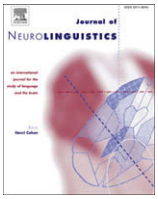
Journal of Neurolinguistics 22 (2009) 384–412

Contents lists available at ScienceDirect

Journal of Neurolinguistics

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



The acquisition of a linguistic skill by adults: Procedural and declarative memory interact in the learning of an artificial morphological rule

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ARTICLE INFO

Article history:
Received 30 September 2008
Accepted 5 December 2008

Keywords:
Artificial language
Morphological rule
Generalization
Declarative memory
Procedural memory
Memory consolidation

ABSTRACT

How does practice make perfect in the acquisition of morphological skill in adults? Participants underwent intensive, multi-session training on an artificial morphological rule (AMR) requiring phonological transformations of verbs according to a semantic distinction. All participants learned to apply the AMR to repeated items, with a power law like improvement in speed and accuracy (group average), both within-sessions and between-sessions (consolidation phase) gains, and robust retention, as in non-linguistic skill learning. Generalization to new items evolved separately for different aspects of the AMR. Phonological aspects were generalized by all participants, independently of explicit (declarative) knowledge, and well fitted by a power function. However, the generalization of the semantic aspect required the explicit discovery of its requisite role, and was not universally attained; when attained, explicit knowledge of the semantic aspect of the AMR coincided with an abrupt increase in accuracy and initiated a phase of fluency gains (proceduralization). Our results suggest that both procedural and declarative memory contribute differentially to the learning of distinct aspects of a morphological rule, at different stages along the mastering of skilled linguistic performance.

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doi:10.1016/j.jneuroling.2008.12.002

1. Introduction

A growing body of evidence suggests that language learning and language use are subserved by cognitive processes that are not unique to language (e.g., Bates, Devescovi, & Wulfeck, 2001; Ellis, 2005; Elman et al., 1996; Hauser, Chomsky, & Fitch, 2002; Saffran, 2002; Saffran, Pollak, Seibel, & Shkolnik, 2007) and specifically, that linguistic learning may share important features with non-linguistic skills acquisition (DeKeyser, 2001; Perruchet & Pacton, 2006; Robinson, 1996; Robinson & Ha, 1993; Schmidt, 1993; Segalowitz, 2003). There are, however, very few studies of language skill learning that were explicitly designed to investigate whether and which of the key features of non-linguistic skill memory generation are manifest in language skill acquisition.

A leading tenet in neurobiological theory of learning and memory is that two independent neural systems subserve long-term memory: the declarative and procedural memory systems (e.g., Mishkin, Malamut, & Bachevalier, 1988; Squire & Zola, 1996). The declarative system has been implicated in the learning and subsequent use of knowledge about novel events and facts ('what'). This type of memory can be established even following a single exposure and explicitly recollected, but may be rapidly degraded. The procedural memory system has been implicated in the learning and retention of skills ('how to') and habits and its establishment necessitates a critical amount of repetitions (practice) and time (e.g., Hauptmann & Karni, 2002; Karni, 1996). The establishment of procedural memory is sometimes conceptualized as implicit learning, i.e., the acquisition of complex structured knowledge independently, to a large degree, of awareness of both the processes and products of acquisition. Explicit learning, in this view, relates to the making and testing of hypotheses in a search for a structure, and may be more conscious and intentional (Cleeremans, Destrebecqz, & Boyer, 1998; Cohen, Poldrack, & Eichenbaum, 1997; Reber, 1989; Stadler & Frensch, 1998). Although, the two memory systems are largely independent of each other, they may interact in a number of ways (Cohen et al., 1997; Kim & Baxter, 2001; Mathews et al., 1989; Poldrack, & Rodriguez, 2004; Squire & Zola, 1996; Sun, Slusarz, & Terry, 2005; Voss & Paller, 2008; Willingham & Goedert-Eschmann, 1999). For example, recent studies suggest that declarative knowledge may turn into procedural knowledge (proceduralization of declarative knowledge) and procedural (implicit) knowledge may be converted into declarative knowledge as a result of accumulating experience (e.g., Anderson et al., 2004; Bitan & Karni, 2003; Logan, 1988; Sun & Zhang, 2004). In the context of language learning it is not clear which memory system is involved in learning a given linguistic task: declarative, procedural or conceivably both these systems (e.g., Ullman, 2001) and perhaps neither, if a language specific learning mechanism exists (Chomsky, 1965; Pinker, 1994).

Evidence from a variety of non-linguistic skill learning paradigms suggests that although procedural learning results in specific (local) changes within the neural system (processing stream modality) engaged in the performance of the trained task, there are key features shared in different instances of procedural learning and memory independent of the nature of the task (Karni & Bertini, 1997).

First, procedural learning and its establishment as long-term memory is characterized by a non-linear relationship between gains (in terms of both speed and accuracy) and the amount of experience (number of practice trials) (Anderson, 1982; Hauptmann & Karni, 2002; Karni, 1996; Karni & Bertini, 1997; Korman, Raz, Flash, & Karni, 2003; Logan, 1988; Newell & Rosenbloom, 1981). The reductions in performance time and error rate are generally held, at least at the level of group mean performance, to take the form of a power function, referred to as the 'power law' of practice, with large gains at the beginning of training and decreasing gains at later stages of practice (Anderson, 1982; Karni, 1996; Logan, 1988; Newell & Rosenbloom, 1981). Several second or artificial language acquisition studies showed that fluency in linguistic usage can be achieved in a manner akin to the proceduralization of non-linguistic skills (Johnson, 1996; Robinson, 1996; Robinson & Ha, 1993; Schmidt, 1993; Segalowitz, 2003). For example, in a seminal study, DeKeyser (1997) reported that (artificial) morphological learning performance improved gradually over time, with the group-average learning curves characterized by a power function, very similar to that characterizing the acquisition of non-linguistic skills (see also Ellis & Schmidt, 1998). Nevertheless, this rather simplified view of the time-course of the learning has been lately challenged by the demonstration that the good fit of a power function to learning curves may reflect only group averaging but does not well represent the actual individual