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6 Age effects in L2 learning: comparing child and adult learners' performance on tests of implicit and explicit memory

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Abstract

In this chapter, we first review several cognitive explanations for age effects in second (L2) language learning, particularly those that relate to different aspects of human memory. We then report the results of a study that compares the performance of age-matched groups of children and adults (native speakers and L2 learners) on explicit and implicit tests of memory of English words read under two conditions (story vs. list). Overall, the obtained findings showed no essential differences in memory performance between 11–13-year-old children and 17–26-year-old adults learning English as their L2. More strikingly, the L2 learners' performance on tests of explicit and implicit memory was very similar to the performance of age-matched native English-speaking children and adults. We discuss contributions of explicit and implicit memory to child–adult differences in L2 learning.

For over half a century, the field of language acquisition has grappled with the "sensitive-periods controversy" (Long, 2007, p. 43). Penfield and Roberts (1959) were among the first to propose that in order for a child to learn a language to nativelike mastery, exposure to a language must occur within a certain developmental "window," described as a critical or a sensitive period. This idea was later taken up by Lenneberg (1967), who speculated that a critical period for language, which was biologically determined through brain maturation, ended around the age of puberty. The critical/sensitive period for language learning, of the kind

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proposed by Lenneberg, thus involves a certain biologically determined period of sensitivity to language followed by a decline in the capacity to learn it (see Bornstein, 1987, for more on critical/sensitive periods).

A wealth of evidence has been amassed in both first (L1) and second (L2) language literature to support the basic assumption underlying the notion of a critical/sensitive period – that learning a language beyond early childhood appears to result in often incomplete, non-nativelike mastery of the language. For instance, cases of L1 deprivation in early childhood due to severe abuse or profound hearing loss, such as Genie and Chelsea (e.g., Curtiss, 1977, 1988), and patterns of sign language learning by deaf individuals (e.g., Newport, 1988) point to the conclusion that full acquisition of some L1 skills (particularly, grammar) is especially hard, if not impossible, beyond early childhood. Similarly, there is ample evidence in L2 literature that children, while often initially slower at L2 learning, eventually outperform adults on a variety of language tasks, and that even the most successful adult learners are seldom fully nativelike in their L2 (e.g., Long, 2007).

At the heart of the sensitive-periods controversy is whether L2 "age effects" are determined by a biologically driven critical/sensitive period or instead arise as a consequence of other factors. Some researchers, like Lenneberg, support the notion of a biologically determined critical/sensitive period for L2 learning. For example, Pulvermüller and Schumann (1994) attribute older children's and adults' diminishing ability to learn an L2 to a gradual decline in neuronal plasticity in specific areas of the brain (for discussion of other neurobiological processes linked to language development, see Jacobs, 1988; Neville, Mills, & Lawson, 1992). Others, however, refute the existence of a biologically determined critical/sensitive period, instead linking age effects to a variety of social-educational factors (e.g., Jia & Aaronson, 2003; Flege, Yeni-Komshian, & Liu, 1999; Moyer, 1999) or cognitive variables (e.g., Hakuta, Bialystok, & Wiley, 2003). Still others, for example, hypothesize that age effects arise as a consequence of the act of prior learning itself, and are not necessarily due to age-bound neurobiological limitations alone. According to this view, older learners' difficulties in L2 learning may be traceable to age-based developmental processes that render speech perception and production more specialized for the processing of L1 input (Bever, 1981), or to a loss of perceptual sensitivities due to older learners' extensive prior experience with their L1 (McCandliss *et al.*, 2002).

An examination of the literature on child–adult differences in L2 learning reveals a number of plausible interpretations of age effects, including those with neurobiological, linguistic, social, attitudinal, experiential, and cognitive underpinnings. It may not be possible, therefore, to give full justice to the complexity of the issue in the confines of a brief chapter (for reviews, see Birdsong, 2009; DeKeyser, 2012; DeKeyser & Larson-Hall, 2005; Montrul, 2008; Muñoz, 2006). Instead, in keeping with the overall focus of the present volume, our goal is to discuss possible contributions of *memory* to age effects in L2 learning. To attain this objective, we first review several cognitive explanations for age effects, particularly those that relate to different aspects of human memory. We then report the results of a study that compares the performance of age-matched groups of children (L1 and L2) and adults (L1 and L2) on explicit and implicit tests of memory of English words read under two conditions. We conclude by discussing contributions of explicit and implicit memory to child–adult differences in L2 learning.

Cognitive and memory-based explanations of age effects

One cognitive explanation of L2 age effects relates to differential involvement of cognitive processing mechanisms in childhood and adulthood due to general ageing (Bialystok & Hakuta, 1999; Hakuta *et al.*, 2003). The assumption underlying this view is that such cognitive functions as memory, attention, speed of processing, and various kinds of cognitive control (e.g., ability to shift between tasks or choose between two competing response sets) deteriorate across the lifespan of an individual as part of general age-bound cognitive decline (Craik & Bialystok, 2008). The proponents of this position cite evidence from a number of studies, including analyses of large-scale census data (Chiswick & Miller, 2008; Hakuta *et al.*, 2003), which indicate that the ability to learn an L2 declines steadily across the lifespan, without the abrupt discontinuities typical of a critical/sensitive period (see Stevens, 2004, for criticisms). Although the claim that general cognitive ageing is responsible for the decline of L2 learning ability across the lifespan is certainly very appealing, there is currently little direct evidence suggesting that differences in cognitive abilities between younger children, older children, and adults determine their eventual L2 learning outcomes.

Another cognitive explanation for age effects invokes quantitative differences in children's and adults' cognitive processing capacity. Known as the "less is more" hypothesis (Newport, 1990), this view holds that children's usually smaller cognitive processing capacity, as compared to that of adults, can actually aid children in L2 learning. According to this hypothesis, children, precisely because they have a narrow processing "window," are able to pay attention to smaller units of language available in the input, to extract relevant information from this input, and to use this information to aid subsequent language processing. By contrast, adults are worse at doing so because their fully developed processing capacity encourages them to process language input holistically, often missing critical form–meaning relationships (Elman, 1993; Kareev, Lieberman, & Lev, 1997; Kersten & Earles, 2001, but see Rohde & Plaut, 1999). In support of this explanation of age effects, Cochran, McDonald, and Parault (1999), for example, showed that adults who were taught some expressions in American Sign Language while performing a concurrent task that limited their processing capacity were better able to apply the learned grammatical patterns to novel contexts than those who were exposed to such expressions without a concurrent task. Although results like these are certainly intriguing, again, there is currently no direct evidence linking younger children's processing limitations to their eventual L2 success.

Another memory-based account of age effects in L2 learning concerns child–adult differences in the involvement of procedural and declarative memory. Ullman (2001, 2005) proposed that the processing and learning of the L1 is subserved by two memory systems: declarative memory responsible for the learning of form–meaning relationships stored in the lexicon and procedural memory responsible for the learning of grammar (see also Paradis, 2009). According to Ullman, the information stored in declarative memory is generally explicit (open to conscious awareness), whereas procedural memory is responsible for implicit learning (learning without awareness). Ullman hypothesized that L2 age effects reflect a diminished role of procedural memory in L2 learning by adults. In other words, the learning associated with the procedural memory system is sensitive to critical-period effects, but declarative memory stays relatively constant (and in fact appears to improve) throughout development. As a result, adult learners tend to rely on the declarative memory system in learning most aspects of the L2, including those that are normally learned through this memory system (lexicon) and those that are typically learned procedurally (grammar).

There are several studies that have provided some (albeit indirect) evidence that differential involvement of declarative and procedural memory in child versus adult L2 learning is linked to learners' L2 attainment. Harley and Hart (1997) showed that a measure of analytical ability (from Pimsleur's Language Aptitude Battery) was the only significant

predictor of L2 proficiency for learners who started L2 instruction in grade 7. In a similar vein, DeKeyser (2000) reported a non-significant correlation between a measure of grammatical sensitivity (based on the Words in Sentences subtest of Carroll and Sapon's Modern Language Aptitude Test) and grammaticality judgment scores for early L2 learners but a significant association between these two measures for late L2 learners (for similar evidence, see Abrahamsson & Hyltenstam, 2008; DeKeyser, Alfi-Shabtay, & Ravid, 2010). If analytical ability and grammatical sensitivity (i.e., the capacity to recognize the grammatical functions of words in sentences) are interpreted as being related to declarative/explicit memory functions, then one interpretation of these findings is that adolescent and adult L2 learners mostly rely on analytical (i.e., declarative/explicit) learning mechanisms, whereas children have access to procedural (implicit) learning mechanisms (DeKeyser, 2000; DeKeyser & Larson-Hall, 2005). In fact, based on this evidence, DeKeyser (2012) recently suggested that the core questions to guide current and future research on L2 age effects are "whether there is a specific period of decline in the ability for *implicit* language learning, and whether any such decline is due to maturational factors" (p. 446, emphasis added). Because implicit memory underlies at least some aspects of implicit learning (Buchner & Wippich, 1998; Kihlstrom, Dorfman, & Park, 2007), an important goal of future research is to clarify the roles of implicit and explicit memory in L2 learning.

Explicit and implicit memory in L1 processing and learning

Before addressing the issue of child–adult differences in the involvement of explicit and implicit memory in L2 learning, it is first important to understand how explicit memory is different from implicit memory and how both kinds of memory are involved in child and adult L1 processing and learning. According to Schacter (1992), explicit memory refers to "intentional or conscious recollection of prior experiences" while implicit memory describes "changes in performance or behavior that are produced by prior experience on tests that do not require any intentional or conscious recollection" (p. 244). Explicit memory is typically measured using "traditional" memory tasks (e.g., recall, recognition) which involve asking participants overtly to remember previously encountered information, such as words, objects, and events. Implicit memory, on the other hand, is frequently assessed using tasks that make no overt link to a previous experience. When performing such tasks (e.g., identifying degraded words or completing word stems, such as completing *ele__* with *elephant* or *elevator*) participants do not realize that their memories for prior events are being accessed, yet their performance on implicit tasks is affected by these memories.

Current L1 literature shows clear dissociations between participants' performance on tests of explicit and implicit memory. The first dissociation between explicit and implicit memory is experimental, most clearly seen within the transfer-appropriate processing (TAP) framework of memory. Originating in experimental observations by Morris, Bransford, and Franks (1977), the TAP framework postulates that human memory performance is determined by the nature of the processing operations involved in learning and subsequent testing episodes (Roediger & McDermott, 1993). In essence, memory performance is best when the processing operations involved in learning are reinstated at test (e.g., asking a participant to memorize a list of words in Phase 1 and explicitly recall them in Phase 2). When viewed within the TAP framework, memory tests are discussed with respect to the processing operations which they incur. Two kinds of processing operations are usually targeted in TAP: conceptual processing, which includes a focus on meaningful, semantic information (e.g., appropriateness of a word to a sentence frame), and perceptual processing, which involves analysis of surface-level, form-related information (e.g., type of print, rhyming of words, or loudness of the speech signal).

The typical experimental dissociation between explicit and implicit memory is related to the extent to which a memory test draws on conceptual and/or perceptual processing. Explicit tests of memory (such as recall and recognition) primarily involve conceptual processing, and are thus more influenced by conceptual than perceptual processing at the time of learning. The reverse is true for implicit tests of memory (such as identification and word-stem completion) because these tests primarily involve perceptual processing. Therefore, results on these tests are more influenced by perceptual than conceptual processing at the time of learning. Thus, for example, emphasizing semantic relationships among individual words in a word learning task, as opposed to their orthographic or phonological relationships, should have a greater impact on explicit recall. In contrast, emphasizing orthographic or phonological relationships among individual words, as opposed to focusing on their semantic relationships, should have a greater impact on implicit word-stem completion. This experimental dissociation between explicit and implicit memory has been documented for both L1 adults (Roediger & McDermott, 1993) and L1 children (McFarland, Duncan, & Bruno, 1983).

The second dissociation between explicit and implicit memory is developmental. Performance on explicit memory tests tends to improve from childhood to early adulthood (e.g., Komatsu, Naito, & Fuke, 1996; Perez, Peynircioğlu, & Blaxton, 1998), probably as a result of greater use of recall strategies, increasing knowledge base, and the development of meta-memory in older children (Pressley & Schneider, 1997). After reaching a certain level in early adulthood, performance on explicit memory tests then tends to decline gradually in late adulthood, possibly as part of general cognitive ageing (Light & Singh, 1987). In contrast, performance on implicit memory tests tends to stay constant throughout an individual's lifespan, from early childhood to late adulthood (Komatsu *et al.*, 1996; Perez *et al.*, 1998).

The current study

One conclusion to be drawn from the review of existing literature on L2 age effects is that there is an increased interest in cognitive, memory-based explanations for child–adult differences in L2 learning. However, what is largely missing from this literature are direct comparisons of child and adult L2 learners' performance on different memory tasks, including tests of explicit and implicit memory. Such comparisons have the potential not only to establish that there are differences in the involvement of explicit and implicit memory in L2 learning, but also to eventually help link such differences to patterns of children's and adults' ultimate L2 attainment. As a first step in accomplishing this goal, the current study compared the performance of native English children and adults as well as native French child and adult learners of English on tests of surprise recall (an explicit memory task) and word-stem completion (an implicit memory task).

Our first objective was to test for an experimental dissociation between explicit and implicit memory, based on the principles of the TAP framework. To address this objective, all participants were tested on explicit and implicit memory tasks following two learning conditions: reading words in context (as part of a story) and in isolation (in a word list). If explicit and implicit memory are dissociable based on an experimental processing manipulation (reading words in context vs. in isolation), then we would expect better performance on explicit recall in the context condition than in the isolation condition, and better performance on implicit stem completion in the isolation condition than in the context condition. Both predictions are based on the TAP principles, namely, that experience with words in context (increased conceptual processing) should have a greater impact on explicit recall, whereas experience with words in isolation (increased perceptual processing) should have a greater impact on implicit stem completion. Our main interest here was to determine whether there would be any difference in the performance of L2 children and adults, as compared to the performance of age-matched L1 children and adults, which would speak to potential differences in the involvement of explicit and implicit memory in L2 learning.

Our second objective was to test for a developmental dissociation between explicit and implicit memory. If explicit and implicit memory are dissociable based on participants' age, then we would expect adults to outperform children on explicit recall, and both children and adults to perform similarly on implicit stem completion. These predictions are based on previous developmental work on explicit and implicit memory suggesting that performance on tests of explicit memory should improve with age but that performance on tests of implicit memory should remain stable. Again, our main concern here was to document any similarities or differences in the performance of L2 children and adults, especially in relation to the performance of age-matched L1 children and adults, which would reveal potential differences in the involvement of explicit and implicit memory in L2 learning.

Method

Participants A total of 88 children and adults were recruited from the Montreal area. They included 45 native English speakers and 43 native French speakers. The samples of English and French participants were further subdivided into two groups according to their age. The two groups of native English speakers consisted of 21 children (15 girls, 6 boys) between the ages of 10 and 13 ($M = 11.2$, $SD = 1.0$) and 24 young adults (12 women, 12 men) between the ages of 18 and 35 ($M = 23.1$, $SD = 4.2$). All children came from monolingual English homes located in predominantly English-speaking areas of Montreal and attended English-medium schools. All young adults were undergraduate students at an English-speaking university. Although most native English speakers reported some experience with French (Quebec is a French-speaking province of Canada), they represented the population of language speakers who learned English as their first language and spoke it natively.

The two groups of native French speakers included 20 children (5 girls, 15 boys) between the ages of 11 and 13 ($M = 11.8$, $SD = 0.7$) and 23 young adults (14 women, 9 men) between the ages of 17 and 26

($M = 19.7$, $SD = 2.3$).[1] These participants had been exposed to French since birth and had been raised in monolingual French homes. At the time of the study, all the children were attending a secondary school in French and learning English as part of regular L2 instruction. Using a 9-point scale (1 = *extremely poor*, 9 = *extremely fluent*), the children self-rated their proficiency in French ($M = 8.0$, $SD = 0.7$) higher than in English ($M = 5.6$, $SD = 1.2$). They also estimated that they used French on average 88 percent ($SD = 8.5$) and English about 16 percent ($SD = 6.3$) of the time daily. Similarly, all the adults were enrolled in a French-medium junior college and attended English courses as part of L2 instruction. They also self-rated their proficiency in French ($M = 8.6$, $SD = 0.5$) higher than in English ($M = 7.0$, $SD = 0.8$), and estimated their daily use of French and English at a mean of 84 percent ($SD = 15.8$) and 27 percent ($SD = 16.2$), respectively.

Because the participants differed in their experiences with English and were likely to vary in their English proficiency, the reading subtest of the Wide Range Achievement Test (WRAT-3, Wilkinson, 1993) was administered to estimate the participants' English reading ability and to ensure that the English children and the French participants possessed the skills necessary to complete the reading tasks successfully. The reading subtest consists of 42 individual words of increasing difficulty that participants are asked to read aloud. The reading scores (summarized in Table 6.1) were submitted to a 2 × 2 (age × native language) analysis of variance (ANOVA), which yielded a significant main effect of age, $F(1, 84) = 53.87$, $p < 0.0001$, a significant main effect of language, $F(1, 84) = 17.58$, $p < 0.0001$, and a significant two-way interaction, $F(1, 84) = 34.20$, $p < 0.0001$. Pairwise comparisons carried out to explore the significant interaction revealed that the English adults scored significantly higher than the remaining three groups ($p < 0.0001$), and that these three groups did not differ in their reading ability ($p > 0.05$). These findings showed that all participant groups demonstrated a reasonable level of reading ability in English but that there were developmental differences in reading ability between the participant groups.[2]

[1] Unfortunately, the sample in the current study made it impossible to match the English and French speakers by gender across the two age groups. While we suspect that this had little effect on our results, future studies should attempt to, as far as possible, match English and French speakers for gender so that any differences could be attributed to their language status with greater confidence.

[2] Although at first glance it may appear counterintuitive that the French children would demonstrate comparable reading ability to the English children, this finding is likely to be specific to the reading task used here. Easy words featured on the WRAT-3 reading ability subtest (e.g., *animal*, *felt*, *finger*, *tree*) were probably easy for both L1 and

Table 6.1 *Mean reading ability (WRAT-3) and working memory (WJ-III) scores for the four participant groups (standard deviations in parentheses)*

Group	Reading ability (WRAT-3)	Working memory (WJ-III)
English children	25.16 (3.61)	13.90 (2.72)
English adults	35.75 (3.63)	21.00 (4.44)
French children	25.85 (4.64)	15.05 (2.52)
French adults	27.13 (3.56)	17.61 (3.27)

In addition to a test of reading ability, the numbers-reversed test from the Woodcock Johnson III Tests of Cognitive Abilities (WJ-III, Woodcock, McGrew, & Mather, 2001) was administered to all participants in their L1 in order to estimate possible differences in working-memory capacity. This test requires participants to hold increasingly difficult sequences of numbers in their short-term memory (for up to 8 digits in total) while attempting to reverse the original number sequence. The working memory scores (summarized for each group in Table 6.1) were submitted to a similar 2 × 2 ANOVA that yielded a significant main effect of age, $F(1, 84) = 44.70$, $p < 0.0001$, and a significant two-way interaction, $F(1, 84) = 9.87$, $p = 0.002$, with no significant main effect of native language, $F(1, 84) = 2.42$, $p = 0.12$. Pairwise comparisons revealed that the English adults scored significantly higher than the French adults, $t(45) = 2.97$, $p = 0.005$, and that both adult groups scored significantly higher than both groups of children ($p < 0.007$), which did not differ from each other ($p > 0.05$). These findings overall showed age- and language-based differences in working memory capacity between participant groups. The implications of these findings are discussed below in relation to the main findings.

Materials All participants were exposed to target words in two experimental reading conditions: in context and in isolation. To achieve this, a total of 40 target words (e.g., *child, heart, minute, scare, sticks, whistle, tiptoe*) were selected from existing materials described in Martin-Chang and Levy (2005) and organized into four mutually

L2 children, whereas hard words (e.g., *discretionary, egregious, omniscient, disingenuous*) were equally hard for both groups.

exclusive sets of 10 target words. The four sets were matched for mean word length (5.7, 6.1, 5.9, and 5.8 characters) and mean word frequency (3.6, 3.6, 3.2, and 3.5 log-based frequency per million), as estimated through the $SUBTLEX_{US}$ corpus of spoken American English (Brysbaert & New, 2009). For the context condition, the first two sets were separately embedded into one short story (*First Class*), resulting in two versions of the same story. The remaining two sets were integrated into another short story (*Halloween*), similarly yielding two story versions. Within a story, each target word was repeated twice, for a total of 20 (2 × 10) target word exposures. The stories ranged between 558 and 582 words in length and between grade 3.6 and grade 4.1 level of reading difficulty for native speakers of English (as analyzed by the Flesch-Kincaid formula). For the isolation condition, the ten target words in each set were shown twice, presented one at a time in random order on a computer screen and read aloud.

In order to measure the involvement of explicit and implicit memory, a surprise explicit recall test and an implicit word-stem completion test were included in this study. The explicit recall task required participants to recall verbally as many of the target words as possible. Verbal recall was deemed more appropriate than written recall considering that English-speaking children and all French-speaking participants were likely to have had less experience with writing in English, which might have inadvertently hindered their performance on this task. Verbal recall also ensured that the participants did not receive additional orthographic exposure to any target words outside of the contextual and isolated reading conditions.

The word-stem completion task is an implicit memory task that requires participants to quickly generate a response based on the first letters of a word (the stem). None of the target words began with a prefix, and each stem could potentially be completed with a number of words, including single- and multi-morphemic words. The task included a total of 30 stems, 20 of which were derived from the target words presented in context and in isolation (i.e., words that were read aloud by the participant) as well as an additional 10 stems from a "control" set of target words (i.e., words that were not seen by participants). Similar to previous studies (Martin-Chang & Levesque, 2011), word stems included the first three letters of the target words (e.g., *tea__* for *teacher*). The order of the reading conditions (context-isolation, isolation-context) was counterbalanced across participants, and the four target sets appeared equally often in the context, isolation, and control conditions.

Procedure Individual testing was carried out by trained experimenters in a quiet room at the participants' school/university or at an alternative location, such as their home or the home of a friend. The entire testing session lasted approximately 25 minutes. Without divulging the memory component of the study, the participants were informed that the general purpose of the investigation was to understand how children learn to read. However, in order to acknowledge the perceived simplicity of the tasks, the participants were also told that their participation would assist in establishing a baseline score for comparison purposes. All participants were asked to direct their full attention to the activities and perform to the best of their abilities. The tasks occurred in the following order: WRAT-3 reading test, exposure conditions (context and isolation), surprise explicit recall, numbers reversed, implicit word-stem completion, and (for all French-speaking participants) vocabulary knowledge test.

For the WRAT-3 reading test, the participants were presented with 42 words of increasing difficulty and asked to read the words aloud, from left to right down the page, to the best of their ability. The testing sessions were not audio recorded. During the task, the experimenter recorded the participants' answers on a separate score sheet and provided no feedback as to the accuracy of their responses. The task ended when participants read ten consecutive items incorrectly or read all the words on the page. For consistency in scoring, each experimenter was trained with regard to the correct pronunciation of the words (e.g., *terpsichorean*). In order to reduce scoring bias against the French participants, each experimenter was also instructed to disregard phonological substitutions commonly found in French-accented English speech (e.g., production of /ð/ as /d/, /h/ deletion and epenthesis). For scoring purposes, one point was given for every word read correctly; in order to be awarded a point, it was required that the entire word was read accurately in accordance with the word's conventional pronunciation.

Next, the participants were exposed to a total of 20 target words through two experimental conditions: in context and in isolation. Words presented in context were read within a short story. A shared reading procedure was employed whereby the experimenter read the majority of the story and the participants read only the 20 words (10 targets × 2 exposures). The participants were asked to follow along with their finger as the reading took place. This was done to replicate the procedure typically followed with children. In addition, this procedure prevented the participants from fixating on the target words for an extended period of time. Paying attention to the story was further stressed as the participants were informed that they would be asked comprehension questions following the completion of the passage. One yes–no question was asked orally after the story had been read; this question did not contain any target words. The stories were typed in Times New Roman size 14 font and printed on 8½ × 11 white paper. All target words were bolded and underlined to make them noticeable from the surrounding print.

Words read in isolation were presented individually at the center of a computer screen. The participants were asked to read the words aloud to the best of their ability as they appeared on the screen. Before seeing the actual target words, the participants were shown two examples (*dog, bird*) to familiarize them with the procedure. The target words, written in Times New Roman size 66 font and displayed at the center of the screen, were presented twice in random order, resulting in 20 (2 × 10) exposures. Each target word appeared on the screen for a total of 2 seconds, followed by a 2 seconds delay during which a fixation point was displayed in the middle of the screen. On the rare occasion that a target word was read incorrectly, the experimenter promptly provided the correct pronunciation. The participants successfully incorporated the experimenter's feedback and corrected their responses on the subsequent encounter with a misread target word. Reading accuracy was thus at ceiling during the second target word exposure in both conditions for all participant groups.

Immediately following both exposure conditions, a surprise explicit memory task was administered. The participants were asked to recall verbally as many of the target words as possible from those that were read previously in a story and in a list. They were also informed that this task was not subject to a time limit and that no penalty would be incurred for incorrect guesses. Upon completing the task, the participants were asked if they had been aware of the study's memory component or otherwise had known to remember the target words that were being read. The answer to these questions was "no" for all participants.

Next, the participants completed the WJ-III numbers-reversed test (Woodcock *et al.*, 2001). The experimenter read aloud a string of numbers of increasing length (e.g., *2...8...4*) at the rate of approximately one digit per second, and the participants were asked to repeat them aloud in reverse order (e.g., *4...8...2*). The participants were provided with two examples before beginning the task. The test continued until the three highest-numbered items in a group were answered incorrectly. A total score was then calculated by summing all correct responses.

The native French speakers (children and adults) performed this task in French to obtain an estimate of working memory capacity that was independent of L2 skill.

Following the working memory task, the implicit word-stem completion test was administered. In this test, the participants saw 30 word stems presented individually in random order for a period of 10 s each. The stems were written in Times New Roman size 66 font and were shown in the middle of a computer screen. The participants were asked to complete each stem with as many words as possible during the allotted 10 s period. They were informed that the stems varied in level of difficulty, but that each item could potentially be answered with multiple correct responses, except names of people or places. Two sample items (*not__* and *lan__*) along with several possible answers (e.g., *nothing, notebook*; *language, land*) were provided with the instructions to the task. Participants generated their answers orally while the experimenter recorded them verbatim on a separate score sheet.

Finally, at the end of the testing session, the native French speakers completed a word knowledge test in order to determine whether they were familiar with the target words. The participants were asked to translate each target English word into French or to leave the response blank if the word was unknown. This task was self-paced, and the participants were given a simple example (mother–*mère*) before starting the test.

Data analysis

The primary measures in this study were proportion of target words recalled in the explicit recall task and the proportion of target word stems completed in the implicit word-stem completion task. These measures were calculated separately in each encoding condition (context vs. isolation). In the recall task, the scores were computed by summing the number of target words remembered correctly from each exposure condition. In the word-stem completion task, the scores were computed by summing all responses for stems completed correctly with a previously read target word. Notably, although participants generated several words for each stem during the allotted time, targets were only scored as correct if they were generated as the first response. Additional scoring criteria were identical in both tasks. Singular–plural differences with nouns (e.g., target *sticks* = response *stick*) were accepted as correct responses. However, inflected and derived forms and other non-exact matches between the targets and the responses were considered wrong (e.g., target *broke* ≠ response *broken*; target *realize* ≠ response *realization*).

This strict criterion was adopted in order to ensure consistent scoring procedures across conditions.

The final proportion scores were derived by dividing the summed scores by the total number of target words in each condition. Because the native French speakers may not have known some target words prior to the experiment, the total number of target words for each native French participant was adjusted by excluding previously unknown words (as revealed through the word knowledge test). Unknown words (those that were translated into French incorrectly or not translated at all) accounted for about six words per child ($SD = 4.9$) and about two words per adult ($SD = 2.2$), out of a total of 40 target words.

Results

For all statistical tests, the alpha level for significance was set at 0.05. All correlations were based on two-tailed distributions.

Explicit recall Before examining the relationship between the participants' age and their performance on the explicit recall task, we first compared the rate of false recall (i.e., words that the participants mistakenly recalled as having been encountered earlier) between the four participant groups. The goal of this analysis was to ensure that the participants had not demonstrated any obvious biases in recalling words encountered in context and in isolation. In the context condition, false recall rates ranged between a mean of 0.7 and 1.2 words. In the isolation condition, false recall rates were comparable, the means ranging between 0.4 and 1.3 words. The number of falsely recalled words for each participant was submitted to a mixed three-way ANOVA with age (child, adult) and native language (English, French) as between-subject factors and exposure condition (context, isolation) as a within-subject factor. This ANOVA yielded no significant main effects or interactions, $F(1, 84) < 2.78$, $p > 0.10$, suggesting that no participant group demonstrated any obvious bias in recalling non-target words from the two exposure conditions.

In the following analysis, we compared the proportion of the target words correctly recalled by the four participant groups. For this analysis, we submitted the participants' recall scores to a similar three-way ANOVA, which yielded a significant main effect of exposure condition, $F(1, 84) = 7.13$, $p = 0.009$, and a marginally significant main effect of age, $F(1, 84) = 3.23$, $p = 0.07$, with no other significant main effects or interactions ($p > 0.05$). This pattern of findings suggested that all participants, regardless of their L1 or age, recalled more words previously

Table 6.2 *Mean proportion of explicit recall for the four participant groups as a function of exposure condition (standard deviations in parentheses)*

Group	Exposure condition	
	Context	Isolation
English children	0.26 (0.15)	0.37 (.013)
English adults	0.34 (0.18)	0.42 (0.21)
French children	0.35 (0.12)	0.37 (0.21)
French adults	0.36 (0.16)	0.43 (0.19)

read in isolation than in context, and that overall there was a marginally significant trend for adults to recall more words than for children. Mean proportions of explicit recall are shown in Table 6.2 and the obtained pattern of findings is depicted graphically in Figure 6.1.

The next analysis sought to determine whether there was a relationship between the participants' explicit recall and their reading ability (as measured through the WRAT-3 reading ability subtest) and their working memory capacity (as measured through the WJ-III numbers-reversed task). To accomplish this, we computed Pearson correlation coefficients between the participants' recall scores (separately for each exposure condition) and their reading ability and working memory scores. These analyses yielded no significant relationships either for the entire sample of participants or for subsets of participants grouped by age and native language ($p > 0.05$). This finding suggested that the participants' explicit recall was not significantly related to their reading ability or their working memory capacity.

Implicit word stem completion Previous research has demonstrated that comparing participants' performance between several treatment conditions on implicit memory tests may depend, at least in part, on having comparable baseline performance rates (Chapman *et al.*, 1994). A baseline performance rate refers here to response rates for "control" materials (i.e., words not previously read by participants in context or isolation). Therefore, in the first analysis, we compared the word-stem completion rates for control words between the four participant groups. Proportions of completed word stems for control words were uniform across the groups of participants and ranged between a mean of 0.19 and one of 0.21. These rates were submitted

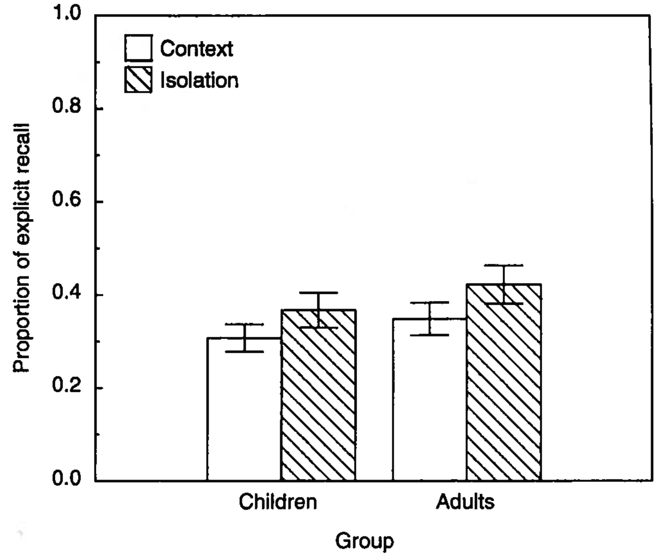

Figure 6.1 Proportion of explicit recall for the combined groups of native English and French children and native English and French adults as a function of exposure condition (context vs. isolation)

to a 2 × 2 (age × native language) ANOVA that yielded no significant main effects or interaction, $F(1, 84) < 0.26$, $p > 0.61$, suggesting that baseline performance rates were statistically comparable. It appears, then, that the participants were equally likely to complete word stems for previously unread words, regardless of their age or native language.

In the next analysis, we compared the proportion of stems completed correctly with a previously read target word. We submitted the participants' stem completion scores to a mixed three-way ANOVA with age (child, adult) and native language (English, French) as between-subject factors and exposure condition (context, isolation) as a within-subject factor. This ANOVA yielded a significant main effect of exposure condition, $F(1, 84) = 36.50$, $p < 0.0001$, and a significant main effect of native language, $F(1, 84) = 17.59$, $p < 0.0001$, with no other significant main effects or interactions ($p > 0.05$). This pattern of findings suggested that all participants, regardless of their native language or age, responded with more words previously read in isolation than in context, a finding that was identical to the memory performance on the explicit recall task. These results also indicated that overall, the native French participants completed more word stems correctly (regardless of the

Table 6.3 *Mean proportion of implicit word-stem completion for the four participant groups as a function of exposure condition (standard deviations in parentheses)*

Group	Exposure condition	
	Context	Isolation
English children	0.30 (0.11)	0.44 (0.15)
English adults	0.33 (0.14)	0.45 (0.17)
French children	0.44 (0.15)	0.57 (0.20)
French adults	0.43 (0.18)	0.53 (0.14)

exposure condition) than the native English participants did. Mean proportions of implicit word-stem completion are shown in Table 6.3, and the obtained pattern of findings is depicted graphically in Figure 6.2.

In the final analysis, we examined whether the participants' word-stem completion was related to their reading ability and their working-memory capacity. As in the previous analysis of explicit recall scores, we computed Pearson correlation coefficients between the participants' word-stem completion scores (separately for each exposure condition) and their reading ability and working memory scores. These analyses revealed a moderate negative association between implicit memory performance in the isolation condition and reading ability, but only for the group of native English adults, $r(23) = -0.54$, $p = 0.007$. This finding suggested that those native English adults who showed higher reading ability on the WRAT-3 reading subtest were also those who demonstrated lower word-stem completion rates on the implicit memory task in the isolation condition.

Discussion

The main goal of the study was to provide direct comparisons of child and adult L2 learners' performance on tests of explicit and implicit memory, in order to investigate the involvement of explicit and implicit memory in L2 processing. Overall, the obtained findings showed no essential differences in memory performance between 11–13-year-old children and 17–26-year-old adults learning English as their L2. More strikingly, the L2 learners' performance on tests of explicit and implicit memory was very similar to the performance of age-matched native English-speaking children and adults.

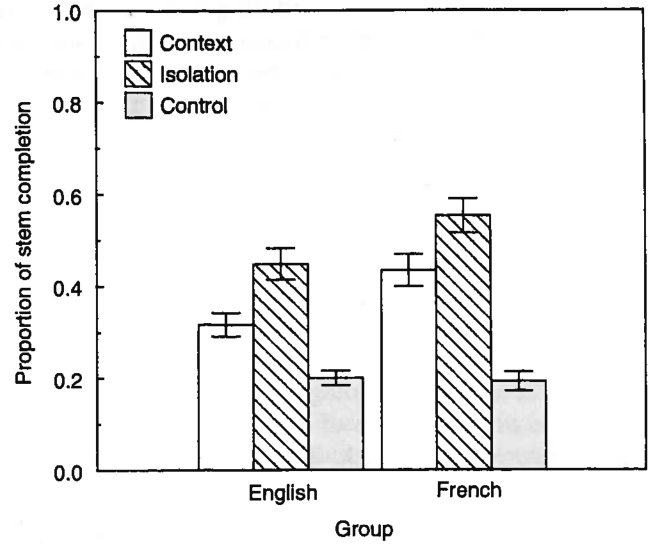

Figure 6.2 Proportion of implicit word-stem completion for the combined groups of native English children and adults and native French children and adults as a function of exposure condition (context vs. isolation vs. control)

Experimental dissociation between explicit and implicit memory

The first objective of this study was to investigate the experimental dissociation between explicit and implicit memory. Our findings provide partial support for a TAP account of memory for words read in different contexts. In line with our predictions, words read in isolation were used more frequently to complete word stems than words read in stories. This suggests that words read in isolation may activate more perceptual processes than words read in meaningful contexts. However, in contrast to our expectations, reading words in isolation (cf. Figures 6.1 and 6.2) also enhanced explicit recall. The superior recall of "list" items is at odds with the large body of literature showing that words read in isolation are disadvantaged on tests of explicit memory in comparison to words read in other kinds of meaningful contexts, such as antonym pairs, passages, scrambled, and coherent texts (e.g., Martin-Chang & Levesque, 2011; Masson & MacLeod, 2000). This finding raises the question of why the words read in context were remembered more poorly than the words read in isolation.

One plausible explanation for this finding is that some participants (e.g., children or L2 learners) were less sensitive than others to contextual information that determines the strength of explicit recall (Lorsbach & Reimer, 2008). However, the findings from the recall task were robust and held regardless of the participants' age and L1 status. Another possibility is that poor readers or readers with smaller working memory, compared to good readers or readers with larger memory capacity, adopted a single-word focus during reading (Faulkner & Levy, 1999), which interfered with contextual processing of stories. However, this explanation is contradicted by the results of the correlational analyses, which revealed no association between the participants' recall performance and their reading ability or working memory capacity.

There are also several methodological explanations for this finding. It is likely that the precise nature of contextual reading influenced the results on the surprise recall task. The contextual reading condition in this study involved a shared reading procedure whereby the experimenter read the majority of the story and the participants read only the target words (which were bolded and underlined to make them stand out from the surrounding text). If the strength of explicit recall, at least in part, depends on the degree of contextual binding of words in context, then it is likely that the target words presented in stories were not processed in as much of a conceptually oriented manner as they could have been. For example, Masson and MacLeod (2000) argued that readers must be "capable of and oriented toward text comprehension" (p. 1096) for contextual binding to occur. In this study, however, the participants may have been listening to the stories with an increased focus on individual words, and their orientation toward the comprehension of the story as a whole may have been obstructed. Clearly, this possibility needs to be explored further by using contextual conditions that do not make target words highly distinctive or that involve participants reading entire stories.

Still another methodological explanation concerns the order of task elements in the experimental procedure. The target words were presented twice in each experimental condition and the surprise recall task occurred immediately (i.e., with no delay between exposure and explicit recall). Ongoing replication projects with L1 speakers have pointed toward a three-way (condition × recency × repetition) interaction, whereby words seen in isolation, more than once, immediately before the surprise recall task are advantaged during explicit recall. Therefore, it is possible that words seen immediately before recall task were still in the participants' short-term memory when they were asked to recall them. Although the target words were also read twice in the context condition, they were separated by large sections of text, which may be at least one reason why an equivalent boost in explicit memory was not observed when words were read in context before the recall task. This interesting possibility needs to be explored further before firm conclusions can be reached.

Developmental dissociation between explicit and implicit memory

The second objective of this study was to test for a developmental dissociation between explicit and implicit memory. Overall, our findings supported this dissociation. The results from the explicit recall task revealed a marginally significant trend for the adult participants to recall more words than the child participants, regardless of their L1. This finding adds to the extensive literature showing improvements in participants' performance on explicit tests of memory over time as a result of developmental changes in encoding and retrieval strategies (e.g., Pressley & Schneider, 1997). This finding is also in line with earlier findings reported by Levesque (2010), who used identical tasks with younger L1 children and found robust age effects for explicit memory, with a group of 7–9-year-old children performing more poorly than a group of young adults. On the other hand, the results from the implicit word-stem completion task revealed no differences in performance between children and adults, regardless of their L1, which is in agreement with the literature on developmental invariance of implicit memory (Komatsu *et al.*, 1996; Perez *et al.*, 1998). This finding supports the idea that a memory system beyond explicit awareness is available early in development and remains relatively stable across the lifespan.

One intriguing finding of this study was that, overall, the L2 participants showed superior performance compared to the L1 participants on the implicit word-stem completion task (see Figure 6.2). This result held regardless of the reading condition and the participants' age. At least one possible explanation for this finding is that L2 learners approached word reading as a potential word learning opportunity, relying mostly on orthographic (perceptual) information to encode L2 words. A similar strategy is used by young children who are faced with an unknown or difficult word: they will first attempt to decode it according to its perceptual (e.g., orthographic) configuration and only then will they rely on surrounding context (if available) to help resolve the decoding ambiguity (e.g., Nation & Snowling, 1998). It is possible that both L2 children and adults engaged in a predominantly perceptual (orthographic) processing of words in both conditions. Therefore, it is not surprising that such enhanced perceptual processing benefited the L2 participants on the word-stem completion task, a test driven by perceptual processing. The significant negative association between implicit memory performance in the isolation condition and reading ability obtained for the native English adults is compatible with this explanation. In a sense, only the native English adults with high reading ability possess the skill that allows them to read isolated words holistically without heavy reliance on perceptual, data-driven, orthographic decoding strategies. As a result of this decreased perceptual processing, these readers tend to perform more poorly on perceptually driven memory tasks than readers with a weaker reading ability.

Explicit and implicit memory and L2 age effects

The current study was conceptualized within a broader area of research on age effects in L2 learning and was motivated by an increased interest in cognitive, memory-based explanations for child–adult differences in L2 learning. The study's main aim was to test claims that child and adult L2 learners might differ in their performance on tests of explicit and implicit memory, which could provide at least one explanation for age effects in L2 learning. Essentially, claims such as these posit that child–adult differences in L2 learning arise due to a developmental shift from implicit to explicit learning processes, which result in children learning the L2 implicitly while adults engage in explicit learning (Bley-Vroman, 2009; DeKeyser, 2000, 2012). Contrary to these proposals, in this study we found little evidence that 11–13-year-old children and 17–26-year-old adults differ with respect to their performance on tests of explicit and implicit memory for L2 words. More importantly, there was no age-based decline in implicit memory performance; in fact, the L2 learners, compared to the L1 speakers, exhibited superior performance on the test of implicit memory. Taken together, these findings suggest that, at least in the context of this study, child and adult L2 learners' implicit memory performance with respect to L2 words is comparable and developmentally stable. These findings are also in full agreement with evidence that adult L2 learners demonstrate such implicit memory effects as auditory priming (enhanced processing of previously heard spoken L2 words) and syntactic priming (increased accuracy in production of previously used L2 structures), which are typically interpreted in terms of implicit learning (see McDonough & Trofimovich, 2008; Trofimovich & McDonough, 2011).

Of course, our findings cannot (and should not) be interpreted as unequivocally challenging the idea that differences in explicit and implicit learning underlie L2 age effects. First, while clearly relevant

to the constructs of explicit and implicit learning, explicit and implicit memory are concepts that are distinct from these constructs (Buchner & Wippich, 1998; Kihlstrom *et al.*, 2007). For instance, Shanks (2003) provides a "traditional" definition of implicit learning as "learning which takes place incidentally, in the absence of deliberate hypothesis-testing strategies, and which yields a knowledge base that is inaccessible to consciousness" (p. 11) and acknowledges that both claims central to this definition (minimal demands of attention and lack of awareness) are far from being settled in the research literature. Even less clear is how implicit memory, which is typically defined in relation to particular memory tasks (e.g., Schacter, 1992), relates to implicit learning (for a review of L2 implicit memory research, see DeKeyser, 2003; Ellis, 2005; Robinson, 2010).

It is also possible that a potential shift from reliance on implicit to reliance on explicit memory structures occurs in a different developmental time frame, not captured within this study, that such a shift is dependent on the context of learning (e.g., classroom vs. naturalistic), or that different aspects of the L2 (e.g., vocabulary vs. grammar or pronunciation) vary in the extent to which they are susceptible to such a shift (DeKeyser, 2003). Clearly, these issues need to be addressed in future research. Finally, the findings of the current study have little to say about the issue of ultimate L2 attainment, in the sense that it is unclear how similarities in L2 child and adult learners' performance on tests of explicit and implicit memory relate to their eventual success in L2 learning. Carefully designed cross-sectional research or, better yet, longitudinal studies, could eventually link children's and adults' memory performance to patterns of their ultimate L2 attainment. In the meantime, the quest for viable explanations of child–adult differences in L2 learning is still on, and cognitive explanations of such differences, including those based on different aspects of human memory function, provide appealing alternatives to a variety of neurobiological, experiential, linguistic, and social accounts of age-based differences in L2 learning.

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