Learning and Individual Differences 44 (2015) 9–15

Contents lists available at ScienceDirect

Learning and Individual Differences

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

Declarative and procedural memory abilities as individual differences in incidental language learning

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ARTICLE INFO

Article history:
Received 8 March 2015
Received in revised form 5 October 2015
Accepted 7 October 2015

Keywords:
Declarative memory
Procedural memory
Incidental learning
Second language
Individual differences

ABSTRACT

This study investigated whether individual differences in declarative and procedural memory abilities predicted the learning and retention of second language (L2) syntactic structures under incidental conditions. Participants were exposed to novel syntactic structures in a semi-artificial language paradigm under incidental learning conditions. After exposure, they were given a surprise recognition task in which they were asked to discriminate old and new sentences, which only could be done on the basis of their syntactic structures. Participants were then given an identical surprise test after a period of no exposure. Declarative memory abilities predicted performance on the immediate, but not delayed, recognition task, whereas procedural memory abilities predicted performance on the delayed, but not immediate, recognition task. The results demonstrate that the previously-reported relationships between declarative and procedural memory abilities and L2 development under intentional learning conditions can also be found under incidental learning conditions.

1. Introduction

Recent research has posited roles for two long-term memory systems, declarative and procedural memory, in second language (L2) learning (Morgan-Short & Ullman, 2012; Ullman, 2005, 2015, in press). These memory systems differ along a number of dimensions, including their relationships with awareness, the computations they perform, and the neural substrates subserving them (Eichenbaum, 2002; Eichenbaum & Cohen, 2001). For example, declarative memory supports the learning of general facts and knowledge (i.e., semantic memory) and autobiographical events from one's life (i.e., episodic memory; Tulving, 1993). Declarative memory is also argued to support both explicit (i.e., with awareness) and implicit (i.e., without awareness) forms of knowledge (Ullman, 2005). Procedural memory, on the other hand, supports motor and cognitive skill learning (Knowlton & Moody, 2008), and appears to underlie the acquisition and execution of sequential skills, such as learning to play a musical instrument. Learning and forgetting in this system are thought to be slower than in declarative memory. Procedural memory consists of implicit knowledge inasmuch as the knowledge contained there is difficult to verbalize and access via introspection.

Several researchers have linked these two long-term memory systems with language functions in children and adults. Both Paradis (2004, 2009) and Ullman (2001, 2004, 2005, 2015, in press) have posited that declarative memory and procedural memory are involved in the acquisition of lexicon and grammar, respectively. For example, Ullman's declarative/procedural (DP) model proposes that in one's first language (L1) declarative memory underlies the acquisition and representation of information stored in the lexicon, including words and grammatically complex forms memorized as whole chunks (due to their frequency). Procedural memory is posited to underlie aspects of grammar thought to rely on combinatorial processing, such as morphosyntax and syntax. The situation in L2 development is hypothesized to be different to some degree. As in the L1, L2 lexical development is argued to rely on declarative memory; however, in contrast to L1 grammar, early L2 grammatical development is argued to rely on declarative memory and this reliance may persist for some time (possibly forever, depending on a factors such as proficiency). It is only in certain circumstances that L2 grammar learning takes place in the procedural system.

Increasing evidence from electrophysiology (e.g., Morgan-Short, Finger, Grey, & Ullman, 2012; Morgan-Short, Steinhauer, Sanz, & Ullman, 2012) and neuroimaging (Morgan-Short et al., 2015; Tagarelli, 2014) supports these predictions. Recent work also indicates that individual differences in declarative and procedural memory abilities correlate with L2 learning (Carpenter, 2008; Morgan-Short et al., 2015; Morgan-Short, Faretta-Stutenberg, Brill-Schuetz, Carpenter, & Wong, 2014). For example, Morgan-Short et al. (2014) investigated whether individual differences in declarative and procedural memory abilities were related to learning of the artificial language Brocanto2 under "implicit" conditions. While the authors label these conditions "implicit,"

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http://dx.doi.org/10.1016/j.lindif.2015.10.003
1041-6080/

they are more similar to intentional learning conditions[1] because participants "were told that they would be learning an artificial language" (Morgan-Short et al., 2014, p. 63). The authors found that their behavioral measures of declarative memory (the paired-associates task from the MLAT-V and a Continuous Verbal Memory Task) predicted grammar learning in Brocanto2 early in training, but not in later stages of training, while measures of procedural memory (Tower of London and Weather Prediction Tasks) predicted their grammar abilities in later phases but not earlier phases of learning, consistent with the predictions of the DP model.

Importantly, these studies supporting the DP model in L2 learning have relied on more intentional learning conditions.[2] However, it has been argued that individual differences are less likely to play roles under more implicit learning conditions (Reber, Walkenfeld, & Hernstadt, 1991; although, see Kaufman et al., 2010; Robinson, 1997, for alternate views), which arguably include more incidental learning conditions. This view has been largely supported in L2 research. For example, several studies have shown that individual differences in working memory predict L2 development in more intentional learning conditions (e.g., Brooks, Kempe, & Sionov, 2006; Kempe & Brooks, 2008; Martin & Ellis, 2012; Tagarelli, Borges Mota, & Rebuschat, 2011, 2015), whereas the relationship between working memory and L2 learning is less clear under incidental conditions, in large part due to mixed results in previous studies. For example, Robinson (2005) found that working memory capacity (assessed by a reading span task) correlated with learning of Samoan syntax under incidental conditions as assessed by an aural, but not visual, grammaticality judgment task (GJT). However, it is unclear whether working memory correlated with learning under incidental conditions because of common underlying mechanisms or because of task demands. Using a semi-artificial language paradigm, Tagarelli et al. (2011, 2015) found no correlations between working memory scores on an operation-word span task or a letter-number ordering task and the acquisition of word order information under incidental learning conditions. Similarly, Grey, Williams, and Rebuschat (2015) found that phonological working memory did not correlate with incidental learning of L2 word order or case marking in a semi-artificial language.

Do learning conditions similarly modulate the relationships between L2 learning and declarative/procedural memory? It is possible that individual differences in declarative and procedural memory correlate with L2 learning but only under more intentional conditions, perhaps in the same way that working memory has been shown to be. On the other hand, if declarative and procedural memory show similar correlations with L2 learning under both intentional and incidental conditions, then it is possible that these memory systems are more associated with language learning in general, rather than being dependent upon specific learning conditions.

2. The present study

The present study set out to investigate the relationships between individual differences in declarative and procedural memory abilities and L2 grammar learning under incidental conditions. Declarative memory abilities were assessed via the LLAMA-B (Meara, 2005), which is a paired-associates task modeled on the MLAT-V paired-associates task used by Carpenter (2008) and Morgan-Short et al. (2014). Procedural memory abilities were assessed by means of a modified serial reaction time (SRT) task (Nissen & Bullemer, 1987). Two research questions were addressed:

1. Is there a relationship between declarative and/or procedural memory abilities and L2 syntactic development under incidental learning conditions?
2. Does a period of no exposure between the exposure phase and testing affect any relationships between declarative and/or procedural memory abilities and L2 syntactic development?

In response to the first research question, it was predicted that declarative, but not procedural memory, abilities would positively correlate with L2 syntax learning abilities when participants were tested immediately after an incidental exposure phase. This prediction follows from the various proposals that declarative memory supports rapid learning in the early phases of L2 grammatical development (e.g., Paradis, 2009; Ullman, 2005). The second research question was motivated by the findings of Morgan-Short, Finger, et al. (2012), who found that L2 training followed by three to six months of no exposure led to more native-like electrophysiological signatures of grammatical processing. One interpretation (but not the only one[3]), is that these native-like signatures show up after no exposure due the slower rates learning and forgetting in procedural, relative to declarative, memory. Following this possibility, it was predicted that procedural, but not declarative, memory abilities would correlate with L2 syntax learning abilities when participants were tested after a period of no exposure.

3. Method

3.1. Participants

Thirty-one monolingual native-speakers of English were given extra credit in their courses to participate in the study (26 females, 25 undergraduates, 6 graduate students, $M_{age} = 21.4$, range: 18–29). All 31 participants completed session one. When participants were asked to return after a one-week minimum interval, 20 participants returned. Due to technical failures, data for all tasks (immediate and delayed recognition tests, SRT task, and LLAMA-B) were only obtained for a total of 18 participants. No participants had prior knowledge of Persian, which was the basis for the syntactic structures used in this study. No participant had taken more than one year of another language in college. All participants reported having normal or corrected-to-normal vision and hearing.

3.2. Materials

3.2.1. Measure of declarative memory

Participants' declarative learning abilities were assessed via the LLAMA-B (Meara, 2005). The LLAMA-B was designed, like the paired-associates task in the MLAT-V, to assess verbal declarative learning and vocabulary learning abilities. In the LLAMA-B participants are asked to memorize words (e.g., "cauac," "akbal," "muluc") that are arbitrarily paired with images of imaginary creatures. Participants are told to study these word-object pairings for two-minutes, after which they will be given a test. In the test phase, participants are cued with a given word and must select the corresponding object. Participants are given accuracy feedback during the test phase, but not during the study phase.

3.2.2. Measure of procedural memory

Procedural learning abilities were assessed with a modified version of the SRT task (Nissen & Bullemer, 1987) adapted from Lum and Kidd (2012). In this task, participants are given a repeating 10-item sequence. The sequence consists of the presentation of a circle inside four squares placed in diamond-shaped pattern on the computer screen. Each location on the computer screen corresponded to a button on a Logitech

[1] Throughout this paper, I refer to any learning conditions in which participants are told (a) to learn and/or (b) that they will be tested as intentional learning conditions (Hulstijn, 2003).

[2] Other research has shown similar correlations between L2 development and common measures of declarative and procedural memory (e.g., Granena, 2013; Linck et al., 2013); however, these studies were not focused on learning conditions and, hence, did not control whether learning was incidental or intentional.

[3] One reviewer rightly points out that other possibilities include procedural memory-supported responses based on processing rather than content retrieval.