, pilot data from our lab indicates a similar advantage for 11-month-olds in learning rule-based vs. associative patterns. Thus the particular characterization of the two systems that Kamhi offers in the target article is challenged by work with infants and some non-humans.

Second, we contend that what was originally construed as a procedural deficit is in fact specifically related to the learning of sequenced patterns, thus also explaining some of the statistical learning difficulties identified in children with DLD's reduced sensitivity to syllable co-occurrence patterns (Benham et al., 2018; Evans, Saffran, & Robe-Torres, 2009) and to implicit patterns in the SRT task (Tomblin et al., 2007). Thus, the deficit in DLD is potentially narrower in scope than it is construed in the target article.

Third and finally, we agree with Kamhi that the implications of a dual process model for early identification, assessment, and intervention are profound. But we suggest that, as noted above, the deficit in DLD does not involve all pattern learning but specifically sequential pattern learning, a distinction that we think has implications for diagnosis and intervention. We contrast the pattern learning system, which is so readily observable in human infants, with a system for observing regularities that emerge from an associatively organized lexicon. We question the explicit/declarative and implicit/procedural dichotomy. Rather, we see a distinction in form-based associative patterns and those that are reliant on sequential pattern learning (which is central to phonological and morphosyntactic acquisition). It remains an open question whether associative learning via the lexicon provides an initial scaffold for children with DLD, or whether sequential pattern learning should be addressed directly in intervention. Regardless, the argument

here is that the procedural/declarative dual process model is not the right one for characterizing typical early development or the deficits underlying DLD.

Acknowledgments

The ideas developed here were supported by NIDCD# R01DC016813 to Lisa Goffman and NSF#1724842 to LouAnn Gerken.

References

Aguilar, J. M., Plante, E., & Sandoval, M. (2018). Exemplar variability facilitates retention of word learning by children with specific language impairment. *Language, Speech, and Hearing Services in Schools, 49*, 72–84.

Barbey, A. K., & Sloman, S. A. (2007). Base-rate respect: From ecological rationality to dual processes. *The Behavioral and Brain Sciences, 30*(3), 241–254. https://doi.org/10.1017/S0140525X07001653.

Benham, S., Goffman, L., & Schweickert, R. (2018). An application of network science to phonological sequence learning in children with developmental language disorder. *Journal of Speech Language and Hearing Research, 61*, 2275–2291.

Dienes, Z., & Perner, J. (1999). A theory of implicit and explicit knowledge. *The Behavioral and Brain Sciences, 22*(5), 735–808. https://doi.org/10.1017/S0140525X99002186.

Evans, J. L., Saffran, J. R., & Robe-Torres, K. (2009). Statistical learning in children with specific language impairment. *Journal of Speech Language and Hearing Research, 52*, 321–335.

Evans, J. S. B. T., & Stanovich, K. E. (2013). Dual-process theories of higher cognition: Advancing the debate. *Perspectives on Psychological Science, 8*(3), 223–241. https://doi.org/10.1177/1745691612460685.

Gerken, L. A., & Knight, S. (2015). Infants generalize from just (the right) four words. *Cognition, 143*, 187–192.

Gerken, L. A., Quam, C., & Goffman, L. (2019). Adults fail to learn a type of linguistic pattern that is readily learned by infants. *Language Learning and Development, 15*(4), 279–294. https://doi.org/10.1080/15475441.2019.1617149.

Gerken, L. A., Wilson, R., & Lewis, W. (2005). 17-month-olds can use distributional cues to form syntactic categories. *Journal of Child Language, 32*, 249–268.

Goffman, L. (1999). Prosodic influences on speech production in children with specific language impairment: Kinematic, acoustic, and transcription evidence. *Journal of Speech Language and Hearing Research, 42*, 1499–1517 PMID: 10599629.

Goffman, L. (2004). Kinematic differentiation of prosodic categories in normal and disordered language development. *Journal of Speech Language and Hearing Research, 47*, 1088–1102 PMID: 15603464.

Gomez, R. L., & Gerken, L. (1999). Artificial grammar learning by 1-year-olds leads to specific and abstract knowledge. *Cognition, 70*, 109–135.

Hsu, J., & Bishop, D. V. M. (2014). Sequence-specific procedural learning deficits in children with specific language impairment. *Developmental Science, 17*, 352–365 PMCID: PMC4031743.

Kamhi, A. G. (2019). Speech-language development as proceduralization and skill learning: Implications for assessment and intervention. *Journal of Communication Disorders* this issue.

McGregor, K. K., Gordon, K., Eden, N., Arbisi-Kelm, T., & Oleson, J. (2017). Encoding deficits impede word learning and memory in adults with developmental language disorders. *Journal of Speech Language and Hearing Research, 60*(10), 2891–2905.

Plante, E., Oglivie, T., Vance, R., Aguilar, J. M., Meyers, C., & Burton, R. (2014). Variability in the language input to children enhances learning in a treatment context. *American Journal of Speech-Language Pathology, 23*, 1–16.

Reber, A. S. (1993). *Implicit learning and tacit knowledge: An essay on the cognitive unconscious.* New York, NY: Oxford University Press.

Saletta, M., Goffman, L., Ward, C., & Oleson, J. (2018). Influence of language load on speech motor skill in children with specific language impairment. *Journal of Speech Language and Hearing Research, 61*, 675–689.

Smith, J. D., Crossley, M. J., Boomer, J., Church, B. A., Beran, M. J., & Ashby, F. G. (2012). Implicit and explicit category learning by capuchin monkeys (Cebus apella). *Journal of Comparative Psychology, 126*(3), 294–304. https://doi.org/10.1037/a0026031.

Tomblin, J. B., Maniela-Arnold, E., & Zhang, X. (2007). Procedural learning in adolescents with specific language impairment. *Language Learning and Development, 3*, 269–293.

Ullman, M. T. (2016). The declarative/procedural model: A neurobiological model of language learning, knowledge, and use. In H.G, & S.S.L (Eds.). *Neurobiology of language* (pp. 953–968). San Diego, CA: Elsevier.

Ullman, M. T., Earle, F. S., Walenski, M., & Janacsek, K. (2019). The neurocognition of developmental disorders of language. *Annual Review of Psychology*. https://doi.org/10.1146/annurev-psych-122216-011555 [Epub ahead of print].

Ullman, M. T., & Pierpont, E. I. (2005). Specific language impairment is not specific to language: The procedural deficit hypothesis. *Cortex, 41*, 399–433.

Ullman, M. T., & Pullman, M. Y. (2015). A compensatory role for declarative memory in neurodevelopmental disorders. *Neuroscience and Biobehavioral Reviews, 51*, 205–222 PMCID: PMC4359651.

Vuolo, J., Goffman, L., & Zelaznik, H. N. (2017). Deficits in coordinative bimanual timing control in children with specific language impairment. *Journal of Speech Language and Hearing Research, 60*, 393–405 PMCID: PMC5533552.

Zelaznik, H. N., & Goffman, L. (2010). Motor abilities and timing behavior in children with specific language impairment. *Journal of Speech Language and Hearing Research, 53*, 283–293.