Does Conceptual Implicit Memory Develop? The Role of Processing Demands

ELAINE S. BARRY
The Pennsylvania State University, Fayette—The Eberly Campus

ABSTRACT. The author investigated the importance of processing considerations within implicit memory in a developmental design. Second-graders (n = 87) and college students (n = 81) completed perceptual (word stem completion) and conceptual (category generation) implicit memory tests after studying target items either nonsemantically (read) or semantically (generated). In support of previous research, the author found no age differences in priming in the nonsemantic study/perceptual test condition. Age differences in priming were found in the semantic study/conceptual test condition, however, where college students had significantly higher priming scores than did children. These developmental dissociations support the theory that the processing requirements of conceptual implicit memory are similar to those in explicit memory. The author also discusses the contribution of the Transfer Appropriate Processing (TAP; H. L. Roediger, D. A. Gallo, & L. Geraci, 2002) framework to understanding these findings.

Keywords: age differences, children, conceptual processing, developmental dissociations, implicit memory, perceptual processing, priming

IMPLICIT MEMORY is the phenomenon whereby previous experience can impact current behavior without conscious awareness. Implicit memory is typically contrasted with explicit memory, which requires conscious awareness, or purposeful remembering. The dramatic changes in explicit memory from childhood to adulthood are well known and have been described elsewhere (cf., Bjorklund, 1987; Kail, 1990; Schneider & Pressley, 1989). Implicit memory seems to take a different developmental path, however. Early in the history of implicit memory research, Tulving (1985) stated that implicit memory appears early and changes very little across the course of development, and Schacter and Moscovitch (1984) suggested that implicit memory appears earlier in development than does explicit memory. These seminal ideas remain the general consensus among implicit memory researchers today (e.g., Graf, 1990; Mitchell, 1993; Parkin, 1997).

In implicit memory research, experimenters typically present participants with stimuli (the “study” phase), making sure that the participant does not know that a memory test will follow. Some time afterward (minutes to weeks), the par-
Participant is presented with a seemingly unrelated task (the “testing” phase), but one that is made easier because of the prior exposure to the original stimuli. The extent to which the current task is completed with information from the original stimuli is referred to as priming. To be sure that implicit memory is being measured, the task is set up such that conscious referral to the original stimuli to complete the task is highly unlikely or impossible.

Early implicit memory research focused on the types of memory tasks used to measure implicit memory. Certain types of tasks seemed to measure implicit memory, so implicit memory was virtually defined by the tasks used to measure it (see Dunn & Kirsner, 1989 for a discussion of this issue). For example, presentation of word stimuli followed by a seemingly unrelated word-stem completion task was typical. Blaxton (1989), however, argued that cognitive processing within implicit memory could be dissociated into perceptual and conceptual components. Prior researchers assumed that implicit memory tests required perceptual processing whereas explicit memory tests required conceptual processing. Thus, a word-stem completion task might rely on the perceptual match of stems with previously encountered word stimuli although the effort of recall required by an explicit memory test is conceptual by definition. It soon became clear, however, that implicit memory tests could require either perceptual or conceptual processing. That is, implicit memory tests could rely on a perceptual match of stimuli at study and test or a conceptual match based on meaning because related stimuli would prime one another. Further complicating the issue, the conditions under which the stimuli are studied may differ in cognitive processing requirements from the conditions under which the stimuli are tested. Processing that requires very little attention, and may sometimes even be automatic, depends heavily upon the perceptual features of the stimuli. Brown and Mitchell (1994) referred to these processing types as nonsemantic, and I adopt that term here to refer to perceptual processing during the study phase. Similarly, processing that requires some cognitive attention or effort, depends heavily on the meaning of the stimuli, and is less likely to be automatic is called semantic. Again, I adopt that term here to refer to conceptual processing during the study phase. Hereafter, the terms nonsemantic and semantic will refer to the perceptual and conceptual processing requirements of the study task, respectively, whereas I retain the terms perceptual and conceptual to refer specifically to the type of processing required by the testing task.

As interest in implicit memory increased, so did the number of empirical studies exploring the nature and development of implicit memory. In many of these studies, the findings have upheld the traditional view that implicit memory shows little or no developmental changes (Anooshian, 1999; Billingsley, Smith, & MacAndrews, 2002; Carroll, Byrne, & Kirsner, 1985; Church & Fisher, 1998; 

Address correspondence to Elaine S. Barry, Penn State Fayette, The Eberly Campus, One University Drive, PO Box 519, Uniontown, PA 15401 USA; esb12@psu.edu (e-mail).
Barry 21

Drummey & Newcombe, 1995; Ellis, Ellis, & Hosie, 1993; Greenbaum & Graf, 1989; Hayes & Hennessy, 1996; Komatsu, Naito, & Fuke, 1996; Lorsbach & Morris, 1991; Lorsbach & Worman, 1989; Mecklenbrauker, Hupbach, & Wippich, 2001; Naito, 1990; Parkin & Streete, 1988; Perez, Peynircioglu, & Blaxton, 1998; Russo, Nichelli, Gibertoni, & Cornia, 1995), whereas other studies have had contrasting results, indicating that implicit memory may in fact undergo developmental changes under certain conditions (Cycowicz, Friedman, Snodgrass, & Rothstein, 2000; Komatsu et al., 1996; Mecklenbrauker, Hupbach, & Wippich, 2003; Murphy, McKone, & Slee, 2003; Perruchet, Frazier, & Lautrey, 1995). If implicit memory does not show developmental changes over time, it would be unique indeed because studies in most other areas of memory have shown developmental changes with age, for example, in autobiographical memory (Fivush & Hammond, 1990), children’s eyewitness testimony (Ornstein & Haden, 2002), feature binding (Lorsbach & Reimer, 2005), location of hidden objects (Marzolf & DeLoache, 1997), metacognition (Wellman, 1983), and strategies (Ornstein & Naus, 1978), to name a few.

Why, then, have relatively few researchers found developmental changes in implicit memory? First, in most of the developmental studies of implicit memory, researchers have used nonsemantic study conditions followed by perceptual retrieval tests (Roediger, 2003), conditions that virtually guarantee the highest level of implicit memory performance (Roediger, Srinivas, & Weldon, 1989). In all of the developmental studies in which this methodology was used, researchers failed to find developmental differences in priming (Carroll et al., 1985; Church & Fisher, 1998; Drummey & Newcombe, 1995; Ellis et al., 1993; Hayes & Hennessy, 1996; Komatsu et al., 1996; Lorsbach & Morris, 1991; Lorsbach & Worman, 1989; Naito, 1990; Parkin & Streete, 1988; Perez et al., 1998; and Russo et al., 1995). In research studies that have shown developmental differences in priming, researchers have generally used a retrieval test requiring conceptual processing (Cycowicz et al., 2000; Komatsu et al.; Mecklenbrauker et al., 2003; Murphy et al., 2003; Perruchet et al., 1995). Few empirical designs include this methodology, probably less than 10% (Roediger).

Second, most researchers have contrasted implicit memory with explicit memory, and have not focused on making comparisons within different implicit memory conditions. Direct comparisons of different types of implicit memory processing demands would be more likely to reveal any age-related changes in implicit memory performance. Similarly, many studies failing to show developmental changes in implicit memory did not include both children and adults in the same design (Carroll et al. 1985; Church & Fisher, 1998; Drummey & Newcombe, 1995; Greenbaum & Graf, 1989; Hayes & Hennessy, 1996; Lorsbach & Morris, 1991; Lorsbach & Worman, 1989; and Russo et al., 1995). In one recent study (Murphy et al., 2003) the authors purported to manipulate knowledge base and tested perceptual and conceptual implicit memory in children and adults. However, these factors were not included in the same
In this study, I used two types of processing considerations during the study phase (nonsemantic and semantic) combined with implicit memory tests requiring two types of processing (perceptual and conceptual) to formulate the hypotheses. Participants were second-graders and college students in the same design. If implicit memory is unitary, develops early, and changes very little, then no dissociations among the implicit memory tests by age would be expected despite the different types of processing requirements involved. However, if implicit memory is in fact dissociable and can be separated into perceptual and conceptual processing components, similar to explicit memory, then dissociations among the implicit memory tests by age would be expected, depending on the specific processing requirements involved. This is what the current study is designed to reveal. If the cognitive processing required for tests of implicit memory are similar to those required by tests of explicit memory, then age-related differences in priming would be expected in at least one of the study/test combinations of this design. According to this view, the conceptual processing demands of the semantic study/conceptual test condition are very similar to the processing demands of explicit memory. As such, this study/test combination would be difficult for children compared with college students, even in implicit memory, and college students would show more priming in this condition. In contrast, the nonsemantic study/perceptual test condition would be expected to replicate most other developmental implicit memory research showing no age-related differences in priming. This is because the study/test combination of this condition matches that of most developmental implicit memory research in which researchers have failed to detect age-related differences in priming. Therefore, I designed this study to determine the extent to which processing conditions during study and test impact priming on implicit memory tasks for children and college students.

Method

Participants

Participants were 87 second-grade children (average age = 7 years, 3 months; range = 7–9 years) from a public elementary school and 81 college students (average age = 25 years, 7 months; range = 18–53 years) from a large, urban university. I selected child participants (47 girls and 40 boys) from a sample of children whose parents gave parental consent for participation, and who themselves assented. The children were not enrolled in remedial or accelerated learning classrooms. I recruited college students (69 women and 12 men) from psychology classes and they participated in exchange for extra credit. All participants were native speakers of English.
Design

The present experiment was a $2 \times 2 \times 2$ factorial design with age (second graders and college students), study condition (nonsemantic and semantic), and test condition (perceptual and conceptual) as between–subjects factors. Crossing study and test conditions created four basic experimental conditions for each age group: (a) nonsemantic study/perceptual test, (b) semantic study/perceptual test, (c) nonsemantic study/conceptual test, and (d) semantic study/conceptual test.

Materials

I created stimulus materials following procedures outlined by Naito (1990), Komatsu et al. (1996), and especially Rueckl and Mathew (1999). I used words as stimuli to avoid the possibility that pictorial stimuli might require both conceptual processing and perceptual processing (Mitchell, 1993). I selected 20 words from McEvoy and Nelson (1982) to use as target words. All words were concrete nouns made up of 5 to 10 letters, and each word appeared in a dictionary intended for first- and second-grade children (Ellis, Imbornoni, & Weeks, 1998). In addition, I checked Age-of-Acquisition (AoA) values where possible (Gilhooly & Logie, 1980) to make sure the selected words had an AoA value of less than 4.0 (corresponding to ages 7–8 years). Because AoA norms appear to be a “reliable and valid measure of real word learning age” (Morrison, Chappell, & Ellis, 1997, p. 528), I eliminated any words that had a value of 4.0 or greater. Another restriction placed on the selected words was that I only included as targets words with stems that could be completed with at least three other words (e.g., mou____: mouth, mountain, mouse). These other words also had to appear in the children’s dictionary.

Finally, a last set of constraints on stimulus construction had to be met. First, I prepared a brief sentence that included each target word and framed its definition for the semantic study task. I wrote each sentence to make it highly likely that all participants, including the second graders, would be able to specify the target word (per Komatsu et al., 1996). Then, I chose category names from McEvoy and Nelson (1982) to fit each target word such that each target word was neither the most commonly given nor the least commonly given response to the category title, so that priming could be detected. Pilot testing assured that completion of generation sentences with target words could be done accurately by second graders and adults, and that the other materials and procedures were appropriate for the target population.

The 20 target words, their frequency values (a normed value that reflects how often a word appears in the English language; Kucera & Francis, 1967), and their AoA (where available) are available from the author upon request, as are all other materials used in this study. As in Rueckl and Mathew’s (1999) study, however, this is a relatively small number of target words for an experiment of this type,
because of a large number of constraints on material construction. Other researchers (Murphy et al., 2003; Perruchet et al., 1995) also have used a small number of target stimuli. I assigned the target words to two lists, matched by frequency values, and the two lists (List 1, \( M = 39.4 \) and List 2, \( M = 39.8 \)) did not differ in frequency from each other, \( t(18) < 1, ns. \) I created a third list of control words (List 3) by choosing words from the second grader’s dictionary that were 5 to 10 letters in length and that matched target items from Lists 1 and 2 in terms of frequency. List 3 (\( M = 39.1 \)) did not differ significantly in frequency from the other two lists. No control word could belong to the same categories nor have the same three-letter stem as target words, and each control word, like the stimulus words, had to be a concrete noun.

Each participant received the control list and either List 1 or List 2 during the study phase, counterbalanced across conditions and lists. The test phase contained only words from List 1 and List 2 and no control words. The control list was included to increase the number of stimuli and to reduce any possible confound of the implicit tests with explicit memory. Thus, because none of the words from the control list appeared on either type of implicit test, and because the number of control words presented was equal to the number of target words presented, it was unlikely that participants would use explicit recollection to aid their implicit memory task performance.

**Procedure**

Participants were tested individually in a session that lasted approximately 20–30 min. The session consisted of three phases: a study phase, a distracter task, then an implicit test phase, always in that order. For college students, the experiment was described as a test of mental categories. Child participants were invited to play a series of word games with the experimenter. In the nonsemantic study phase, participants were instructed to determine as quickly as possible if words presented on 3 in × 5 in (7.6 cm × 12.7 cm) notecards contained the letter A. If participants stated that there was no A present in a word that actually contained one, they almost always immediately self-corrected. On the rare occasion that this did not happen, the experimenter asked the participants to be sure about their response. Therefore, all participants accurately identified the presence or absence of an A in the words that were studied nonsemantically.

In the semantic study phase, participants were given a sentence completion (definition) task to generate the target words. For these semantically studied words, almost all participants (91%) correctly provided the target word immediately after the clue was given. When this did not happen immediately (7% of participants), or if the participant produced a word other than the target (2% of participants), the experimenter asked for another response. On the rare occasion that this prompt also failed to generate the target word, the experimenter gave the participant a choice of words, selected such that the target word would always
be chosen. For example, a choice of banana or pine tree might be given for the sentence “A monkey likes to eat something yellow called a __________.” Most of these corrected responses were from the second graders.

After a difficult 5 min distracter task in which children circled the different object among a set of similar objects, and adults counted backward by threes, participants completed tests of implicit memory. The perceptual implicit memory test was a list of word stems to be completed with the first real word that came to mind (e.g., ban______). To minimize age differences in completion rates, child participants simply completed the stems, whereas college students completed the stems as quickly as possible, with the experimenter seemingly timing their responses. For the conceptual implicit memory test, participants responded as quickly as possible with the first exemplar that came to mind after being given the category name (e.g., Fruit: __________). Results of previous research (e.g., Murphy et al., 2003) have shown that these types of speeded tasks make it unlikely that participants will use explicit recollection to aid their implicit memory performance.

In each case, half of the items to be completed at test were items that were previously presented to the participant (List 1 or List 2), and the other half were from the other test list, which they had not previously seen (List 2 or List 1). Completion of the words from the list the participants had never seen was included to provide a baseline measure of completion rates for the target words and to disguise the true nature of the implicit test. Results of previous research (i.e., Murphy et al., 2003) have shown this technique to reduce the possibility of contamination from explicit memory. Order of questions for both study and test were counterbalanced across all conditions.

**Results**

*Preliminary Analyses*

I found no effect of gender for second-graders, $F(1, 84) < 1, ns$, or college students, $F(1, 79) = 3.78, p > .05$, so the effect of gender was not considered further.

To ensure that List 1 and List 2 words did not differ in their probability of being completed, I analyzed the probability of each item (target word) being produced in each condition in relation to the list in which it appeared. Because List 1 and List 2 words were split to fully counterbalance the items in this design, four word groups were entered into this analysis (Lists 1a, 1b, 2a, and 2b). See Table 1 for a list of $F$ values and their associated probabilities. I found no effect of list for studied or unstudied items no matter how they were studied (read or generated) or tested (word stem completion or category production).

To examine any effects that the testing task had on priming scores or target completions, I analyzed the proportion of target words completed in the unstudied
(baseline) condition by a $2 \times 2 \times 2$ analysis of variance. Only the two-way interaction between study and test reached significance, $F(1, 160) = 4.72, p = .03$. None of the main effects were significant, nor were any other two-way interactions or the three-way interaction, all $Fs < 1$, $ns$. Thus, baseline target completion rates were not significantly different across age or across study or test conditions, but they were higher for the two conditions in which processing demands between study and test were matched. In developmental implicit memory research, however, baseline completion rates often differ across age groups. In these cases, most researchers use a relative priming score suggested by Snodgrass (1989), computed to account for differential baseline scores by respondents in implicit memory research [(studied − unstudied targets completed) / (1 − unstudied)]. Although this dependent measure is especially useful when baseline completion differs among experimental groups, Snodgrass also recommends this method for calculating priming even when baseline completions do not differ. Because this measure calculates priming (or learning) as a proportion of possible change rather than absolute change, it is a more appropriate measure for measuring priming in implicit memory. Therefore, as suggested by Snodgrass, and used by other researchers (Billingsley et al., 2002; Cycowicz et al., 2000; Hayes & Hennessy, 1996; Komatsu et al., 1996; Loveman, van Hooft, & Gale, 2002; Perez et al., 1998; Rajaram & Roediger, 1993; Russo et al., 1995), the dependent variable in this study is the relative priming score. Results were the same, however, when absolute difference priming scores were entered into the analysis instead of relative priming scores.

Table 2 presents the data entered into the main analysis of this study. Mean priming scores are presented for each age group, study condition, and test condition, as well as the means for the main effect tests and all associated standard deviations. To ensure that there was an effect of priming, I tested the priming scores by age and

<table>
<thead>
<tr>
<th>Study</th>
<th>$F(3, 40)$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceptual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsemantic</td>
<td>0.45</td>
<td>.72</td>
</tr>
<tr>
<td>Semantic</td>
<td>0.15</td>
<td>.93</td>
</tr>
<tr>
<td>Unstudied</td>
<td>1.34</td>
<td>.28</td>
</tr>
<tr>
<td>Conceptual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsemantic</td>
<td>0.40</td>
<td>.76</td>
</tr>
<tr>
<td>Semantic</td>
<td>2.10</td>
<td>.12</td>
</tr>
<tr>
<td>Unstudied</td>
<td>0.05</td>
<td>.98</td>
</tr>
</tbody>
</table>
study/test condition to see if they were significantly different from zero (a priming score close to 0 would indicate no priming). All priming scores in the conditions of interest for this study were significantly different from zero.

**Hypothesis Testing**

I analyzed information from Table 2 with a 2 (age) × 2 (study) × 2 (test) analysis of variance, where all variables were between–subjects. Priming scores did not differ by age, $F(1, 160) = 1.36, p > .1$, study condition, $F(1, 160) < 1, ns$, or test condition, $F(1, 160) = 2.17, p > .05$) alone, replicating previous work showing that priming is roughly equivalent between adults and children. This study was designed, however, to determine if second graders and college students would show developmental differences in priming depending on processing requirements during different combinations of study and test conditions.

Priming scores for study/test combinations did differ as a function of age, as indicated by the significant three-way interaction between age, study, and test, $F(1, 160) = 8.77, p < .003$. This effect was further explored with two additional planned analyses. Figure 1 depicts the means from Table 2 graphically and by

![Table 2](image)

**TABLE 2. Means and Standard Deviations of Relative Priming Scores by Age, Study Condition, and Test Condition**

<table>
<thead>
<tr>
<th>Study condition</th>
<th>Test condition</th>
<th>Perceptual</th>
<th>Conceptual</th>
<th>Marginals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td><strong>Second graders</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsemantic</td>
<td>.124</td>
<td>.245$^*$</td>
<td>.127</td>
<td>.217$^*$</td>
</tr>
<tr>
<td>Semantic</td>
<td>.097</td>
<td>.143$^*$</td>
<td>.116</td>
<td>.199$^*$</td>
</tr>
<tr>
<td>Marginals</td>
<td>.111</td>
<td>.197</td>
<td>.121</td>
<td>.206</td>
</tr>
<tr>
<td><strong>College students</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsemantic</td>
<td>.233</td>
<td>.338$^*$</td>
<td>.107</td>
<td>.258</td>
</tr>
<tr>
<td>Semantic</td>
<td>.031</td>
<td>.257</td>
<td>.382</td>
<td>.320$^*$</td>
</tr>
<tr>
<td>Marginals</td>
<td>.129</td>
<td>.312</td>
<td>.244</td>
<td>.318</td>
</tr>
</tbody>
</table>

$^*$Priming scores were significantly different from 0 at $p < .05$.  

![Graph](image)
In the nonsemantic study/perceptual test condition, second-graders (\(M = 0.124\)) and college students (\(M = 0.233\)) did not differ in their priming, \(F(1, 39) = 1.40, p > .05\). Although the mean priming score of the college students was larger, this was not a statistically significant difference, consistent with previous research finding greater priming in adults compared with children that was not statistically significant (e.g., Komatsu et al., 1996; Russo et al., 1995, Experiment 2). In contrast, in the semantic study/conceptual test condition, the second graders had significantly less priming (\(M = 0.116\)) than the college students (\(M = 0.382\), \(F(1, 40) = 10.60, p < .002\).

I then analyzed each age group separately. Second graders had significant priming, and equivalent priming, \(F(3, 83) < 1, ns\), across all four study/test combinations. College students did not have significant priming in two conditions (the “mismatch” conditions: nonsemantic study/conceptual test and semantic study/perceptual test) so no analyses were performed on these data. I found significant priming for college students in the two match conditions (nonsemantic

**FIGURE 1.** Priming scores by age and study/test condition. Nsem-Perc = nonsemantic study/perceptual test condition. Nsem-Con = nonsemantic study/perceptual test condition. Sem-Perc = semantic study/perceptual test condition. Sem-Con = semantic study/conceptual test condition.
study/perceptual test and semantic study/conceptual test), and priming did not differ significantly across these two conditions, $F(1, 38) = 2.04, p > .05$.

Post hoc Tukey analyses showed that the interaction between study and test, $F(1, 160) = 10.09$, was significant at $p < .002$, indicating that priming scores for each type of test were influenced differently by type of study. In particular, priming in the nonsemantic study/perceptual test condition ($M = 0.17, SD = 0.295$) was similar to the priming in the nonsemantic study/conceptual test condition ($M = 0.11, SD = 0.234$), whereas priming in the semantic study/perceptual test condition ($M = 0.06, SD = 0.206$) was significantly less than priming in the semantic study/conceptual test condition ($M = 0.24, SD = 0.293$).

**Discussion**

In this study, nonsemantic study (word reading) and semantic study (word generation) were orthogonally crossed with a perceptual implicit memory test (word stem completion) and a conceptual implicit memory test (category production). Children and college students did not differ significantly in their priming in the omnibus test, nor in the nonsemantic study/perceptual test condition, replicating previous findings in developmental implicit memory research (i.e., Drummey & Newcombe, 1995; Naito, 1990; Parkin & Streeete, 1988; Perez et al., 1998). It was predicted that this specific study/test combination would result in the “easiest” processing demands, allowing even young children to benefit from prior experience as much as adults because a perceptual processing system seems to appear early in memory development. Thus, this prediction was supported, not surprisingly, because most of the extant literature in implicit memory development consists of this type of study/test combination, and has failed to yield age-related priming effects.

However, children and adults did show significant differences in their priming in the semantic study/conceptual test condition, supporting previous work finding age-related differences in implicit memory (Komatsu et al., 1996; Perruchet et al., 1995). Effectively, this should be the most difficult condition in terms of processing demands, and the one in which the most age differences in priming should be seen. Because this condition necessitates conceptual processing at both study and test, it is the condition that would be most sensitive to implicit memory performance differences by age if implicit memory is similar in processing requirements to explicit memory. Because baseline performance was not different by age, study, or test condition, differences in priming attributable to any of these variables are especially important. In other words, baseline completions indicated that neither children nor college students had difficulty with the tasks, yet, the processing demands of the semantic study/conceptual test condition revealed age-related differences in priming. In a way, if the task is easy to perform (as baseline performance seemed to indicate), then it may be tempting to expect no age-related differences in priming. This was not shown in the
current study and was not predicted because of the role that processing demands were expected to play in conceptual implicit memory performance. Specifically, I expected older participants to experience greater priming than younger participants in the condition dominated by conceptual processing, and they did. This result is similar to traditional findings in explicit memory, which is also dominated by conceptual processing. Once again, the importance of processing considerations within implicit memory is underscored.

The most priming occurred in the two conditions that had matching study/test processing requirements (nonsemantic study/perceptual test and semantic study/conceptual test, see Table 2). The importance of matching study/test requirements to explain both explicit and implicit memory findings has been explored through the Transfer Appropriate Processing (TAP) framework (Roediger et al., 2002). According to the TAP framework (Morris, Bransford, & Franks, 1977), when processing requirements of the study and test episodes match, memory performance should be optimal. This should hold true for implicit memory as it does for explicit memory. Results of this study supported the TAP framework, and indicated that under some circumstances, but not others, implicit memory shows developmental changes from childhood to adulthood. In particular, following the suggestion that processing demands in implicit memory parallel processing demands in explicit memory (i.e., Rappold & Hashtroudi, 1991), conceptual processing demands showed similar developmental changes in implicit memory as in typical explicit memory work, whereas perceptual processing demands did not show developmental changes in implicit memory.

One consideration of this study must be the possibility of contamination by explicit memory. This is not a concern for child participants, whose explicit memory and ability to use strategies is relatively poor compared with adult participants (see Kail, 1990; Murphy et al., 2003). However, several measures were taken in this study to ensure that explicit contamination was not a problem. First, following Richardson-Klavehn, Clarke, and Gardiner (1999), unintentional instructions were used both in the encoding tasks and retrieval tests to reduce the possibility of contamination by explicit memory. Second, adult participants were told that their responses were timed and that they should respond as quickly as possible, thus reducing the possibility of explicit remembering later. See McKone and Slee (1997) and Billingsley et al. (2002) for discussions on how difficult recall conditions make explicit contamination of an implicit memory task highly unlikely, especially under conditions when the participants are apparently timed (Murphy et al.). Third, an entire research literature exists on the effects of nonsemantic (“shallow”) encoding conditions versus semantic (“deep”) encoding conditions on implicit memory (e.g., Craik & Lockhart, 1972). Under almost all conditions, semantic processing during study leads to much greater recall than does nonsemantic processing. In this study, the college students’ priming was not significantly different between the nonsemantic study/perceptual test condition and the semantic study/conceptual test condition. Therefore, it is unlikely that
these participants used explicit strategies to enhance their implicit memory tests, or the semantic study/conceptual test condition likely would have been significantly higher. Fourth, 50% of the testing materials were new stimuli, helping to ensure that the priming scores reflected implicit memory and not explicit memory (Murphy et al.; Roediger & McDermott, 1993). Finally, in postexperiment interviews I asked college students which words they recalled from the study phase of the experiment. When these words were taken out of the testing responses (i.e., removed from priming scores), the overall pattern of results did not change, although the mean priming for the semantic study/conceptual test condition for college students was reduced to 0.31. This did not change the overall pattern of results, however.

In addition to the main analyses of this study, results revealed other interesting patterns for the two mismatch conditions for which no hypotheses were put forward. First, in the two mismatched processing conditions, college students did not show significant priming, whereas second graders did. This is an intriguing finding, and one that could not have been predicted, especially because baseline performance did not differ between the two groups. Because these two study/test conditions mismatched both processing conditions and modality, however, it is unclear which of these factors is responsible for the lack of priming by the college students. Much work in the adult implicit memory literature has shown cross-modal priming (e.g., Blum & Yonelinas, 2001; David & Hirshman, 1998; Loveman et al., 2002; Pilotti, Bergman, Gallo, Sommers, & Roediger, 2000; Rueckl & Mathew, 1999), whereas other work has found cross-processing priming (e.g. Brown & Mitchell, 1994; Rajaram & Roediger, 1993; Schwartz, 1989). Therefore, it may be that for adults, the combination of mismatching processing requirements and modality may result in nonsignificant priming. Further studies should be designed to determine whether this is so, and if it is, why. In adults, for example, Richardson-Klavehn et al. (1999) found priming from generating words to be less than priming from reading words for a word stem completion test (similar to the present results). They interpreted their finding to support the existence of both modality-specific and modality-independent lexical processes, both important in perceptual implicit memory but themselves dissociable. Thus, their research also supports the idea that dissociations can be found within implicit memory tests as well as between implicit and explicit memory tests, because of the importance of processing considerations.

Similarly, in the semantic study/perceptual test condition, second graders had more priming than adults, although once again this difference was not statistically significant. As with the nonsemantic study/conceptual test condition, the results suggest that when implicit memory tests have a strong perceptual component at the test phase, children can still do well relative to adults with regard to priming scores. These findings may support Komatsu et al.’s (1996) claim that perceptual processes may be more accessible to children than conceptual processes. Indeed, these results may also suggest that perceptual processing is more available to
young children than it is to adults, who also have conceptual processing available in their cognitive repertoire. Could it be that for some cognitive tasks (such as those often used by memory researchers) adults may actually prefer to use conceptual processing, even if it does not benefit them? No hypotheses were put forward for these mismatch conditions, however, so post hoc interpretations of these findings and other speculations must be made cautiously. Further research is needed to delineate the necessary and sufficient nature of the type of nonsemantic or perceptual processing in implicit memory that allows children to do well, and the extent to which conceptual implicit memory tests are responsible for age-related priming effects, independent of the type of study.

Further, in the nonsemantic study/conceptual test condition, college students produced fewer category exemplars than did the second graders. Although this difference was not significant, Perez et al. (1998) found a similar result. In their study, college student participants produced fewer words in the category production task than did child participants. Perez et al. attributed this to the college students’ higher baseline completion performance, but when they used the Snodgrass (1989) method of calculating relative priming scores, their results were the same. They did not offer any other explanation for these findings. A possible explanation may be found in an earlier study. Drummey and Newcombe (1995) examined the relation between perceptual facilitation and explicit memory and suggested that one mechanism for the growth of explicit memory may be developing an understanding that perceptual facilitation is an indication of familiarity and hence, a form of memory. In other words, a later developing explicit memory may depend on an earlier developing perceptual memory. Perhaps children in the current study and the Perez et al. study relied on their most available cognitive processing (perceptual), which allowed them to achieve significant priming even in the conceptual testing condition. College students may have relied more heavily on cognitive processing at the expense of perceptual processing. This dependence on conceptual processing may have become a liability under cross-modal and cross-processing conditions.

In addition to the Drummey and Newcombe (1995) explanation, there may be another possible reason for college students’ poor performance compared with children’s performance in the nonsemantic study/conceptual test condition. It may be that the processing requirements (between implicit memory and explicit memory, or within implicit memory) interact as the memory system develops. Figure 1 shows that second graders displayed a stable level of performance across the study/test conditions in this study, whereas college student performance fluctuated greatly depending on those factors. Early in memory development, a stable perceptual system may set the groundwork for the growth of conceptual processing. Later, when conceptual processing has become more central to memory, it may influence the perceptual system in conditions when both are activated. Once again, however, these post hoc explanations must be offered modestly because further research is needed to clarify these issues.
In the current study, younger participants demonstrated as much priming as older participants in a perceptual implicit memory task for which they had studied nonsemantically. Nonsemantic study with a perceptual test represents the least demanding processing condition in which children, as well as adults, can do well. In fact, the results of this analysis further suggest that children can benefit to the same extent as adults under these circumstances. Older participants, however, benefited more from semantic study (had more priming) when they were tested conceptually. This implicit memory finding parallels the voluminous literature on the development of children’s explicit memory (cf., Bjorklund, 1987; Kail, 1990; Schneider & Pressley, 1989), highlighting the pivotal role of processing in memory. In other words, semantic study combined with a conceptual test is very similar to the processing required by explicit memory tests. The results of this study suggest that under these conditions, these similar processing demands result in comparable age-related differences wherein older participants outperform younger ones. Thus, the findings support the processing view of implicit and explicit memory over a multiple memory systems approach. The TAP approach was supported in this study by the main analyses, wherein I found significant priming in the two matched processing conditions. Finding process dissociations within implicit memory that parallel the explicit memory literature with respect to age-related differences strengthens the importance of a processing approach to memory. Future research on processing demands in implicit memory will necessitate focusing attention on appropriate testing methods so that different types of tests that nonetheless represent the same type of processing can be used, thus expanding the available methodology and avoiding other confounds (such as modality).

**AUTHOR NOTE**

*Elaine S. Barry* is an associate professor of human development and family studies at The Pennsylvania State University, Fayette—The Eberly Campus. Her research interests focus on memory processes, especially the development of implicit and explicit forms of memory and the role of implicit memory in depression.

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