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Adults' and 8-Year-Olds' Learning in a Foreign Word Repetition Task: Similar and Different

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Abstract

Although the significance of age in second language acquisition is one of the most hotly debated issues in the field, very few studies have directly addressed age differences in the language learning process. The present study investigated learning in a foreign-word repetition task. Young Finnish adults and 8-year-olds repeated back Korean words. Some words occurred once whereas others occurred five times. After the session, a surprise old/new recognition task was administered. Both groups' repetition accuracy improved for recurring but not nonrecurring words. Latencies got shorter for all words. The groups were reliably able to recognize recurring but not nonrecurring words. However, the adults performed substantially better in this memory task with an explicit component. No advantages for children were detected.

Keywords

Second language acquisition; nonword repetition; age; phonological memory

Introduction

Children and adults differ as second-language (L2) learners both with respect to acquisition rate and final outcome (e.g., DeKeyser, 2012). Such observations have led to strong beliefs among the general public that all second and foreign language teaching is best directed at children at the youngest possible age. Research in second language acquisition has revealed a more complex picture of factors that may explain the results commonly seen. In the last few decades, a sizable literature has been published on the topic of age effects in L2 learning, excellently reviewed in a number of recent theoretical articles and chapters (e.g., Birdsong, 2005; Birdsong, 2006; DeKeyser, 2012; DeKeyser & Larson-Hall, 2005; Singleton, 2001). A main question concerns whether biological constraints limit ultimate L2 attainment at different ages. DeKeyser (2013) outlines three main challenges for this question. The first one targets the shape of the function of ultimate attainment regressed against age of acquisition. A maturational hypothesis predicts that the relationship over the maturational period is characterized by one function showing a clear break at the end of this period, with later years characterized by a different or no clear relationship. However, to date, no consensus exists among L2 researchers as to what role confounded factors may play in the final L2 outcome. Such factors include first language (L1) similarity to L2, amount and quality of L2 exposure, amount of formal L2 education, aptitude, and various social and motivational factors. The second challenge for research is to better characterize the amount of variance in outcome accounted for by nonmaturational variables. The third challenge, according to DeKeyser, is to increase our understanding of the nature of the maturational changes. A hypothesis suggested by some L2 researchers (e.g., Bley-Vroman, 1990, 2009; DeKeyser, Alfi-

Shabtay, & Ravid, 2010; DeKeyser & Larson-Hall, 2005; Paradis, 2009) proposes that children and adults have different learning processes available to them. The present study addresses DeKeyser's third question about the nature of the developmental changes. It does this in the context of a specific task, one that has previously been found to be correlated with aspects of early language learning, especially vocabulary acquisition, in both L1 and L2. It compares the performance and learning of 8-year-old children with that of young adults in phonologically accurate repetition of foreign words as a function of item recurrence. It further probes the extent to which overt recognition of the presented items is available to the two age groups in an unexpected test.

Background to the Study

Implicit and Explicit Memory Processes

An influential hypothesis advanced in the discussion of the role of sensitive or critical periods in L2 learning has been one asserting that children rely necessarily more on implicit mechanisms of learning (DeKeyser & Larson-Hall, 2005) whereas adults can make use of their better explicit memory. In the longer run, implicit memory is then assumed to do a better job than explicit memory. This hypothesis is similar to Michael Ullman's (2001, 2004) suggestion that many central aspects of language acquisition and learning, such as syntax and phonology, rely on implicit procedural rather than explicit declarative memory. Procedural memory, reflected in improved responses in skilled tasks as a function of repetition, is generally assumed to be available from birth whereas declarative memory, memory for facts and events, is mostly thought to be slowly built up during development.

Although the implicit-explicit hypothesis is a good starting point for exploration of differences between adults' and children's language learning, it requires substantial elaboration if it is to be able to provide detailed predictions regarding the specific aspects of language that are learned differently at different stages of maturity. The concepts implicit and explicit learning/memory also require clarification. In the memory literature (e.g., Schacter, 1987), implicit and explicit memory were originally related to patient data showing that lesions to certain structures in the brain, such as the hippocampus and surrounding medial-temporal lobe regions, caused profound amnesia, an inability to encode new memories so that they could be consciously recalled later. In severe cases, also old memories became inaccessible. These memory impairments were described as affecting explicit, intentional memory processes. In contrast, deeply amnesic patients were still able to learn new motor, as well as cognitive, skills. This was evidenced by their improvement with repeated performance in, for instance, structured problem-solving tasks, despite no explicit memory for the training episodes (Schacter, 1987).

The conceptual jungle of memory and learning definitions on the explicit–implicit axis was elegantly mapped for L2 acquisition research in a theoretical review by Hulstijn (2005). Following his summary of the literature, a commonly accepted definition of *explicit memory* describes it as performance in tasks in which participants are asked to recall or recognize material they were exposed to in specific past events (Schacter, 1987). In implicit versions of the task, participants are not asked for recall but to perform a task on the materials previously presented to them and on novel materials. *Implicit memory* is measured by performance characteristics such as accuracy and speed

differences between items from the targeted event and items not presented in that event as well as by an increased probability of producing previously studied material as responses in elicitation tasks. *Explicit and implicit knowledge* refers to awareness or lack of awareness, respectively, of regularities in, for instance, some language knowledge a participant possesses. *Explicit and implicit learning of language* may be distinguished by a conscious intention to find out about such regularities compared to lack of such intention. In experimental research, implicit learning has been probed by tasks that measure accuracy and speed improvement in tasks as a result of practice (i.e., repetition). Implicit (nonconscious) abstraction of patterns and rules has been measured by comparing performance on repeated structures compared to novel structures that deviate from patterns in previous input. In these paradigms, abstraction of structure is inferred from slower/less accurate performance on the deviant stimuli. Finally, the division into explicit and implicit learning is often confused with *intentional learning* versus *incidental learning*, which refer to the participants' conscious efforts to acquire specific knowledge as contrasted with acquisition happening without conscious intention to learn, as a consequence of (possibly repeated) exposure. In paradigms such as *artificial grammar learning*, in which a hidden complex pattern underlies a sequence of stimuli or tasks, explicit tests of recognition or recall are used to probe explicit knowledge acquired during task performance whereas implicit knowledge is tested by comparing performance accuracy and timing for sequences deviating from the hidden pattern compared to sequences adhering to it.

Although these definitions should allow classification of memory and learning processes in individual instances into binary

categories, this is not straightforward even for laboratory tasks, let alone learning in the real world. The problem arises from the fact that most tasks rely on both kinds of memory/knowledge/learning. It has turned out to be difficult, if not impossible, to prove that only one kind was employed in any specific case. In the present study, we observed performance in an ecologically valid language task, oral repetition of words in an unfamiliar language. The task instructions did not refer to either memory or learning. Thus, any learning process was likely to be incidental.

We report three outcome measures for changes in performance in this task. Over the course of the experiment, the first two outcome measures—improved phonological accuracy and shorter latencies before the repetition response onset—were assumed to reflect implicit (unaware) perceptual and motor learning. Such learning could involve participants getting better at perceiving phonetic features or prosodic regularities, improving at segmenting the stimuli into chunks that could be held in working memory and/or translated to motor responses, or getting faster at programming the articulatory repetition responses. The accuracy and latency measures rely on implicit memory, as they do not depend on awareness of details of the learning episode (Knowlton & Foerde, 2008). Our third outcome measure was an explicit test of recognition memory for the encountered items. Recognition memory is thought to depend on two separate processes: conscious *recollection* of the learning episode during which a tested item was encountered and a *feeling of familiarity* without recall of the details of a previous encounter with the tested item (Yonelinas, 2001). Neither familiarity- nor recollection-based responses can occur without some awareness of the item having been encountered before, suggesting that both processes contribute to

an explicit response of recognition. However, in a word memory task, they differ, as recollection depends mainly on conceptual features of the word and the context at its encoding, whereas familiarity-based recognition responses rely on the similarity in the perceptual experience of a previously encountered word and the test word. This distinction guided a previous comparison of 10–13-year-old children and young adults in implicit and explicit tests of L1 and L2 (Trofimovich, Martin-Chang, & Levesque, 2012). Below we will review briefly what is known about the developmental aspects of implicit memory and learning, as a background to why we might expect differences between children and adults in different types of memory tasks.

Implicit and Explicit Memory Development

Although both implicit and explicit kinds of memory seem to be present from birth (Rovee-Collier, 1997), years of research have mapped out dramatic developmental improvements in children's explicit memory. These are paralleled by developments in a well-known brain structure, the hippocampus, until age 4–5 and in prefrontal cortex well into adolescence. The changes are thought to reflect more efficient encoding and consolidation processes (Bauer, 2004, 2009). During childhood, encoding and storage rates in explicit memory improve whereas retrieval success when encoding is controlled appears to remain constant. The balance of vulnerability between the two appears to shift from encoding and storage toward retrieval during memory development (Bauer, 2009).

Implicit memory is generally agreed to be in place from birth. However, it is unclear whether all types of nondeclarative memory can be assumed to have the same developmental characteristics. The available

research on different types of learning processes (reviewed in Lloyd & Newcombe, 2009) has established that *perceptual priming* (e.g., sensitivity to repeated auditory or visual characteristics of verbal stimuli) stays stable at least from age 3 onward. In contrast, developmental findings regarding *conceptual priming* are more variable and appear to reflect the increasing interconnectedness of concepts in semantic memory. Conceptual priming occurs, for instance, in tasks where participants are asked to think of examples of vegetables after they have recently been presented with names of a set of vegetables. Recently encountered vegetables are more likely to be named. *Statistical (implicit) learning* of rule-governed verbal and other sequences seems to be possible from infancy (Saffran, Aslin, & Newport, 1996). *Procedural learning* of motor and cognitive skills is a further form of implicit learning. Although differences in procedural learning have been proposed to lie behind variable language learning outcomes in learners of different ages (Paradis, 2009; Ullman, 2001), there is presently little systematic research addressing such claims.

A small number of studies have investigated sequence learning in children. A recent study by Arciuli and Simpson (2011) targeting children 5–12 years of age reported better memory for encountered stimulus triplets in older children in an implicit visual sequence learning task. A brain imaging study by Thomas and her colleagues (Thomas et al., 2004) found superior learning in young adults compared to 7–11-year-old children in a motor sequence learning task. Although partly different brain areas seemed to be involved in children and adults, activity in the basal ganglia (the right caudate) correlated in both groups with behavioral learning measures. Both behavioral effects and the caudate signal were stronger in the adults. Another study

comparing 6-year-olds, 8-year-olds, 10-year-olds, and young adults in a similar motor sequence learning task (Savion-Lemieux, Bailey, & Penhune, 2009) found differences between age groups in an accuracy measure of mapping visual stimuli to response fingers and keys. This was interpreted to reflect explicit memory aspects of stimulus–response mapping. Older groups were consistently faster but all groups' speed improved with sequence repetition. Finally, despite the robust differences in performance, there were no age differences in explicit recognition and recall measures of sequence memory. The authors concluded that implicit learning and explicit knowledge were not linked in this visuo-motor sequence task. Another recent behavioral study (Weiermann & Meier, 2012) investigated incidental sequence learning with nested sequences at the level of conceptual tasks (three different categorization tasks) and motor responses. These authors also reported sequence learning in young adults to be independent of the explicit knowledge the participants accumulated during the task. In contrast, only those children between 7 and 16 years old who could explicitly recall sequence knowledge showed reaction time effects indicative of learning in this task with a complex sequence structure. This result is opposite to what one would expect if children relied more on implicit than explicit forms of sequence knowledge.

Recent studies have directly addressed the procedural language acquisition hypothesis by Ullman (2001) by investigating correlative relationships between aspects of language development and performance in statistical or sequence learning tasks. So far, procedural learning tasks have not been found to predict acquisition of past-tense morphology in English (Lum & Kidd, 2012) or in the morphologically complex Finnish (Kidd &

Kirjavainen, 2011). Furthermore, Ullman and Pierpont's (2005) hypothesis of a procedural deficit underlying specific language impairment did not receive support from a study of a small group of Danish children with specific language impairment (Lum & Bleses, 2012), as no relationships between motor sequence learning and past tense or vocabulary tasks could be detected. A direct association between motor sequence learning and syntactic priming in 4-year-old children was reported by Kidd (2012). However, a significant relationship was not seen between procedural learning and language production responses immediately after exposure to the syntactic model structure. Only in a subsequent test did a significant relationship emerge. The study also suffers from floor effects as half of the children showed no priming in the immediate test and only 19–33% of them showed effects in the posttest. Those that showed priming produced only one primed construction on average. To summarize, implicit memory and learning take many forms. Perceptual priming appears to change little since infancy whereas the developmental trajectories of statistical and skill learning are less clear. How explicit and implicit forms of learning support each other or compete at different ages and in different tasks also requires more research.

The Neural Substrates of Implicit and Explicit Memory and Learning

The hypotheses of Paradis (2009) and Ullman (2001), suggesting that major aspects of L1 development (almost everything except the addition of vocabulary) depend on implicit learning processes and that children rely on these processes also when acquiring a second language, rest upon a view of modular neurophysiological separation of implicit and explicit learning and memory systems. Implicit learning of sequences (e.g., phonology and syntax) is suggested to be

accomplished by a network of structures known to be involved in motor sequence learning, such as the basal ganglia and the cerebellum, in addition to perisylvian cortex. In contrast, explicit memory for sequences and lexical items is thought to rely on the hippocampus and surrounding areas as well as mesial temporal cortex and the anterior cingulate (Paradis, 2009). Ullman's research has stressed the importance of a procedural memory system based on specific channels in frontal (Broca's area)/basal-ganglia circuits and parts of the cerebellum, but also involving the supramarginal gyrus in the parietal cortex and aspects of superior temporal cortex including the superior temporal sulcus (Ullman & Pierpont, 2005).

From the point of view of language acquisition as an example of skill learning, some of the more interesting research involves explicit and implicit learning of verbal sequences. In a recent study (Kalm, Davis, & Norris, 2013), participants were asked to immediately recall auditorily presented sequences of letters. Among the sequences, some were new whereas others were repeated over the experiment (the so-called Hebb learning task). As usually observed in this task, recall for the repeated sequences improved over six repetitions. New methods (multivariate pattern analysis) in functional magnetic resonance imaging (fMRI) data processing made it possible to locate the newly constructed sequence representations to brain regions in the temporal lobe, hippocampus, and insula. Moreover, voxels in the hippocampus and medial temporal lobe appeared to identify the individual sequences. These findings point to a potential mechanism for supporting the long-term memory for verbal sequences such as words and repeatedly heard utterances. However, a central point of interest is the role of implicit versus explicit mechanisms in the learning process itself. Most of the

research on this question involves motor sequence learning.

A study by Ferdinand, Mecklinger, and Kray (2008) investigated explicit and implicit visuo-motor sequence learning. Participants were divided into explicit and implicit groups by instructions and were administered a posttest of explicit knowledge. The dependent measures were electroencephalography–based event-related potential components recorded from the scalp. The responses suggested sequence learning in both groups. Both explicit and implicit learners also showed responses (ERN/Ne) indicating error detection after incorrect motor responses and deviations from anticipated sequences in irregular sequences (N2b). However, only the explicit group showed a P3b component indicating conscious processing of deviant stimuli. These data suggest that both aware and unaware sequence learning rely partly on the same mechanisms, including a feedback error signal.

A fMRI study of motor sequence learning by Gheysen, Van Opstal, Roggeman, Van Waelvelde, and Fias (2010) tried to eliminate a number of confounding factors interfering with interpretation of brain involvement in the implicit learning process itself. The researchers replicated activation of a large bilateral brain network including parietal, temporal, and frontal cortical areas as well as parts of the cerebellum and left posterior caudate in the visuo-motor mapping component of the task when sequences were random. However, only anterior hippocampal activation had a tight relationship to the incremental learning process related to repeated sequences that was observed behaviorally. These findings suggest that the hippocampus, usually associated with explicit memory tests or content storage, can play a significant role in implicit motor sequence learning in healthy adult brains.

Finally, an alternative to the modular view of anatomically separate memory systems supporting declarative memory and implicit aspects of memory, such as perceptual, motor, and cognitive skill learning has been put forward by MacKay and his colleagues (for a recent review, see MacKay, James, Taylor, & Marian, 2007). In this *binding theory* view, aspects of memory as well as language comprehension and production depend on two major learning mechanisms. Slow, incremental learning relying on massive repetition, is accomplished by processes termed *engrainment* that are modeled to allow many fast activations to slowly strengthen associations between content units in a memory network. In contrast, fast associative learning is accomplished by *binding processes* that enable content nodes in a distributed network to stay activated for a prolonged time period and memory strengthening of their connections to occur. According to this theory, everyday online language comprehension and production rely on fast activations (with accumulating engrainment), whereas fast learning of new declarative knowledge as well as new language structures relies on binding processes of different kinds for different types of contents. This theory, applied to L2 learning, would give rise to a family of hypotheses about the availability of different binding processes to speed up acquisition of different kinds of language patterns (e.g., phonological structure, morphology, syntax, form–meaning associations) as well as a possibly changing balance between engrainment and binding processes (resembling aspects of the implicit–explicit learning dichotomy). Note that, in this theory, intentional rehearsal of structures would have the same result on binding and engrainment as passive exposure.

In summary, data from memory research in adults have revealed several

complex brain networks that contribute both to the encoding of new information and its retrieval depending on intentionality, awareness, and the characteristics of the learning process. The contributing brain areas appear to work together to produce different aspects of memory and learning. Furthermore, parts of the hippocampus have been linked to the storage of both explicitly and implicitly learned knowledge/procedures. Although dissociations can be detected at the brain level and in patients with selective brain damage, it is not clear whether such dissociations can be observed at the behavioral level in everyday memory functioning, for instance in language tasks. Data from sequence learning experiments suggest that explicit and implicit systems may work side by side in an intact brain to learn and represent sequences. Finally, binding theory (MacKay et al., 2007) proposes that dissociations between performance in memory and learning tasks do not depend on well-circumscribed memory systems but on the balance of engrainment and binding processes, which may have content-specific neural substrates.

There are currently not enough data from neuroimaging studies to evaluate the hypothesis that children's L2 learning relies relatively more on implicit memory than that of adults. Anatomical studies have documented continued brain development before adolescence (e.g., Wilke, Krageloh-Mann, & Holland, 2007). In particular, the development of brain lateralization has been suggested to explain maturational changes in potential for language acquisition (Lenneberg, 1967). A recent study of 1–6-year-old children reports on the developmental course of white matter myelination asymmetries indicative of developing connectivity in the brain (O'Muircheartaigh et al., 2013). While a number of both left- and right-dominant

asymmetries were found, their relationship with language abilities changed with age in complex ways until about age 4 years, at which time the relationships stabilized, suggesting an end to a possible critical window.

Experimental Research of Age Effects in L2 Learning

The present knowledge of developmental changes in brain functioning is not sufficient to resolve the controversies about differences between children's and adults' L2 acquisition. On the behavioral side, fairly few studies have examined language-learning processes in the laboratory. Although already many years ago Snow and Hoefnagel-Hohle (1977) reported an advantage for adults in an L2 experimental pronunciation task, most previous studies have examined ultimate attainment in immigrant populations. This has ecological validity but is limited by many confounding variables related to the child versus adult language learning experience in a new country. Thus, more controlled research is needed to better characterize L2 memory processes in children compared to adults. One experimental study by Trofimovich and his colleagues (Trofimovich et al., 2012) addressed children's and adults' performance in implicit and explicit memory tests for L2 words. The 11–13-year-old participants and young adults were exposed to written words in a conceptually supportive condition (reading them as parts of a story) and in a condition favoring more superficial coding based on perceptual features (reading words in isolation). The conceptual condition was expected to result in better explicit memory whereas the more superficial condition should have supported implicit memory. The study did not detect any differences between children's and adults' performance on either an explicit memory test (surprise recall of the read

words) or an implicit memory test (completion of word stems). The objective in the current experiment is to continue experimental investigation of age differences in L2 memory by concentrating on age differences in one specific type of learning reflected in improvement of performance in a foreign word repetition task over a single session. We compared a group of Finnish young adults with a group of 8-year-old children in a Korean-word repetition task.

Repetition Tasks and the Present Study

Foreign-word repetition has been found to be a good predictor of (at least early) acquisition rate in L2 learning in formal settings, especially in otherwise homogenous samples (Dufva & Voeten, 1999; French, 2006; Service, 1992; Service & Kohonen, 1995). A small number of studies (Ellis & Sinclair, 1996; French & O'Brien, 2008) further suggest that the ability to accurately repeat foreign words is also closely related to the learning of morphosyntax. Such findings, along with extensive research of the role of phonological short-term memory in L1 acquisition, led Baddeley, Gathercole, and Papagno (1998) to propose that a phonological subcomponent of working memory serves as a language acquisition device. This component, the *phonological loop* in the influential working memory framework developed by Baddeley and Hitch (Baddeley, 1986; Baddeley & Hitch, 1974), is assumed to support both pseudoword repetition and immediate memory for phonologically coded item sequences (although see Gathercole, 2006, and related comments for a discussion). A slightly different interpretation was suggested by a study of incidental pseudoword learning during a short-term memory task that

required immediate recall of ordered sequences of pseudowords (Service, Maury, & Luotoniemi, 2007). The pattern of results indicated that the critical process shared by phonological short-term tasks and longer-term learning of words may be the encoding of novel items rather than the storing of them in a temporary buffer. This encoding aspect is even more prominent in single-item repetition tasks than in immediate recall of pseudoword or digit sequences. As there is a substantial body of work suggesting that nonword, pseudoword, and foreign-word repetition tasks tap into processes playing a role in both L1 and L2 learning (for a review, see Gathercole, 2006), we thought that learning in this task can provide a window into core processes in language acquisition.¹

The present study, therefore, investigated whether improvements in a foreign-word repetition task in terms of accuracy and/or speed can be detected in adults and children over a single session. Theories of statistical learning of phonology (Pierrehumbert, 2003) have proposed that abstraction of phonemes occurs in perception-production loops between speakers and hearers from phonetic variants in different syllabic positions (e.g. syllable-initial /k/ in *cat* and syllable-final /k/ in *back*). The prosodic information of these different positions is assumed to be attached to the syllable representations that are stored. Further refinement of phonotactic development is thought to depend on statistical inferences over lexically represented types (as opposed to encountered tokens) as the developing lexicon grows. Some evidence for phonotactic learning being mediated by the lexicon has been found in L1 nonword repetition tasks in children (Edwards, Beckman, & Munson, 2004; Zamuner, 2009).

¹ Note that, although there is an ongoing debate about the direction of causality between pseudoword repetition and vocabulary size in L1 acquisition (see Melby-Lervag et al., 2012, for a recent contribution to the debate), the matter is less controversial in L2 learning. In the longitudinal study of Service (Service, 1992; Service & Kohonen, 1995), vocabulary 3 years ahead was predicted from English pseudoword repetition at a point when the students only knew a few English words. In French's (2006) work, repetition of Arabic words was as good a predictor of English learning by L1 French speakers as repetition of English pseudowords.

To explore the role of complete word forms in phonotactic learning in the current study, we asked whether learning effects in word repetition, if they can be measured in a single session, are restricted to recurring items. This might be expected if learning proceeded in an item-by-item manner in which phonemes and their associations are first strengthened inside specific items before general phonotactic relationships are extracted. Another possibility is that more general learning of phonological and phonotactic patterns, benefitting new and old items alike, could be seen. We studied both implicit (improved repetition accuracy and fluency) and explicit (old–new recognition) measures of memory as these could reveal qualitative differences in L2 learning between children and adults (Ullman, 2001).

Our study expands upon findings by Majerus, Linden, Mulder, Meulemans, and Peters (2004) in a somewhat different task. These researchers also studied phonotactic learning in an experimental setting. They had adults and 8-year-olds listen to consonant-vowel sequences that adhered to simple segment- or syllable-level rules while performing a drawing task. At the end of the session, the subjects were tested in a pseudoword repetition task. Both groups showed evidence of incidental learning by repeating pseudowords that followed the rules from the familiarization sequence more accurately than pseudowords that did not. In the present study, the language material is authentic natural language and the exposure phase involved active repetition rather than passive listening.

The repetition task was chosen to allow us to contrast performance on specific items with general familiarization with foreign phonological patterns. In addition, implicit and explicit memory measures of improvement could be compared. We expected all participants to get more

accurate and faster during the repetition task. In line with hypotheses put forward by Ullman (2001, 2004), Paradis (2009), and DeKeyser and Larson-Hall (2005), we expected children to show greater improvement than adults on implicit memory measures (improved repetition accuracy and faster reaction times) whereas adults were expected to show more learning in an explicit recognition task, where performance could be boosted by conscious recollection. If learning was mediated by encountered tokens, we expected words that were presented five times to show greater implicit learning effects than words that had occurred only once. We also expected recognition scores for items repeated five times to be better than for items encountered only once as a result of either strengthened memory representations or higher odds that at least one of the encounters among five would be recollected.

Method

Participants

The participants were 27 children recruited from elementary schools situated near the University of Helsinki and 28 adults recruited from universities, polytechnics, and a vocational school, all also in Helsinki. Based on population statistics in Helsinki, the two samples were expected to be similar in socioeconomic status and parental level of education. No general cognitive test scores were available for the two groups. However, previous research has shown pseudoword repetition and nonverbal intelligence measures to be unrelated (e.g., Gathercole, Service, Hitch, Adams, & Martin, 1999). Data from three children and two adults were unavailable for analysis because of a technical failure of the headphones used for stimulus presentation. One child withdrew from the experiment without finishing the task. The mean age of the remaining 23

child participants (11 males) was 8.9 (SD = 0.30) years and the mean age of the 26 adult participants (10 males) was 24.5 (SD = 3.50) years. Informed consent was obtained from adult participants and the parents of the child participants. Criteria for participation included: (a) Finnish as the only language spoken at home, (b) no diagnosed language disorders such as dyslexia, (c) no diagnosed reduction of hearing, and (d) no knowledge of Asian languages. Additional criteria for adults were: (a) no studies of non-European languages as major or minor subjects at university and (b) no phonetics, linguistics, or speech-language pathology studies at university. None of the participants had had any significant previous exposure to Korean. Child participants were given stickers and adult participants two movie tickets as compensation for their time.

Stimuli

Korean was chosen as the language of the stimuli simply because it could be assumed equally unfamiliar for both the adults and the children in this study. That is, it was expected that neither children nor adults would even be able to identify the language as Korean because of the unfamiliarity of the sound patterns of the words. There are considerable differences between the current L1 of the participants (Finnish) and Korean with respect to both phonetics and phonology. In particular, stop consonants are categorized differently in Korean and Finnish. For instance, the Korean dental stops have three categories characterized by different amounts of aspiration: /t'/ (unaspirated), /t/ (lightly aspirated), and /tʰ/ (heavily aspirated). Finnish does not have aspirated stops but distinguishes between two unaspirated categories /t/ and /d/, which are allophones of the same consonant in Korean. Also the phonotactic patterns differ between Finnish and Korean.

Korean syllables take the form (C)(Glide)V(C)(C) (Kim & Shibatani, 1976), whereas Finnish syllable structure is (C)V(V or C)(C) (Karlsson, 1982, p. 134). Another difference is that Korean consonants in coda position are released only if they are followed by a vowel in the following syllable. Unreleased consonants are resyllabified at the ends of utterances. A previous study suggested that unfamiliar phonological segments impair nonword repetition accuracy for items of variable length whereas unfamiliar phonotactic structure affects longer items exclusively (Kovacs & Racsmany, 2008). We avoided including phonemes considered difficult for Finnish speakers to articulate, as identified by an instructor of Korean to speakers of Finnish (J-Y. K.). This was because we were interested in evaluating the quality of the representations of the phonological word forms in working memory that were used to produce the repetition output not the effect of motor skill on pronunciation accuracy (Kovacs & Racsmany, 2008).

In total, 82 three-syllable, 82 four-syllable, and 41 five-syllable Korean words or two-word combinations chosen from Korean textbooks served as the stimulus pool. The words were clearly articulated by a native Korean speaker and recorded to waveform audio format (wav) using a 44,100-Hz sampling rate at 16 bits per sample. Silences at the beginnings and ends of stimulus files were removed. A ramp of 25 milliseconds was adjusted to the beginning and a ramp of 40 milliseconds to the end of every sound file to avoid clicks.

There were two kinds of stimuli: recurring and nonrecurring stimuli. The recurring words were presented five times and the nonrecurring words only once during a repetition task. Each participant repeated a list with 50 recurring and 75 nonrecurring words. The stimulus list had 20 three-syllable, 20 four-syllable, and 10 five-syllable words

that were randomly selected from the pool of Korean words to be the recurring items. The stimulus list had also 30 three-syllable, 30 four-syllable, and 15 five-syllable words that were randomly selected from the stimulus pool to be the nonrecurring words. Each list consisted of five blocks and each block included all the 50 recurring words and 15 (6 three-syllable, 6 four-syllable, and 3 five-syllable) nonrecurring words. To control for variation in difficulty between individual stimulus words, four different stimulus lists were counterbalanced between subjects in the repetition task: the original list with the stimuli in semi-random order, this order reversed, the original list with the recurring and nonrecurring words switched, and a reversed-order version of it. Seventy words (35 recurring words and 35 nonrecurring words) from the foreign-word repetition task were randomly chosen to serve as “old” stimuli in a recognition memory task along with 70 words that were new to the participants. The proportions of stimuli of different syllable lengths were the same as in the foreign-word repetition task.

Design and Procedure

Foreign-Word Repetition Task

The participant sat in front of a laptop computer (Apple MacBook 2.1 with a SigmaTel Audio sound card) and the experimenter sat beside him/her in a quiet room. The majority of the children’s data was collected in schools and the majority of the adult data in a psychology laboratory. The participants’ task was to repeat back each foreign word that they heard from the headphones. They were told to speak up and try not to make noisy movements. Before the experiment, 10 stimulus words were presented for practice. The stimuli were presented using Presentation 11.0 software. The repetition responses of the participants were recorded using a minidisk recorder.

Response latencies were registered using a voicekey. The sound threshold for triggering the voicekey was adjusted individually for every participant. When the sound threshold was exceeded, a response time was recorded and there was a 2,500-millisecond pause before the beginning of the next stimulus to allow time for comfortable completion of the repetition response. After every 40 or 41 stimuli (7 breaks), there was a break until the participant indicated they were ready to continue. Typically, the breaks were quite short and filled with a few sentences of conversation. The breaks did not coincide with block boundaries.

Foreign-Word Recognition Task

There was a short break of a few minutes filled with chat between the foreign-word repetition task and the recognition task. In this surprise task, stimulus words were presented over headphones attached to a laptop computer and the participants responded either “old” or “new” by pressing marked keys on the laptop keyboard. An “old” response was given if the participant thought that they had heard a word during the foreign-word repetition task and a “new” response was given if they thought they had not. Response hands for “new” and “old” responses were counterbalanced between subjects. The participants were informed that they would hear both “old” words that they had heard only once and others that they had heard many times during the word repetition task. This was emphasized as it served to prevent memory of multiple encounters being used as the sole cue for “old” responses.

Results

The digitally recorded repetition responses produced by the participants during the first and the last (fifth) block were rated by a linguistically trained native

Korean speaker who was blind to which responses had been produced in the first and which in the last block. In connection with a different study (Nora et al., 2012), we compared a phonological scoring system with one based on a rating scale. The two produced identical results. We therefore followed the customary phonological scoring procedure for pseudoword and foreign-word repetition in this study. There were two scoring systems. In the syllable-based scoring system, a point was given for every accurately repeated syllable also when preceding syllables had been omitted. A syllable was considered to have been accurately repeated if none of its phonemes were missing or replaced with another Korean phoneme. Perfectly native-like articulation or prosody was not required. In word-based scoring, a point was given if the whole word had been accurately repeated, that is, with no Korean phonemes omitted or added or switched in sequence or replaced by other Korean phonemes. In this scoring, all words had equal weight, whereas the syllable-based scoring led to a slight overweighting of longer words, such that, for example, the proportion of possible points from four-syllable words was .4 in syllable scoring and .42 in word scoring and the corresponding weights for five-syllable words was .2 in syllable scoring and .26 in word scoring. In the nonword/pseudoword repetition literature, word-level scoring is the most commonly reported measure.

Repetition Accuracy

Both the syllable and word scoring results for Korean word repetition accuracy were analyzed. However, as the two sets of analyses showed identical patterns, only word-level analyses are reported here. To evaluate the reliability of the scores, a sample of 402 tokens were scored by a second native speaker of Korean. The two

scorers agreed on 81.34% of the responses. Figure 1 shows the average percentages of accurate word repetitions of recurring and nonrecurring words by both groups in the first and the fifth block. The results were analyzed with a $2 \times 2 \times 2$ ANOVA, with group (children vs. adults) as a between-subjects factor and block (first vs. fifth) and word type (recurring vs. nonrecurring) as within-subjects factors. A small number of planned pairwise contrasts of interest rather than a blanket of post hoc tests were used to further probe the detailed effects involving group. A conservative Bonferroni-corrected alpha level (.0125) keeping familywise alpha at .05 was used. The main effect of group did not reach significance, $F(1, 47) = 1.913$, $p = .1731$, $\eta_p^2 = .039$. However, the results showed a main effect of word type, $F(1, 47) = 8.335$, $p = .0059$, $\eta_p^2 = .151$, as recurrent words were repeated more accurately than nonrecurrent words. Although the main effect of block was not significant, $F(1, 47) = .128$, $p = .722$, $\eta_p^2 = .003$, the analysis revealed an interaction of block and word type, $F(1, 47) = 21.807$, $p = .000025$, $\eta_p^2 = .317$, which stemmed from the two word types showing opposite patterns over the experiment. The performance for recurrent words improved between block 1 and block 5 whereas performance for nonrecurrent words declined from block 1 to block 5. All interactions with group were nonsignificant: interaction of group and word type, $F(1, 47) = .165$, $p = .686$, $\eta_p^2 = .003$, interaction of group and block, $F(1, 47) = .053$, $p = .8189$, $\eta_p^2 = .001$, and, most interestingly, the three-way interaction between group, word type and block, $F(1, 47) = .000000027$, $p = .9996$, $\eta_p^2 = .000$.

A planned contrast showed that, in block 1, the difference between performance on recurring (60.8%) and nonrecurring (61.1%) words was not significant, $F(1, 47) = .03$, $p = .8725$,

Cohen's $d = .02$, whereas recurring words were repeated significantly better in block 5 (66.0%) than nonrecurring words (56.7%), $F(1, 47) = 41.51, p = .0001$, Cohen's $d = .56$. Two other planned contrasts showed that repetition accuracy for recurring words got significantly better between block 1 and block 5, from 60.8% to 66.0%, $F(1, 47) = 12.97, p = .0008$, Cohen's $d = .34$, and that repetition performance deteriorated somewhat for the nonrecurring foreign words, from 61.1% to 56.7%, $F(1, 47) = 9.02, p = .0043$, Cohen's $d = 0.26$. Thus, whereas the task appeared to be sensitive to improvement over the experimental session for foreign words occurring five times, no differences in repetition accuracy between the two age groups could be detected either visually or in the statistical analysis.

As nonword length has a stronger effect on L1 repetition performance in special populations, such as children with specific language impairments, than in typical participants (Gathercole & Baddeley, 1990), an interaction between group and stimulus length in the present study could reveal performance differences between the two age groups. For this reason and to facilitate future replication attempts for the results, a further $2 \times 2 \times 3$ ANOVA was computed to look at possible interactions between group, block, and syllable length (three, four, or five syllables) of the repeated material. Both the effects of block, $F(1, 47) = 29.97, p = .0001, \eta_p^2 = .389$, and syllable count, $F(2, 94) = 132.83, p = .0001, \eta_p^2 = .737$, were significant. Repetition accuracy was better in block 5 than block 1. Repetition accuracy was best for three-syllable items (78.6%), intermediate for four-syllable items (59.7%), and poorest for five-syllable items (40.5%). There were no detectable interactions between block and item length. The main effect of group was nonsignificant, $F(1, 47)$

$= 1.183, p = .2822, \eta_p^2 = .025$. No interactions involving group approached significance (all $F_s < 1$).

Repetition Latency

Repetition latencies were measured from the onset of the model Korean word to the onset of the vocal response. The data of three children and two adults were excluded due to frequent artificial triggering of the voicekey. As it is common for reaction time data to contain outliers, median rather than mean latencies of individual subjects were entered into all the analyses. Outliers were not removed. Figure 2 shows the mean response latencies of both groups in the different blocks for both recurring and nonrecurring words. Children and adults appear to perform similarly throughout blocks. As expected, learning for recurring words seems larger. Statistical analysis confirmed these patterns in the data.

The results were analyzed with a $2 \times 5 \times 2$ ANOVA, with group as a between-subjects factor and block and word type as within-subjects factors. The main effect of group did not approach significance, $F(1, 42) = .13, p = .7218, \eta_p^2 = .003$, but there were significant effects of block, $F(4, 168) = 33.62, p < .0001, \eta_p^2 = .445$, and word type, $F(1, 42) = 28.07, p < .0001, \eta_p^2 = .401$. The analysis also revealed a significant interaction between block and word type, $F(4, 168) = 18.06, p < .0001, \eta_p^2 = .301$, indicating a larger effect of block for the recurring than the nonrecurring words. As with the accuracy results, the interaction between block and group was not significant, $F(4, 168) = 1.98, p = .1003, \eta_p^2 = .045$. Importantly, neither was the three-way interaction between group, block, and word type, $F(4, 168) = 1.43, p = .2253, \eta_p^2 = .033$. Both effect sizes were very small.

Because we were interested in the effects of recurrence over the experiment,

planned contrasts were computed between the recurring and nonrecurring words in the first and the fifth block, separately. The Bonferroni-corrected test-specific alpha-level for these contrasts was .025. Whereas the latency difference was nonsignificant in block 1, $F(1, 42) = .14, p = .7095$, Cohen's $d = .05$, recurring words were significantly faster than nonrecurring words in block 5, $F(1, 42) = 58.29, p = .0001$, Cohen's $d = .65$.

Recognition Memory

One child participant's performance was excluded from analysis of the recognition task because she had always pressed the same button. The d -prime difference statistic between normalized hit and false alarm values was computed as a measure of recognition performance. Figure 3 shows the d -prime values for the two groups and the two kinds of words. The performance of the adults was generally better ($M = 69.81\%$, $SD = 4.89$ correct trials for adults and $M = 62.14\%$, $SD = 5.79$ for children). The d -prime values were analyzed with a two-way ANOVA, with group as a between-subjects factor and word type as a within-subjects factor. The analysis confirmed a significant main effect of group, $F(1, 46) = 25.79, p < .0001, \eta_p^2 = .359$, as well as a significant and substantial advantage for recurring words, $F(1, 46) = 238.10, p < .0001, \eta_p^2 = .838$. Adults performed clearly better than children. Also the interaction between group and word type was significant, $F(1, 46) = 9.97, p = .0028, \eta_p^2 = .178$, as the difference between recurring and nonrecurring words was greater for the adults than the children. Adults correctly recognized 50% ($SD = 18.57$) of the nonrecurring and 87.80% ($SD = 10.59$) of the recurring words. The corresponding percentages for children were 45.45% ($SD = 12.12$) and 75.07% ($SD = 13.78$). Thus,

the interaction effect comes from (a) the better recognition performance of the adults, compared to the children, for the recurring words and (b) the performance for the nonrecurring words being near chance for both groups.

Discussion

The current study set out to compare the changes in performance of adults and 8-year-old children in a foreign-word repetition task. Specifically, the hypothesis that different learning processes, reflected in different memory measures, are available to children than adults was investigated in the learning context of foreign word repetition. As the participants' instructions were only to repeat the foreign words they heard, any learning taking place can be described as incidental. Two implicit performance measures (foreign-word reproduction accuracy and latency) both showed improvement over the experimental session. Moreover, both measures showed greater improvement for items repeated five times compared to those repeated only once over the experiment. Contrary to our hypotheses, adults and children had very similar learning patterns, and no effects involving subject group approached significance.

The results in the surprise recognition task were different. Here, adults were significantly more likely than children to correctly recognize words that they had encountered five times during the recognition experiment. Neither group was able to reliably tell the difference between words repeated once and completely new words. These results suggest that there are no detectable differences in the implicit aspects of early processes in phonological word-form learning between young adults and 8-year-old children. The findings resemble those reported by Snow and Hoefnagle-Hohle (1977) in a laboratory imitation task

with foreign words and phonemes embedded in words. These authors found equal improvement by children of different ages and young adults over 20 repetitions of the items. Our results also resemble those of Trofimovich et al. (2012) in terms of a failure to show superior performance by children in an implicit memory test.

Why Are Adults Better in the Recognition Task?

In contrast to the lack of age differences in our performance measures, the adults in our study outperformed the children in a recognition memory task involving the encountered words. This points to superior explicit memory retrieval for word forms in adults. However, recognition performance appeared to develop slowly over repetitions as both groups were at chance for items encountered only once during the experiment. There are two possible accounts for how conscious recognition could improve over trials when it was not present after a single encounter with a stimulus. One possibility is that some type of memory representations not accessible to explicit retrieval are formed already during early trials and these are strengthened on subsequent encounters until they exceed a criterion for conscious recognition. This criterion level could be different for children and adults. A second possibility is that each encounter with a stimulus creates a representation that can be cued for later recognition with some low probability. After five encounters the probability that at least one of the encounters has created such a representation would have exceeded the criterion limit for 88% of stimuli for the adults and 75% of the stimuli for the children.

If there is no difference between the age groups in the criterion for conscious recognition, adults may still have been

forming better accessible memory traces from the start. In other words, this explanation entails a *better-encoding hypothesis*. These traces would then have been made even better accessible over repetitions, reaching criterion for recognition earlier than those of children. According to a *differential-encoding-probability hypothesis*, on the other hand, adults would be more likely to form a later accessible representation on each stimulus trial. The finding that both groups performed at chance level in the recognition task after a single encounter, speaks somewhat against the differential-encoding-probability hypothesis. Both hypotheses are compatible with an attentional explanation of adults being better focused on the task.

Performance on recognition tests is generally modeled to be the result of two separate processes: a feeling of familiarity, which can also be captured in implicit memory tests, and conscious recollection, which determines performance in explicit recall tests (Yonelinas, 2001). It is conceivable that children's recognition responses relied more on an implicit feeling of familiarity than on recollection, whereas adults may have benefitted from both processes. The better-encoding hypothesis could additionally reflect adults engaging in better transfer-appropriate processing (Morris, Bransford, & Franks, 1977) of stimuli, that is, forms of encoding that are more likely to be useful in future tasks and would boost recollection. Adults' feature-encoding processes could be more sophisticated and therefore more likely to allow access to the representations and the context they were presented in based on some content-based cue. In the above mentioned study, Trofimovich et al. (2012) found no differences between children and adults in an explicit memory test (word recall). They also found no extra benefit from a story context at encoding. In fact, all

participants did better after reading single words with no context. In that study, the child participants were a little older (11–13 years old). The study task was to read meaningful words aloud. Both the older age of the children and the previous familiarity and meaningfulness of the words may have contributed favorably to the children's explicit memory performance in that experiment. Further, the story context condition with shared reading by the teacher and the students may have led to attentional overload. In our study, by contrast, few associative links were readily available to the stimuli in a completely unfamiliar language that was unrelated to the present participants' L1, and the task was simple oral repetition.

To summarize, there was a pattern of more reliable recognition by adult than child participants of Korean words that had been encountered five times in combination with inability by either group to recognize words that had been encountered once. As no differences between the two groups could be detected in implicit measures of learning, a plausible explanation is that adults were able to encode richer representations of the unfamiliar stimuli that either included associations to their existing database of knowledge of languages or benefitted from some other previously existing knowledge in memory.

Item Length as a Probe for Child-Adult Differences

The present study showed that longer words were harder to repeat accurately than shorter words. However, the effect of item length did not interact with the effect of block or group. Thus, similar improvement was seen for all item lengths in both age groups. A previous study of nonword repetition (Kovacs & Racsmany, 2008) found that items with unfamiliar phonemes are

harder to repeat than items with only L1 phonemes independent of their length. In contrast, the presence of unfamiliar phonotactic sequences in the items to be repeated only affected longer items (particularly six-syllable items as compared to four-syllable items). Item length in pseudoword repetition tasks has also been found to interact with specific language impairment, so that language-impaired children perform more poorly on long items than typically developing children while there is no detectable difference on the shorter items (Gathercole & Baddeley, 1990). The learning effects in the present study did not interact with item length, suggesting that length-sensitive processes at the level of phonotactic predictability may have played less of a role.

Implicit vs. Explicit Learning

A key question in the L2 acquisition literature concerns the extent to which implicit and explicit learning and memory processes differentiate between L2 learning in children and adults. According to proposals put forward by Ullman (2001, 2004) and Paradis (2009), children should rely more on implicit processes. The developmental literature suggests that perceptual learning changes little in childhood (Lloyd & Newcombe, 2009). However, many recent studies suggest superior performance by adults in motor sequence learning tasks (Savion-Lemieux et al., 2009; Thomas et al., 2004; Weiermann & Meier, 2012) and superior performance by older children compared to younger children (age range 5–12) in a statistical learning task (Arciuli & Simpson, 2011). The ability to explicitly recall previously formed memory traces may also be present from birth, although it develops dramatically in capacity throughout childhood (Bauer, 2004, 2009). Attempts to directly relate capacity for procedural

learning and aspects of language development have mostly failed (Kidd & Kirjavainen, 2011; Lum & Bleses, 2012; Lum & Kidd, 2012), with one study that reported a positive relationship suffering from serious floor effects (Kidd, 2012). Thus, the general literature on memory or L1 development does not lend strong support to a close tie between procedural learning ability and L2 acquisition success. The present finding of a lack of differences between adults and 8-year-olds in a foreign-word repetition task does not point to a difference in the availability of implicit learning processes to children and adults. However, could it be that adults under some circumstances rely more on explicit memory and that this hinders their implicit acquisition processes? Are we dealing with an either/or situation in which reliance on one set of processes negatively affects learning contingent on the other set? Further, is there an interface between the two? Paradis (2009) has strongly argued that an interface between metalinguistic knowledge and implicit competence is impossible because implicit competence cannot enter consciousness. However, does this necessarily mean that no explicitly accessible representations can affect implicit processes?

Repetition tasks have perceptual, representational (storage), and motor components. Better accuracy and faster responding as a function of stimulus-response repetition are usually interpreted as signs of implicit skill learning. However, it is conceivable in the case of recurring words that explicit memory for having encountered a stimulus word before could help align the memory representation formed at the previous encounter with the representation being created by an incoming word. This top-down process could serve to bias the perception of an incoming word to match a previously created representation of the same word in terms of phonological

segmentation and phonotactic structure. On the other hand, such a top-down process need not rely on explicit memory for a previous encounter. Thus, the present accuracy and latency measures test implicit memory for items and patterns, but we cannot rule out learning being affected by explicit top-down influences. However, the seemingly very similar accuracy and speed results in our two age groups suggest that the better availability of representations for repeatedly encountered words to the adults did not affect their performance on the repetition task.

According to the binding theory put forward by MacKay (MacKay, 1990; MacKay et al., 2007), incremental learning by engrainment depends on repetition: the more, the better. This is the kind of implicit learning amnesic patients are capable of. It gives rise to memory representations that may or may not depend on the hippocampus (see, e.g., Gheysen et al., 2010; Johnson, Suzuki, & Rugg, 2013; Verfaellie, LaRocque, & Keane, 2012). However, engrainment can also be achieved strategically by deliberate rehearsal to create repetition from within. Thus, the binding hypothesis does not predict learning consequences from a difference between intentional and incidental learning but rather from the participation of engrainment processes on their own or the addition of one or more subcortical binding processes. Binding processes make fast learning of associations possible and create representations that are easily accessible in the future. In a foreign-word repetition task, the binding processes have to achieve binding of units of phonological structure to a word form representation that can be held in working memory to guide production. Possible additional semantic binding processes can bind the sound of the word form to meanings of similar-sounding word forms already in long-term memory. For instance, the Korean word *telewum* could

bring to mind English *telephone* or Swedish *telefon*, likely to be familiar to the adult but not the child participants in the present study. It is possible that the implicit learning results in the present study depended on the recruitment of phonological binding processes only, whereas the recognition task additionally benefitted from semantic associations.

Some clues to what is going on in the repetition task can be inferred from a recent study in which we (Nora et al., 2012) used magnetoencephalography, that is, measures of the magnetic fields created by neural activity, to investigate brain responses to Korean words in a similar repetition task as the one in the current investigation. In this experiment, all our participants were young adults and Korean words were contrasted with Finnish-sounding pseudowords. Recurring stimuli caused a left temporal response to decrease and a correlated left frontal response to increase between 600 and 1,200 milliseconds from auditory stimulus onset. These response patterns are compatible with an interpretation that sensory–motor integration loops were being set up. Such loops could be the basis of improvement in repetition of specific items.

How Does Foreign-Word Repetition Relate to L2 Vocabulary Learning?

Storkel (e.g., Storkel, Armbruster, & Hogan, 2006; Storkel & Lee, 2011) describes three separate stages in word learning commonly proposed in the cognitive literature. The first stage involves detection that a novel word has been encountered and triggering of a process that creates a new lexical representation for it. The second stage involves the formation of a lexical representation. The third process results in integration of this representation with preexisting lexical representations so that it can, for instance, compete with them in a

production task. Our present task differs from regular word learning in that we did not pair the word forms with meanings. Further, all word forms were novel on the first encounter and thus should have triggered lexical representation creation processes. Differences in performance on the fifth encounter suggest that lexical form representations had been created and a process of fine-tuning them was underway. However, although both repetition accuracy and speed measures showed similar amounts of learning in children and adults, the created representations appeared to be more accessible for conscious recognition in adults than children. This suggests at least partial independence between explicit memory retrieval and implicit repetition performance. Possibly, such a memory advantage for the adults contributes to faster initial L2 learning by older students in language immersion (Aoyama, Guion, Flege, Yamada, & Akahane-Yamada, 2008) and a continued advantage under limited exposure conditions (e.g., Walsh & Diller, 1979).

We found no evidence for general improvement in repetition of previously unencountered Korean words. This suggests that learning in one experimental session was limited to forming representations for the patterns inside the encountered word forms. No evidence for general phonological or phonotactic pattern learning could be detected. However, it is not impossible that such learning happens during consolidation processes that occur over days and possibly depend on sleep (Dumay & Gaskell, 2007).

Conclusion

The present study compared young adults' and 8-year-olds' phonological learning in a foreign-word repetition task during a single session. Although reliable learning could be detected in both repetition accuracy and latency, no effects involving group approached significance. In contrast,

adults performed clearly better than children in an unexpected recognition memory task on words that they had repeated five times. Neither group was able to reliably recognize words they had repeated only once. We conclude that, on the surface, early stages of forming representations for new word forms appear to progress similarly in children and adults. However, as the created representations were better accessible to adults in an explicit recognition memory task, we cannot rule out hidden qualitative differences in trace encoding. Theorizing along the lines of the binding theory proposed by MacKay (MacKay, 1990; MacKay et al., 2007) can help us to reformulate the implicit–explicit hypotheses of L2 learning. This approach separates slow incremental learning based on an engrainment process from the recruitment of subcortical content-specific binding processes that allow fast creation of associations. In binding theory, anatomically separate implicit and explicit memory systems are not assumed. Instead a number of brain areas contribute to information processing and learning in different tasks, with performance in individual memory and other tasks dependent on the various content-specific binding processes involved. We hypothesize that the similarities between children and adults in implicit memory measures reflect similar engrainment effects in both groups. In contrast, the differences between the two age groups in recognition memory might be explained by children relying mainly on phonological binding processes and adults having access to more semantic binding nodes to support explicit recollection.

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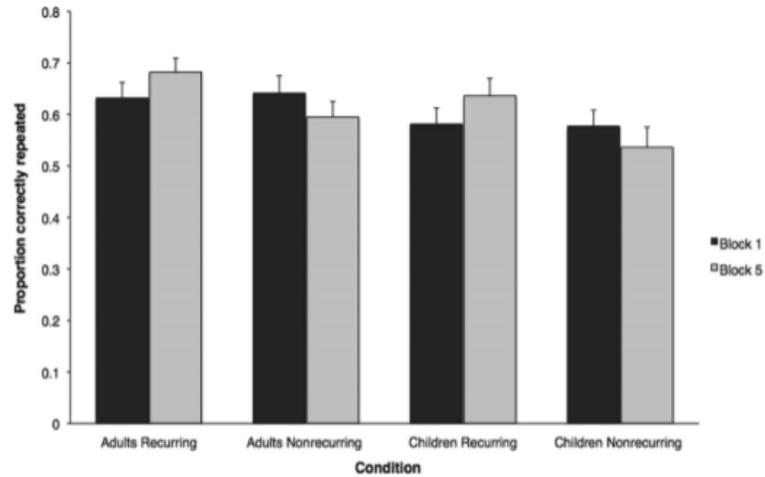
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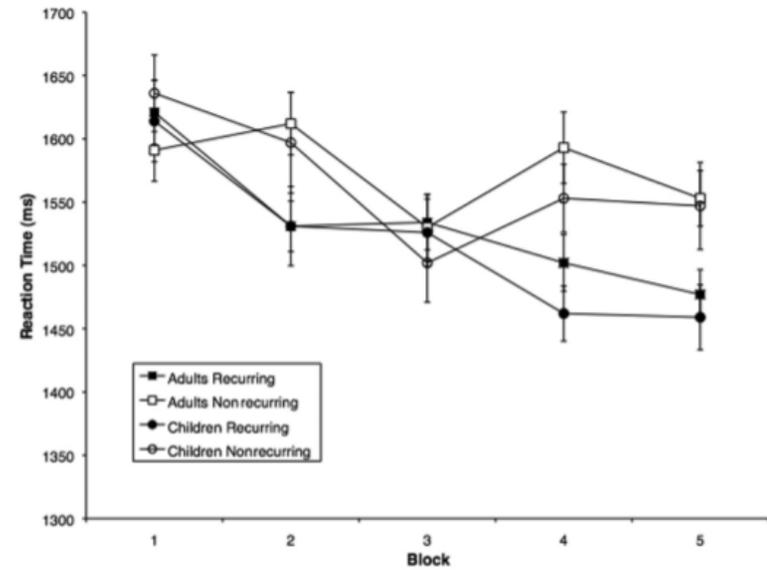
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Figure 1



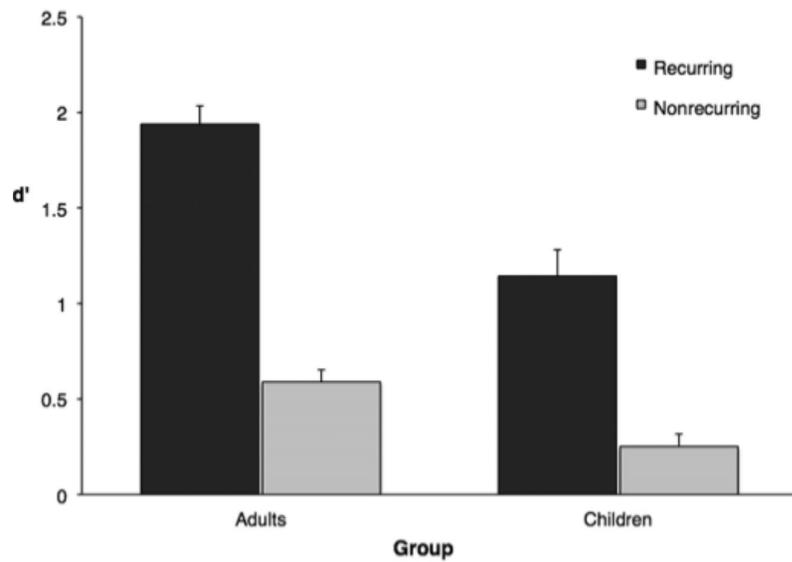
Proportion of correct repetitions by children and adults in the first and fifth stimulus blocks. The error bars are standard errors of the mean. Adapted from Service et al. (2014)

Figure 2



Latency of onset of repetition response from onset of model Korean word for recurring and nonrecurring words in adults and children as a function of stimulus block. Adapted from Service et al. (2014)

Figure 3



Recognition performance (d-prime) for recurring and nonrecurring words by adults and children.

Adapted from Service et al. (2014)