Dissociations between implicit and explicit memory in children: The role of strategic processing and the knowledge base

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Abstract

A review of the literature shows that explicit memory develops substantially from three years of age to adulthood, while implicit memory remains stable across this age range. Previously, this developmental dissociation has been attributed to different memory systems, or to confounds with perceptual vs. conceptual processing. Prompted by an alternative developmental framework, the experiments reported here provide evidence against both interpretations. Instead, it will be argued that (a) the implicit–explicit developmental dissociation reflects differences in strategic processing (strategy use and metamemory) across childhood and (b) that implicit memory can show development if a child’s knowledge base in the tested domain is developing with age.

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This paper considers the childhood development of implicit and explicit memory from approximately 3 years of age to adulthood. As addressed here, “implicit” and “explicit” refer to tests of long-term memory that, after a similar study phase and study-test delay, differ only in the nature of their retrieval phase (Graf & Schacter, 1985). Explicit memory requires conscious recollection of a target’s presentation in
the study phase, and is assessed via tasks such as free recall, cued recall, and old–new recognition. *Implicit memory*, in contrast, is independent of conscious recollection, and is instead assessed via the phenomenon of *repetition priming* in tasks such as naming degraded pictures, category exemplar generation, and word-stem-completion. In the latter task, for example, priming is revealed when the instruction to “Complete cha__ with the first word that comes to mind” produces the target completion *chair* more often when this item was present at study (primed condition) than when it was not (baseline condition).

In adults, implicit and explicit memory are dissociated under many circumstances (for review, see Roediger & McDermott, 1993). For example, amnesic patients perform very poorly on explicit tests of memory, but perform normally or near-normally on a range of implicit memory tests (e.g., Jacoby & Witherspoon, 1982; Warrington & Weiskrantz, 1968). In normal adults, explicit memory is much more severely affected than implicit memory by levels-of-processing manipulations (e.g., Craik & Tulving, 1975; Jacoby & Dallas, 1981) and by divided attention (Parkin, Reid, & Russo, 1990; Parkin & Russo, 1990) while, at the same time, implicit memory is much more severely affected than explicit memory by study-test mismatches in perceptual form (e.g., auditory study phase–visual test phase; Rajaram & Roediger, 1993).

In adults, there has been much theoretical debate about the origins of implicit–explicit dissociations. Two theories have received particular attention. According to the *memory systems account* (e.g., Moscovitch, 1994; Schacter & Tulving, 1994; Zola-Morgan & Squire, 1993), different brain systems support explicit and implicit memory, perhaps by providing two distinct storage locations or two distinct retrieval routes to a common storage location. According to the alternative *perceptual vs. conceptual processing account* (Blaxton, 1989), apparent dissociations between implicit and explicit memory reflect confounds with the perceptual (appearance- or form-based) vs. conceptual (semantic or meaning-based) nature of the information required by the task. For example, in early studies of implicit–explicit memory differences, it was common to use word-stem-completion (a perceptual task) as the implicit test, and free recall (a primarily conceptual task) as the explicit test. We note, however, that many studies in the adult literature have now carefully equated the nature of processing across their implicit and explicit tasks (e.g., for perceptual processing, stem-completion has been contrasted with stem-cued recall), yet have still reported clear implicit–explicit dissociations (e.g., Challis, Velichovsky, & Craik, 1996; Schwartz, Rosse, & Deutsch, 1993).

**An implicit–explicit dissociation in childhood development**

In the childhood literature, a striking developmental dissociation between implicit and explicit memory has been reported. Specifically, while explicit memory is well known to improve even into adolescence (Kail, 1990), the usual finding of implicit memory studies to date is of no age-related increase in priming. Of 18 published studies, 15 have concluded that implicit memory is stable across a wide age range (3 years to adulthood).
To date, only two possible explanations of this developmental dissociation have been considered, both of which have been appropriated from the adult literature discussed above. Early developmental articles (pre-1995) tended to favor a memory systems account (e.g., Naito, 1990; Schacter & Moscovitch, 1984). Here, it was argued that implicit and explicit systems reach physiological maturity at different ages, with implicit memory reflecting an “early-developing” system, and explicit memory a “late-developing” system. We note that, on the basis of current evidence at least, the memory systems account remains a viable possibility.

Alternatively, several authors (e.g., Komatsu, Naito, & Fuke, 1996; Perruchet, Frazier, & Lautrey, 1995; Perez, Peynircioglu, & Blaxton, 1998) observed that early developmental studies confounded implicit vs. explicit retrieval with perceptual vs. conceptual processing, and thus considered a processing account. Given that most studies had examined implicit memory for perceptual information (the standard test in children being the picture-fragment identification task), it was suggested that age-related development of implicit memory might be manifested if conceptual processing was required. Experimental support for this hypothesis, however, has been unconvincing. Several studies have used an explicit comparison task that is well matched for type of processing to the implicit test. For conceptual processing, the implicit category exemplar generation task (“What is the first animal that comes to mind?”) has been contrasted with an explicit category-cued recall task (“What was the animal that was on the study list?”; Perez et al., 1998; Perruchet et al., 1995). Similarly, for perceptual processing, implicit object identification tasks have been contrasted with explicit old–new recognition for the same pictures (Carroll, Byrne, & Kirsner, 1985; Drummey & Newcombe, 1995; Hayes & Hennessy, 1996; Parkin & Streete, 1988). Despite this close matching, however, the standard implicit–explicit dissociation has been obtained in all cases.

**Factors in explicit memory development**

In this paper, we suggest that current theories of implicit–explicit dissociations in childhood development are limited in scope. In particular, there is a well-established literature on the origins of development in explicit memory tasks that, so far, has been ignored in the discussion of children’s implicit memory. As we will demonstrate, this literature is theoretically relevant to understanding implicit–explicit dissociations in children. In addition, it leads to an empirical prediction that—in contrast to the standard finding of no age-related change in implicit memory—a situation might exist in which implicit memory shows strong age-related development.

In explicit memory tasks, childhood improvement has traditionally been attributed to a combination of four factors (for reviews, see Kail, 1990; Schneider & Pressley, 1989). The first is an increase in basic capacity for long-term memory (e.g., Brainerd & Pressley, 1985), as suggested by the maturational development of brain structures known to be involved in explicit memory in adults. These include the hippocampal formation, which appears to be functional within the first two years of life (Nelson, 1997) and reciprocal connections between the hippocampus and...
The neocortex, which take somewhat longer to mature (Bachevalier, 1990). The second factor is age-related improvement in children’s knowledge base in many domains. There is empirical evidence to show that enhanced background knowledge improves explicit memory. For example, children who are soccer experts show better recall for a story about a soccer game than do same-age children who are soccer novices (Schneider, Korkel, & Weinert, 1989; also see Chi, 1981; Chi, Feltovich, & Glaser, 1981). Finally, two factors are associated with strategic processing, namely memory strategies and metamemory. Explicit memory is enhanced by both the employment of deliberate memory strategies (such as rehearsal, or imposing one’s own semantic organisation on the material; Wellman, 1988), and the appropriate control of such strategies via metamemory (the awareness of one’s own memory abilities; Flavell & Wellman, 1977; Wellman, 1983). Children’s skills in both these areas begin to emerge only at around 5–6 years of age, and continue to improve well into adolescence (e.g., Ornstein & Naus, 1978; Rohwer, 1973; Wellman, 1983).

In determining overall memory performance at any given age, these four factors are presumed to interact, rather than to operate in an additive fashion (Weinert, Schneider, & Knopf, 1988). Moreover, different explicit memory tasks may place differential emphasis on the various factors. For example, a common finding is that development is stronger in recall than in old–new recognition (e.g., Brown & Campione, 1972; Kilburg & Siegel, 1973). This difference has been attributed to the fact that recall is more dependent on strategic retrieval processes than is recognition (Brown, 1975; Flavell, 1970).

Towards a more complete theory

The aim of the present paper is to investigate implicit memory development within a theoretical framework that considers the traditional “four factors” of the childhood explicit memory literature and, moreover, integrates these with adult theories of explicit–implicit dissociations where appropriate. We further consider a full range of adult theories, not merely the two approaches—the systems account and the perceptual vs. conceptual processing account—that have been translated to the developmental literature to date. In seeking an integrative framework, our first intention is to consider the broadest possible range of explanations for the standard finding that explicit memory increases with age but implicit memory does not.

We suggest that at least four possible interpretations of the developmental dissociation between implicit and explicit memory need to be considered. In addition to current accounts in terms of early vs. late systems (equivalent to different “basic capacities”), or confounds with perceptual vs. conceptual processing, two other alternatives based on a developmental factors approach merit consideration: a strategic processing account and a knowledge base account.

1 There are also behavioral studies investigating a developmental increase in “basic memory capacity” (e.g., Dempster, 1985), but these have addressed short-term memory, not long-term memory.
Several authors in the adult literature (particularly Jacoby, 1991) have argued that an important difference between implicit and explicit memory is that explicit memory is sensitive to strategic processes, but implicit memory is not. Indeed, it is usually argued that implicit memory is non-strategic at both encoding and retrieval: at retrieval, the participant does not have to try to remember, providing no motivation for implementing a deliberate strategy; at encoding, a lack of sensitivity to dividing attention in the study phase (Parkin et al., 1990; Parkin & Russo, 1990) again argues for no reliance on strategic resources. Thus, we suggest that while the improvements in strategic processing that occur across childhood contribute to age-related enhancements in explicit memory, implicit memory might remain developmentally stable partly because strategic processing does not contribute to implicit performance at any age.

Turning to possible contributions of the knowledge base, we suggest that the recent emphasis on implicit–explicit confounds with perceptual vs. conceptual processing could, in fact, be re-characterized as an issue about knowledge base effects. Perceptual form and semantic meaning are different aspects of knowledge about an item. Moreover, these can develop at different rates, with perceptual knowledge often established earlier than conceptual knowledge (e.g., a child knows what a gun looks like well before he or she knows the full implications of its semantic relationships with hunting, inner-city murder, gun lobbies, and so on). Thus, in focusing on perceptual priming, we suggest that the current childhood literature on implicit memory has been confined to circumstances in which the relevant knowledge base is stable with age.

By far the most common task used to assess priming in children has been identification of degraded objects. Although we know of no relevant empirical evidence, we suggest that perceptual knowledge of common objects should be well established by 5 years of age; this is particularly the case given that stimuli in object identification studies are specifically chosen to be familiar to young children, and are always shown in standard views. Of 13 studies testing priming for common objects, only one has reported a small age-related increase (Cycowicz, Friedman, Snodgrass, & Rothstein, 2000), with 12 others showing no such effect (Anooshian, 1997; Carroll et al., 1985; DiGiulio, Seidenberg, O’Leary, & Raz, 1994; Drummey & Newcombe, 1995; Hayes & Hennessy, 1996; Lorsbach & Morris, 1991; Lorsbach & Worman, 1989; 

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2 These results refer to findings with an absolute measure of priming (i.e., priming = primed score – baseline score). Several authors (e.g., Parkin, 1993) have suggested a relative measure instead, because baseline performance in the object-naming task improves across age groups. The particular approach suggested (Snodgrass, 1989) calculates priming as the absolute improvement in performance divided by the maximum possible room for improvement. We are currently preparing a separate article detailing problems with this measure. Here, we note briefly that (a) theoretically, there are strong reasons to doubt its appropriateness for comparisons across age groups because it relies on a learning model in which asymptotic performance with practice is assumed equal for all ages, and (b) empirically, studies differ substantially in how big the baseline difference is, and yet all show the same lack of development in absolute priming. Thus, we see no reason to disbelieve the general conclusion that priming in object naming is not affected by age (also see Experiment 2).
Studies using other perceptual tasks have also found no age effect on implicit memory. This includes priming for faces in familiarity decision (Ellis, Ellis, & Hosie, 1993), for written English in both naming degraded words (DiGiulio et al., 1994) and stem-completion (Anooshian, 1997), and for the Japanese Hiragana script in word-fragment completion (Komatsu et al., 1996; Naito, 1990). Again, we argue that these studies have tested stimulus domains for which there is little or no development in underlying knowledge across the age range tested. Perceptual knowledge of faces has been shown empirically to be fully intact by 6 years at the latest (e.g., Carey & Diamond, 1994; Gilchrist & McKone, in press). Perceptual knowledge of Hiragana words (a regularly pronounced letter-based script) is well established in first and second Grade Japanese children, and its usage in fact reduces with age following transfer to the Kanji script (S. Kinoshita, personal communication, April 2001). Only the two experiments using English words (Anooshian, 1997; DiGiulio et al., 1994) tested a stimulus class for which perceptual knowledge improves after age 5, but in each case the youngest age groups tested were already 8 or 9 years old.

Thus, we suggest that the state of the knowledge base (developing or stable) might be an important factor in the standard developmental dissociation between implicit and explicit memory. Implicit memory (at least in perceptual tasks) has been tested only for stable knowledge domains and, with implicit retrieval, no other developmental factors (strategy use, metamemory, or basic capacity development) are available to enhance performance in older age groups. With explicit memory, in contrast, performance can still improve with age due to the contributions of the other factors (particularly strategic processing), even when stable underlying knowledge domains are used.

**Could implicit memory show age-related development?**

The arguments above lead to an interesting proposal, namely that *implicit memory might increase with age* when the underlying knowledge base is undergoing simultaneous development. According to theories of priming in adults, there are various possible mechanisms by which priming could be affected by pre-existing knowledge. According to “activation” or “modification” approaches to implicit memory (e.g., Graf & Mandler, 1984), priming results from temporary changes to the state of localized units representing an item (Morton, 1969), or to connection weights in a network of distributed representations (Bowers, 2000). Within this framework, priming might be greater for items that have a pre-existing representation than for those which do not, and/or be affected by the strength of connections between familiar items. According to the alternative “episodic” or “instance” theories of implicit memory (Logan, 1990; Roediger & McDermott, 1993), pre-existing knowledge might influence implicit memory via the same mechanism by which it is generally presumed to affect explicit memory (cf. Bjorklund, 1987): specifically, enhanced
background knowledge allows for encoding of a richer trace at study, leading to more possible retrieval routes to the target at test.

What specific types of changes in knowledge might then be relevant to studies of implicit memory in children? By 5 years of age, most common items are familiar in themselves. Perceptual knowledge of an item’s appearance is also well established. Within conceptual information, however, certain aspects of knowledge are known to improve substantially with age.

Basic conceptual relationships to other items are established in 5-year-olds. For example, a child knows that an apple and orange are associated, and that both are members of the category fruit (Bjorklund & de Marchena, 1984). Researchers have, however, identified two changes beyond this age that are of particular relevance to the present study. First, when given a set of items that can be grouped in different ways (e.g., monkey, carrot, banana, and rabbit), young children prefer to group on the basis of associative relationships (i.e., monkey–banana, rabbit–carrot), while older children and adults prefer to group on the basis of categorical relationships (e.g., monkey–rabbit, banana–carrot; Bjorklund & de Marchena, 1984). This suggests that, even when younger children are familiar with a category relationship, the strength or richness of categorical links between items increases with age, in comparison to the strength of associative links. Second, within categorical knowledge, atypical exemplars (e.g., frog for the category animal) show a stronger age-related increase in connection strength to the category label than typical exemplars (e.g., dog for the category animal). For example, Rosch (1973) found that time to verify category membership improved with age more for atypical exemplars than typical exemplars, even between 10 years and adulthood. These results indicate that category knowledge improves well into adolescence, particularly for atypical exemplars.

With respect to explicit memory tasks, the age-related changes in category knowledge described above are known to affect performance. For example, Bjorklund and Thompson (1983) showed that the standard typicality advantage in recall (typical exemplars are recalled more accurately than atypical exemplars) was larger when child norms, rather than adult norms, were used to define typicality. Similarly, Kobasigawa (1974) found that children’s spontaneous use of category label cue-cards at test increased between 6 and 11 years, corresponding to an overall improvement in recall accuracy with age.

With respect to implicit memory, little is known about the possible effects of changes in category knowledge on the development of priming. Only four priming studies have used conceptual processing tasks. While all cases employed category knowledge as the relevant domain (assessing priming in the category exemplar generation task), three did not mention exemplar typicality. Thus, the lack of an age-related increase in priming in these studies (9 years—Adult, Anooshian, 1997; 3–5 year-olds, Greenbaum & Graf, 1989; Grades 2–4, Perez et al., 1998) might be attributable to testing only highly typical exemplars and thus a relatively stable knowledge domain. This idea receives some support from an intriguing result obtained in the remaining study. Also using category exemplar generation, Perruchet et al. (1995) found an age-related increase in priming in a first experiment, and failed to do so
in a second experiment with different items. Based on a post hoc analysis of item typicality, these authors then suggested that priming was stable with age for typical exemplars, but increased with age for atypical exemplars. (In fact, the latter result was obtained in only one of the two experiments.)

Perruchet et al.’s (1995) suggestion of an age-related increase in priming for atypical category exemplars is consistent with our idea that implicit memory might improve with age if the underlying knowledge base is simultaneously developing. Their result, however, was obtained only post-hoc and in only one of two experiments. There is a need to either replicate or discount the finding, particularly by testing a broader age range than the two years covered in Perruchet et al.’s study (approximately 7- to 9-year-olds). Moreover, in order to conclude that any development revealed was a knowledge base effect, rather than a general conceptual processing effect, it would be necessary to include a comparison with priming in a conceptual knowledge domain that is well established even in the youngest age group tested. As argued earlier, one such domain is relationships based on association (e.g., rabbit–carrot) rather than on taxonomic category.

The present study

In the present study, we examined implicit memory in children across a broad range of theoretically relevant circumstances. Of primary interest was the idea that an age-related increase in implicit memory might be revealed if, and only if, the underlying knowledge base was developing over the age range tested. Across Experiments 1–3, therefore, we assessed the effects of age on (a) conceptual priming with a developing knowledge base (categorical relations involving atypical exemplars), (b) perceptual priming with a stable knowledge base (the same items presented in an object naming task), and (c) conceptual priming with a stable knowledge base (a largely overlapping set of items presented via associative relationships). The items we used as stimuli were already familiar to the youngest age group tested; thus, “a change in knowledge base with age” in our experiments refers to structural changes within the organisation of categorical knowledge, rather than to adding new target items. Each experiment also tested explicit memory. Depending on the particular implicit task, the explicit test was either cued recall or a variant of old–new recognition. It should be kept in mind, however, that these two explicit tasks are differentially sensitive to strategic processing in the retrieval phase, and thus could show different developmental patterns.

In all experiments, due regard was given to methodological issues. First, the age range tested—5 years to adults—was wide enough to allow for the manifestation of memory development, if indeed it did occur. Second, implicit and explicit memory tasks were carefully matched in all respects except for the retrieval instructions given at test (cf. Schacter, Bowers, & Booker, 1989). Third, every effort was made to ensure that performance on the implicit memory tasks was not contaminated by unwanted use of explicit memory strategies in the older participants (cf. Bowers &
Schacter, 1990; Jacoby, 1991; McKone & Slee, 1997). Fourth, the type of processing used for the study task was matched to the type of processing required for the test task (e.g., generating category exemplars in the test phase was preceded by confirming category membership in the study phase) to ensure activation of the test-relevant aspects of knowledge at study. Finally, baseline differences across age groups—that is, age-related improvements in the unprimed condition—were avoided in all tasks used in the present study. This is important because it avoids debate about whether priming should be calculated in absolute or relative-to-baseline terms (Parkin, 1993).

Experiment 1 – conceptual category knowledge

Experiment 1 investigates implicit and explicit memory for atypical category exemplars in category generation tasks (cf. Perruchet et al., 1995). The items chosen were familiar even to the youngest children tested. Moreover, the children were aware that the items were members of their target categories (see Method). However, given the evidence discussed in the introduction, we argue that atypical category relationships is a domain for which conceptual knowledge develops substantially between 5 years of age and adulthood.

Experiment 1a: Implicit memory

At study, participants in each of four age groups (Kindergarten, Grade 3, Grade 5, adults) were presented with names of atypical exemplars of common semantic categories (e.g., frog for the category animal) and were asked to confirm the category membership of each item (e.g., “Is this an animal?”). At test, a category exemplar generation task was used (e.g., “Tell me the first five animals you can think of”). This test task is the same as that used in previous investigations of conceptual implicit memory development, with a minor change in procedure. Usually, the participant is asked to generate only one item in response to the category cue. Here, we asked participants to generate five items because, with atypical exemplars, we felt this would be necessary in order to allow any priming effects to show up.

Method

Participants

Child participants in all experiments in this study attended government schools in predominantly middle class neighborhoods in Canberra, Australia. Adult participants were either first year undergraduate psychology students of the Australian National University (ANU), participating for course credit, or volunteers from the ANU community.
Experiment 1a participants comprised 15 children from Kindergarten (age range 5–7 years), 15 children from Grade 3 (age range 8–9 years), 15 children from Grade 5 (age range 10–13 years), and 15 adults (age range 17–37 years, $M = 20.9$ years). Thirty seven of the participants were female and 23 were male.

**Design/materials**

There were 40 target items in all, comprising two atypical exemplars from each of 20 common semantic categories (see Appendix A). These targets were divided into two sets (List A and List B). One set of 20 targets acted as the primed (studied) list and the second set acted as baseline (unstudied) targets from the same semantic categories. The role of each list as studied or unstudied was counterbalanced across participants, and priming was measured as the number of studied targets produced at test minus the number of unstudied targets.

**Selection of categories and exemplars.** Care was taken to ensure that each category, and both exemplars chosen from that category, were familiar even to Kindergarten children. Target items also had to be sufficiently concrete for pictorial representation in Experiment 2.

Where possible, atypicality of the target exemplars was ensured by selecting categories and items available in the Posnansky (1978) category norms for aurally presented items for children in Grades 2–6. The Posnansky norms provide a measure of category generation strength; that is, the percentage of children who produce a given exemplar to a given category name. For example, the exemplar frog of the category animal has a category generation strength of 4.8% making this a very atypical exemplar of the category (cf., dog was the most typical exemplar with a generation strength of 95.2%). Fifteen suitable categories were identified from these norms, the target items for which ranged in category generation strength from 1.6 to 23% ($M = 7.8\%$). A further three categories were selected using the Battig and Montague (1969) category norms for adults. Category generation strengths for items from these categories ranged from 2.5 to 9.7% ($M = 4.7\%$). Norms were not available for the final two categories, and target items from these categories were judged to be atypical exemplars by the first author. In assigning one exemplar from each category to List A and the other to List B, the degree of atypicality was matched across lists as far as possible.

**Study and test list construction.** The study list for each participant comprised the 20 studied target exemplars from either List A or List B as appropriate, plus 20 filler items (a total of 40 items). Filler items were included purely to allow “no” answers to the study phase questions (see Procedure) and were not exemplars of any category used at test. The test list contained 40 generation trials, comprising the 20 target categories, plus an additional 20 categories that bore no relationship to any item seen in the study phase.

**Procedure**

All participants were tested individually in a single half-hour session. Participants were given four practice trials prior to each phase of the experiment, with items and
categories not used in the experiment. Participants were then presented with one of six random orders of trials in the study phase and one of three random orders of trials in the test phase.

At study, stimuli were presented in a manner designed to directly emphasize the relevant conceptual aspects of each item, while minimizing the perceptual information provided about visual appearance. For each trial, participants were asked to think of the specified item (e.g., “Think of a frog” or “Think of a pram”). They were then required to respond yes or no verbally to a question about the conceptual properties of the item. For target exemplars, this question always regarded the category membership of the item (e.g., frog; “Is this an animal?”) and the correct answer was always yes. This ensured that the category membership of each target exemplar was positively activated at study. For fillers, a non-categorical conceptual question was asked (e.g., pram; “Can you mow the lawn with this?”) to which the correct answer was always no. (A category membership question was not used for filler items because we could not find enough non-target categories that were: familiar to Kindergarten children; clearly distinct from target categories; and not used at test.)

The study-test delay was approximately five minutes. During this period, distractor task trials required children to decide which line was the shortest of three, and adults to judge if two numbers ranging between 3 and 13 digits were the same or different.

At test, participants were read a category name (e.g., animal), and were asked to generate the first five items of that category which came to mind. All five responses given were recorded and the number of times a target was produced when it had been studied (primed) and unstudied (baseline) was scored.

A number of procedures were used with the aim of ensuring that priming scores reflected implicit, rather than explicit, memory. In addition to ensuring that only 50% of the categories presented at test were old (see Roediger & McDermott, 1993), it was emphasized to participants that “it did not matter what their responses were just as long as they named the first five items that popped into their heads.” Participants were informed that the total time to produce the items would be recorded, and could see the experimenter apparently timing them with a stopwatch (in fact, response times were not recorded). Further, participants in the two oldest age groups were given a brief memory strategies questionnaire at the end of the test phase to assess the possible role of explicit retrieval (cf., Bowers & Schacter, 1990; McKone & Slee, 1997). These participants were asked whether they were aware that some of the test items came from the study list and, more importantly, whether they deliberately tried to retrieve these items from the study list. Responses revealed that most participants were aware that some of the items they produced had been seen at study. However, none reported deliberately trying to recall these items.

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3 Since young children’s metamemory is extremely poor, it was unlikely that administering the post-test memory strategies questionnaire to children younger than 10 years would be informative.
Experiment 1a: Results

Performance on the study phase questions was evaluated in order to confirm (a) that the category membership of the target items was familiar even to Kindergarten children, and (b) that there was no response bias to say either “yes” or “no.” In all age groups, accuracy for target items (yes answers) was at least 17.4 out of 20 (M = 18.8); accuracy for filler items (no answers) was at least 19.0 out of 20 (M = 19.6).

In the test phase, responses consisted of the five items generated in response to each category cue. These were coded to give the number of studied targets produced and the number of baseline targets produced. The maximum score in each of these conditions was 20.

Table 1 presents mean primed (studied) and baseline (unstudied) target production rates, in addition to priming scores. Baseline performance was low as expected for atypical items and, as can be seen in Table 1, there was no suggestion that baselines increased progressively with age. Thus, an absolute measure of priming (priming = primed − baseline) was appropriate (Parkin, 1993).

Table 1 shows priming as a function of age. Clear age-related development is evident, and this was confirmed statistically. Throughout this paper, developmental trends were assessed via trend analysis rather than one-way analysis of variance, since the former technique has greater power for picking up increases with age. In the present experiment, there was a significant linear trend, F(1, 56) = 21.55, MSE = 3.21, p < .01, indicating that priming generally increased from Kindergarten through to adults. To confirm that development occurred across the full age range tested, each age group was also compared to its neighboring age group. Independent samples t tests confirmed that priming was significantly greater in Grade 3 than in Kindergarten, t(28) = 4.04, p < .01, and was significantly greater in adults than in Grade 5, t(28) = 2.55, p < .05, while the difference between Grade 3 and Grade 5 was not significant, t(28) = 1.18, p > .1.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Kindergarten</th>
<th>Grade 3</th>
<th>Grade 5</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studied</td>
<td>3.40 (1.80)</td>
<td>6.87 (1.85)</td>
<td>5.73 (1.53)</td>
<td>6.20 (1.93)</td>
</tr>
<tr>
<td>Unstudied</td>
<td>0.87 (0.83)</td>
<td>1.80 (1.37)</td>
<td>1.47 (1.13)</td>
<td>0.20 (0.41)</td>
</tr>
<tr>
<td>Priming</td>
<td>2.53 (1.73)</td>
<td>5.07 (1.71)</td>
<td>4.26 (1.98)</td>
<td>6.00 (1.73)</td>
</tr>
</tbody>
</table>

Mean number of target exemplars generated in response to the category cue for studied (i.e., primed) and unstudied (i.e., baseline) items. Priming calculated as studied − unstudied. Scores are out of 20. Standard deviations are given in brackets.

Note. All figures presented in tables are reported rounded to the nearest hundredth.
Thus, Experiment 1a demonstrated that priming in the category generation task clearly improved with age, with adults showing 2.5 times as much priming as 5-year-old children (Kindergarten) and 1.5 times as much priming as 11-year-old children (Grade 5). Note that the conditions under which this development occurred were: (1) the stimuli were atypical exemplars of the category; and (2) conceptual processing of category membership was required at both study and test.

Experiment 1b: Explicit memory

Experiment 1b was similar to Experiment 1a, but used explicit rather than implicit retrieval. At test, a category cued recall task was used to assess explicit memory performance. This task was chosen because it matches the implicit category generation task in all aspects, apart from the nature of the retrieval instructions given at test. Given that the explicit memory task used in Experiment 1b is a cued recall task (which is sensitive to strategy use), it was expected that performance would improve substantially across the age range tested (also see Perez et al., 1998). The specific aim of Experiment 1b was to confirm that age-related improvement does occur for the materials used in Experiment 1a, and to also gain some estimate of the magnitude of this development for the purposes of Experiment 1c. Only two age groups were tested (Kindergarten and adults). All aspects of the study phase and distractor phase were identical to Experiment 1a.

Method

Participants

The 30 participants comprised 15 children from Kindergarten (age range 4–5 years) and 15 adults (age range 18–43 years, $M = 23.5$). Fifteen of the participants were female and 15 were male.

Design/materials/procedure

All materials were identical to those in Experiment 1a. The procedure for Experiment 1b was also identical, except that an explicit cued recall task was substituted at test. On each test trial, participants were given a target category name (e.g., animal) and asked to recall the exemplar of that category which had been presented on the study list (e.g., frog). Participants were given as much time as they wanted to recall each item. To avoid distressing participants (especially Kindergarten children) by demanding recollection from categories for which no items had been seen, explicit memory was tested only for the 20 categories used at study. (This procedure differed slightly from the implicit memory condition of Experiment 1a, in which participants were tested on the 20 studied categories plus 20 unrelated filler categories.)
Experiment 1b: Results

In all age groups, accuracy on the study phase questions was at least 17.8 out of 20 for target items and 19.4 out of 20 for filler items. This again confirmed appropriate activation of category membership at study.

Using the same procedure as for priming scores in Experiment 1a, explicit cued recall scores were calculated as the number of correctly recalled studied exemplars minus the number of falsely recalled baseline exemplars (in fact, false recall was zero for all participants). Results showed strong age-related development of explicit memory for category-based conceptual information. As can be seen in Table 2, cued recall performance was nearly twice as good for adults as for Kindergarten children, and this difference was highly significant, $t(28) = 5.97, p < .01$. This pattern replicates findings of many studies showing development of explicit memory in free and cued recall tasks.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Kindergarten</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studied</td>
<td>8.47 (3.34)</td>
<td>15.27 (2.89)</td>
</tr>
<tr>
<td>Unstudied</td>
<td>0.00 (0.00)</td>
<td>0.00 (0.00)</td>
</tr>
<tr>
<td>Cued recall</td>
<td>8.47 (3.34)</td>
<td>15.27 (2.89)</td>
</tr>
</tbody>
</table>

Mean number of target exemplars recalled in response to the category cue for studied (i.e., primed) and unstudied (i.e., baseline) items. Cued recall calculated as studied − unstudied. Scores are out of 20. Standard deviations are given in brackets.

Experiment 1c: Divided attention at study

Experiment 1a demonstrated that priming for atypical category exemplars increased with age from 5 years to adulthood. Using the same stimuli, cued recall was also shown to improve over the same age range in Experiment 1b. Thus, although no participants in Experiment 1a reported using explicit retrieval on the memory strategies questionnaire, it might still be argued that the increase in priming simply reflected contamination from the use of explicit memory by older participants. Experiment 1c was designed to confirm that the age-related improvement of priming scores found in Experiment 1a genuinely reflected the development of implicit memory.

The approach taken in Experiment 1c was to reduce adults’ explicit memory to the Kindergarten level obtained in Experiment 1b. Introducing divided attention at study for adult participants did this. Previous studies agree that dividing attention
in adults has no effect on priming but substantially impairs explicit memory (e.g., Parkin et al., 1990; Parkin & Russo, 1990; Russo & Parkin, 1993) and this pattern of effects has been found specifically with priming for conceptual information in a category-exemplar generation task (Isingrini, Vazou, & Leroy, 1995).

To divide attention in Experiment 1c, adult participants performed a digit monitoring task simultaneously with the study task. A pilot test was used to ensure that the digit monitoring task was difficult enough to reduce adults’ explicit memory performance to the level of Kindergarten children (with full attention). Adult levels of implicit memory were then re-assessed with the same divided attention study phase, and the findings compared to the implicit memory results found in Experiment 1a. Under these conditions, a demonstration that priming in adults still exceeds that obtained for Kindergarten children in Experiment 1a would provide direct evidence that explicit memory contamination was not responsible for the developmental trend revealed in that experiment.

Method

Participants and design

Data analyzed in Experiment 1c came from a total of 90 participants, with 15 per condition. For the implicit full attention conditions, the Experiment 1a data for Kindergarten children and adults were re-used (19 females, 11 males). For the explicit full attention conditions, the Experiment 1b data for Kindergarten children and adults were re-used (15 females, 15 males). A new group of 30 adult participants (22 females, 8 males) was selected for the adult implicit divided attention and adult explicit divided attention conditions \( n = 15 \) per condition; age range 17–40, \( M = 21.3 \).

Materials and procedure

Stimuli used in Experiment 1c were the same as those used in Experiments 1a and 1b. The only change in procedure was the introduction of divided attention at study. At study, participants in the two new divided attention conditions (implicit and explicit) were required to perform a digit monitoring task simultaneously with the study task. Because the primary task (category membership decisions) involved auditory presentation, the digit monitoring task was presented visually. Digits were presented using PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993) on a Macintosh computer. A continuous stream of single digit numbers ranging from 1 to 9 was presented in random order at a rate of 1 s per item. Participants were required to press the spacebar on the keyboard every time three odd numbers or three even numbers appeared in succession (e.g., for \( ... 4, 1, 3, 5, 7, 9, 2, ... \), a response was required after 5, again after 7, and again after 9), thus forcing the participant to attend to three successive trials at all times. To ensure that participants were indeed dividing their attention between tasks, and not shifting their attention from one to the other, they were instructed to respond to each category membership
question within one second, and questions were presented at the same rate in the divided attention conditions as in the full attention conditions of Experiments 1a and 1b. Five participants (three explicit, two implicit) appeared to be deliberately shifting their attention from one task to the other, as evidenced by extremely slow responses to the category membership questions. These participants were replaced.

At test, the procedure was identical to Experiment 1a for the adult divided attention implicit memory group, and to Experiment 1b for the adult divided attention explicit memory group. On the post-test memory strategies questionnaire, none of the participants in the implicit memory group reported deliberately retrieving items from the study list.

**Experiment 1c: Results**

Study phase performance on the primary task was as good in the divided attention conditions ($M = 19.4$; score out of $20$) as in the full attention conditions ($M = 19.6$; score out of $20$), confirming that adult participants were correctly activating category membership of the target items even with divided attention. Responses to the digit monitoring task were then checked to ensure that participants in the divided attention conditions were not simply ignoring the secondary task. Mean digit monitoring accuracy was $84\%$ ($SD = 17\%$) for adults tested under implicit memory conditions and $85\%$ ($SD = 12\%$) for adults tested under explicit memory conditions. Thus, performance on the secondary task was good and, more importantly, did not differ between the implicit and explicit groups. Overall, both the category membership decision task and the digit monitoring task indicate that participants were successfully dividing their attention to produce adequate performance on both the primary and secondary tasks.

Table 3 shows the mean number of target items generated in the two new divided attention conditions, when studied (primed) and unstudied (baseline). Baseline per-

<table>
<thead>
<tr>
<th>Memory condition</th>
<th>Implicit</th>
<th>Explicit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studied</td>
<td>5.20</td>
<td>7.93</td>
</tr>
<tr>
<td></td>
<td>(2.04)</td>
<td>(3.58)</td>
</tr>
<tr>
<td>Unstudied</td>
<td>0.20</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>(0.41)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Priming/recall</td>
<td>5.00</td>
<td>7.93</td>
</tr>
<tr>
<td></td>
<td>(1.77)</td>
<td>(3.58)</td>
</tr>
</tbody>
</table>

Mean number of target items generated in response to the category cue for studied (i.e., primed) and unstudied (i.e., baseline) items, for adult participants tested under divided attention conditions. Priming (implicit memory) calculated as studied – unstudied. Recall (explicit memory) calculated as studied – unstudied. Scores are out of 20. Standard deviations are given in brackets.
formance did not vary as a function of either age or attention condition (cf. Table 1 from Experiment 1a and Table 2 from Experiment 1b). Implicit memory scores were therefore calculated in the same way as in Experiment 1a (i.e., priming = primed − baseline). Explicit memory scores were calculated in the same way as in Experiment 1b (i.e., cued recall = number of correctly recalled studied items − falsely recalled baseline items).

**Effect of dividing attention on explicit memory.** Fig. 1a shows mean cued recall scores under divided attention, compared to the full attention conditions taken from Experiment 1b. It can be seen that dividing attention at study substantially impaired explicit memory in adults, reducing their mean recall score to slightly below that of the Kindergarten children with full attention. Independent samples t tests confirmed that explicit memory in adults was significantly lowered compared to their mean in the full attention condition, $t(28) = 6.18, p < .01$, and that their performance with divided attention did not differ significantly from that of Kindergarten children with full attention, $t(28) < 1$. These findings demonstrate that dividing attention at study successfully removed all age advantage for adults in explicit memory.

**Effect of dividing attention on implicit memory.** With the adults’ age advantage in explicit memory removed, it was possible to examine whether dividing attention correspondingly removed the age advantage in the implicit memory task. Fig. 1b shows priming under divided attention conditions in comparison to the full attention conditions taken from Experiment 1a. It can be seen that the effect of dividing attention at study was much less severe for the priming task than it was for the cued recall task. Independent sample t tests revealed that priming in adults was not significantly reduced by the divided attention manipulation, $t(28) = 1.56, p > .1$, and that it remained significantly above that of Kindergarten children, $t(28) = 3.86, p < .01$. These findings show that implicit memory increased with age even when there was no explicit memory advantage in adults. This provides direct experimental evidence

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Fig. 1. Effects of divided attention as a function of age group for (a) a category cued recall task (explicit memory), and (b) a category-exemplar generation task (implicit memory). Maximum score is 20.
that the development attributed to implicit memory in Experiment 1a did not reflect explicit contamination of the priming scores but, instead, was genuinely implicit.

**Experiment 1 Discussion**

Experiment 1 examined memory for category-based conceptual information using atypical category exemplars. As expected, explicit memory developed with age using these materials. The major finding, however, was a clear demonstration that implicit memory also increased with age. In terms of the previous literature using the category exemplar generation task, this finding confirms Perruchet et al.’s (1995) suggestion that age-related development of priming can occur for atypical category exemplars. Our results differ from those of Greenbaum and Graf (1989), Anooshian (1997), and Perez et al. (1998), but as discussed earlier these studies failed to report exemplar typicality (and, in the first case, tested only a very small age range of 3- to 5-year-olds). It should also be noted that the present study is the first to demonstrate that the development obtained with atypical category exemplars is genuinely implicit. While Perruchet et al. reported development of priming, no attempts were made to demonstrate that the development found was not due to explicit memory contamination.

Turning to the theoretical implications of the results, the finding that implicit memory can develop with age immediately discounts the memory systems account of implicit–explicit dissociations in childhood. This theory (e.g., Naito, 1990) claims that a basic capacity for implicit memory matures early, while an explicit memory system matures late. The present results provide a clear counter-example to the first part of this claim: priming increased substantially not only beyond 5 years of age, but even beyond age 10. Thus, implicit memory can be “late developing,” with improvement apparent over a similar age range to explicit memory.

In terms of the “four factors” approach to memory development in childhood, the development revealed on the explicit test used in Experiment 1b (category-cued recall) could have its origins in any or all of the four factors: strategies and their control through metamemory can operate in recall tasks; the underlying knowledge base tested was developing with age; and any increase in basic capacity would also contribute to age effects. With respect to implicit memory, however, the situation is very different. Although we have shown here that implicit memory can be “late developing,” we would hardly want to suggest that a basic capacity for implicit memory increases beyond age 5 (given that in other circumstances no development is observed). It also seems highly unlikely that strategies and/or metamemory could be responsible for our age effects on priming. It is generally accepted that, at retrieval, implicit memory relies on automatic rather than strategic processes (Jacoby, 1991); moreover, our finding that implicit memory still developed even when adults were given divided attention at study (Experiment 1c) suggests that strategic processing at encoding was not a contributing factor. In terms of the four factors approach, therefore, this leaves us with only one reasonable interpretation of the development of implicit memory obtained in Experiment 1, namely that it arose because the underlying knowledge base for atypical categorical relationships was developing with age.
Experiment 2: Perceptual form of common objects

Experiment 1 revealed improvement with age of implicit (and explicit) memory for conceptual knowledge of atypical category relations. In Experiment 2, we tested the same items as in Experiment 1, but now presented them as pictures of common objects. Both study and test tasks emphasized perceptual (i.e., appearance-based) aspects of the stimuli rather than conceptual aspects, and there was no reference made to the taxonomic category, semantic associations, or function of the item. All items used can be found in young children’s picture books, arguing that the perceptual form of these objects should be well represented by the age of 5 years. Our presumption was, therefore, that the knowledge base tested in Experiment 2, unlike that tested in Experiment 1, was developmentally stable across the age range employed.

Experiment 2a: Implicit memory

The study task in Experiment 2a required participants to judge the orientation of pictures as upright or upside-down; this task requires reference to knowledge of the standard form of the object depicted and is thus perceptual in nature. The implicit test task was degraded picture naming. Perceptual processing also drives this task, in that it requires matching the degraded image to an internal representation of object shape.

An important design feature of Experiment 2a was that baseline performance was experimentally equated across age groups. In all previous studies using a naming degraded objects task, performance in the unprimed condition improved steadily across groups, leading to substantial debate (e.g., Drummey & Newcombe, 1995; Komatsu et al., 1996; Parkin, 1993; Russo et al., 1995) about whether priming should be calculated in absolute terms (i.e., priming = primed accuracy − baseline accuracy), or in relative-to-baseline terms. In the present experiment, we avoided this issue by varying the degradation level across age groups to match baseline accuracy across all ages. This involved, for example, deleting fewer pixels from the image for Kindergarten children than for adults. The specific degradation levels necessary were determined using pilot testing. Under conditions of matched baselines, absolute and relative measures of priming necessarily lead to the same conclusion regarding development.

Method

Participants

The 60 participants comprised 15 children from Kindergarten (age range 5–6), 15 Grade 3 children (age range 8–9), 15 Grade 5 children (age range 10–11), and 15 adults (age range 17–37 years, M = 22.7). Thirty three of the participants were female and 27 were male.
Design

Implicit memory was assessed for each of the four age groups using tasks requiring perceptual processing (i.e., identification of common objects) at both study and test. At study, participants were asked to determine whether a line drawing of each item was presented upright or upside down. At test, participants were asked to name briefly presented versions of the pictures seen at study, which had been degraded by removal of pixels (a random 84, 89, 90, and 91% of pixels removed for Kindergarten, Grade 3, Grade 5, and adults, respectively). These were mixed with degraded pictures of unstudied objects.

Materials

List A and List B target items from Experiment 1a (see Appendix A) were again counterbalanced across the primed and baseline conditions for different participants. For the purposes of the perceptual tasks, each item was represented as a line drawing, taken from the Snodgrass and Vanderwart (1980) set where possible. Targets not depicted in this set were drawn by the first author in a similar style. All target items were shown upright at both study and test. Drawings of the filler items used in the study phase were all available from the Snodgrass and Vanderwart (1980) set, and were shown upside down.

Procedure

The procedure of Experiment 2a was similar to that for Experiment 1a, with the exception of the change to perceptual study and test tasks. At study, pictures were presented using PsyScope software (Cohen et al., 1993) on a Macintosh computer. Participants were told what the upcoming trial would depict (e.g., “I am going to show you a picture of a frog”) and were then told they would have to make a decision regarding its orientation (“Is it the right way up?”). The picture was then presented in the center of the screen for two seconds, with no degradation. Participants responded orally. The correct answer was yes (upright) for all target items, and no (upside down) for all filler items.

At test, 40 trials (all List A items plus all List B items) were presented on a computer in one of three random orders. On each trial, participants were required to focus on a central fixation point and the experimenter pressed a key to present a degraded picture. The degraded picture was presented for 100 ms and participants were required to name it as quickly as possible, guessing if they had to. Brief presentation of test cues was used in order to limit the chances of explicit contamination (Weldon, 1993). Once presented, the name given to each item was recorded (reaction time was not) and the number of times a target was correctly named when it had been primed (studied) and unprimed (baseline) was scored.

A number of procedures were used to ensure that the priming scores reflected implicit rather than explicit memory. If Kindergarten and Grade 3 children did not respond with an item’s name within 2 s, and Grade 5 children and adults did not
respond within 1.5 s, the trial was taken to be an error. These short cutoff times were used to encourage the participants to give the first response they thought of and to prevent them having enough time to deliberately retrieve an answer from the study phase of the experiment. At the end of the test phase, participants in the Grade 5 and adult groups were given a memory strategies questionnaire. None of the participants reported deliberately retrieving items from the study list.

Experiment 2a: Results

Performance on the study questions was evaluated in order to confirm that the perceptual form of the target items had been correctly activated. In all age groups, accuracy to recognize targets as upright was at least 19.2 out of 20, and to recognize fillers as upside-down was at least 19.4 out of 20.

Implicit test phase data consisted of the number of correctly named degraded target items, and the number of correctly named degraded baseline items. Table 4 presents means of these values, as well as priming scores, as a function of age. First, it can be seen that reducing the level of picture degradation successfully raised baseline performance in each age group to the same level as that for adults. Trend analysis failed to find any significant linear trend of age on baseline scores, \( F < 1, \, MSE = 3.46 \). Second, Table 4 shows that there was no increase of perceptual priming with age.

The observation of no development in priming was supported using a number of statistical methods. Trend analysis on the priming scores revealed no significant linear effect of age, \( F(1, 56) = 1.8, \, MSE = 4.46, \, p > .1 \). In order to confirm that this lack of development was unlikely to reflect a Type II error, confidence intervals on the slope of the developmental trend were calculated. This was done via a regression analysis whereby the exact age of each subject (rather than age grouping) was used to predict priming scores. This analysis revealed 95% confidence intervals that included both negative slopes (lower bound = a decrease of 0.021 absolute priming

<table>
<thead>
<tr>
<th>Table 4</th>
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</thead>
<tbody>
<tr>
<td><strong>Experiment 2a (degraded picture naming)</strong></td>
</tr>
<tr>
<td>Age group</td>
</tr>
<tr>
<td>Studied</td>
</tr>
<tr>
<td>Unstudied</td>
</tr>
<tr>
<td>Priming</td>
</tr>
</tbody>
</table>

Mean number of target names correctly generated in response to the degraded picture cue for studied (primed) and unstudied (baseline) items. Priming calculated as studied – unstudied. Scores are out of 20. Standard deviations are given in brackets.
units per year of age) as well as positive slopes (upper bound = an increase of 0.128 units per year). Thus, priming in the object identification task remained developmentally stable with age.

**Experiment 2b: Explicit memory**

Experiment 2b assessed the development of memory in an explicit analogue of the degraded picture naming task. Participants were briefly presented with degraded pictures at test. The task was to identify if the item was old or new (i.e., old–new recognition) and, if it was identified as old, the participant was asked to name it. This task is directly comparable to the implicit version of the degraded picture naming task of Experiment 2a; the only difference was that the object was named only if it was “old.”

According to the “four factors” approach, Experiment 2b minimizes three of the four possible sources of development in explicit memory. The choice of recognition reduces the emphasis on strategies and metamemory in comparison to either free recall or cued recall. The choice of perceptual information for common objects also implies a stable underlying knowledge base for these items. This leaves only an age-related improvement in a basic capacity as a source of possible development. Although some previous studies have found that perceptual explicit memory can remain stable with age (e.g., Kilburg & Siegel, 1973; Perez et al., 1998), it is commonly presumed that a basic capacity for explicit memory develops with age, and the memory systems account of implicit/explicit dissociations certainly argues that an explicit basic capacity continues to improve beyond age 5 years. Thus, the systems account (Naito, 1990) would predict development in the present experiment, despite the minimisation of all other contributing factors.

**Method**

**Participants**

Only two age groups were tested. The 30 participants comprised 15 Kindergarten children (age range 5–6) and 15 adults (age range 18–38, \( M = 20.5 \) years). Nineteen of the participants were female and 11 were male.

**Design/materials/procedure**

All aspects of the experiment were the same as for the implicit condition in Experiment 2a, with the exception of the response required at test. Test stimuli were presented exactly as in the implicit conditions (i.e., pictures were presented for 100 ms at 84% pixel degradation level for Kindergarten children and 91% for adults) but participants were now required to identify whether the stimuli were old or new, and then to name the items identified as old. No time limit on response was enforced. The number of studied and baseline items correctly named was recorded.
Experiment 2b: Results

At study, accuracy to recognize target items as upright was at least 19.2 out of 20 in all age groups. Accuracy to recognize filler items as upside down was at least 18.2. With respect to test phase performance, Table 5 shows the number of pictures correctly claimed to be old and correctly named in the perceptual explicit test, for studied items and baseline items. Analysis of baseline performance (i.e., falsely naming a new item) revealed no significant difference with age, \( t(28) = 1.96, p > .06 \). More importantly, no age-related development of explicit memory for perceptual information was found, \( t < 1 \), with mean memory scores (i.e., studied – unstudied) almost identical for Kindergarten children and adults (see Table 5). A less strict coding of the data, where a response was considered correct if the participant correctly recognized the item as old even if they could not name it, produced the same result, with mean recognition scores (i.e., hits–false alarms) of 13.7 for Kindergarten children and 13.8 for adults.

These results show, therefore, no development of explicit memory. This is similar to the findings of several previous studies that have assessed performance in picture recognition tasks (e.g., Brown & Campione, 1972; Kilburg & Siegel, 1973).

Discussion

The results of Experiment 2 have implications for both implicit and explicit memory in childhood. In the implicit test (Experiment 2a), no development of priming was found for perceptual information about common objects. This is the same conclusion drawn by most of the previous studies testing priming in object naming, but can be considered more convincing because, for the first time, baseline performance in this task was experimentally equated across age groups. Theoretically, our finding is consistent with the idea that when the underlying knowledge base is stable, priming fails to develop with age. This can be contrasted with the results of
Experiment 1a, where the knowledge base was developing and an age-related increase in priming was found for the same target items.

A second outcome of Experiment 2 was the finding that explicit memory showed no development with age (Experiment 2b). This finding contrasts with a common presumption in the developmental literature—and certainly in the memory systems account of implicit/explicit memory dissociations in children—that a basic capacity for explicit memory develops throughout childhood. Note that in the present experiment, all other obvious sources of development were minimized. The knowledge base tested was developmentally stable. The test task was a variant of simple old–new recognition, and so was likely to place, in comparison to cued recall or free recall tasks, only weak emphasis on strategic factors at retrieval. Moreover, the study phase required a simple judgment of picture orientation, also suggesting a weak emphasis on strategic factors at encoding. However, if it were the case that a basic capacity for explicit memory increased throughout childhood, then despite the removal of all other contributing factors, an age-related improvement in explicit memory would necessarily still be obtained. Our opposing finding suggests that, in contradiction to the general presumption, there is no basic capacity development of explicit memory beyond 5 years of age.

Taking the results of Experiments 1 and 2 together, an important implication emerges for the origin of implicit–explicit dissociations in childhood. In particular, the memory systems account of developmental patterns has now been refuted via two counter-examples: in Experiment 1 we found that implicit memory performance could improve throughout childhood; in Experiment 2 we found that explicit memory performance can sometimes be developmentally stable from 5 years of age. These patterns are exactly the reverse of those predicted by the view that implicit memory is an “early” developing system, while explicit memory is a “late” developing system.

**Experiment 3: Conceptual associative knowledge**

Experiment 3 tested implicit and explicit memory for associative relationships (e.g., rabbit–carrot). As argued in the introduction, knowledge of associative relations appears to be largely intact in young children (Bjorklund & de Marchena, 1984; Bjorklund & Jacob, 1985; Frankell & Rollins, 1985). Like Experiment 1, Experiment 3 assesses a circumstance for which processing is conceptual. Unlike Experiment 1, however, the relevant knowledge base is stable across the age range tested.

To allow comparison between our two conceptual priming experiments, Experiment 3 was as similar as possible to Experiment 1. The target items of Experiment 1 were re-used wherever possible (32 out of 40 items in common). Since the categorical relationships employed in Experiment 1 were atypical (e.g., animal–frog), so too were the associative relationships used in Experiment 3: for example, the target frog was cued via the weak associate green. Finally, we used tasks requiring the subject to internally generate items at retrieval in both experiments: in Experiment 1, memory was assessed by either category generation (implicit) or category-cued recall
In terms of predicted outcomes, we have argued so far that the patterns of implicit memory development revealed in Experiments 1 and 2 can be attributed to the state of the knowledge base tested (developing in Experiment 1 vs. stable in Experiment 2). If this analysis is correct, then in Experiment 3 we would expect to observe no age-related increase in priming, given the stable underlying knowledge domain. Alternatively, our Experiment 1 and 2 findings could be seen to be consistent with a conceptual vs. perceptual processing account: specifically, when conceptual processing was tested (Experiment 1) both implicit and explicit memory improved with age; when perceptual processing was tested (Experiment 2), in contrast, both remained stable with age. If this latter interpretation were correct—that is, if it is conceptual processing rather than a developing knowledge base that produces greater priming with age—then implicit memory should show age-related improvement for the conceptual task used in Experiment 3.

**Experiment 3a: Implicit memory**

Experiment 3a tested implicit memory in an associate-generation task. All four age groups were tested (Kindergarten, Grade 3, Grade 5, and adults). At study, participants were presented with items that were semantically associated with, but not categorically related to, a cue word (e.g., *frog* for the cue word *green*) and were asked to judge whether the words were associated with each other (e.g., “Does frog go with the word green?”). At test, an associate-generation task, requiring five responses, was used to test implicit memory (e.g., “Tell me the first five things that you can think of that go with the word green”).

**Method**

**Participants**

A total of 60 participants comprised 15 children from Kindergarten (age range 5–6 years), 15 children from Grade 3 (age range 8–9 years), 15 children from Grade 5 (age range 10–11 years), and 15 adults (age range 18–36 years, $M = 21.5$). Thirty one of the participants were female and 29 were male. A further 10 adults were pilot tested to select stimuli.

**Materials**

As far as possible, the target items in Experiment 3a were the same as those selected for Experiment 1a. There were 40 target items in all, which comprised two atypical associates for each of 20 cue words. The 40 target items were again divided into two sets (List A and List B), which were counterbalanced across participants with respect to primed or baseline status.
Selection of cue words and associates. Experiment 3a had in common 32/40 target items with Experiment 1a (see Appendix A for full list). For example, in Experiment 1a the targets frog (List A) and crocodile (List B) were both cued as atypical exemplars of the category animal. For the purposes of Experiment 3a, we required a cue word that was weakly associated to both targets. These cues (e.g. green for the pair frog and crocodile) were initially selected by the first author. To confirm selection, 10 adult pilot participants were (a) given each cue word (e.g., green) and asked to generate the first five words that came to mind in association to this cue, and then (b) from a list of several words, to circle any items they believed to “go with” the cue word (e.g., green: toaster, penguin, frog, eyebrow, etc.) Associative weakness was indicated if the target items (frog or crocodile) were not spontaneously generated as responses in the first task, but were confirmed as associates in the second task. To meet these criteria, eight of the target items from Experiment 1a needed to be changed.

Study and test list construction. The study list for each participant included a total of 40 items, comprising the 20 target associates of either List A or List B as appropriate, plus 20 filler items. None of the filler items was associated with any of the cue words used in the experiment. The test phase consisted of 40 generation trials, comprising the 20 target cues (e.g., green) plus an additional 20 cue words (e.g. jewelry) which had no relationship to any item seen in the study phase.

Procedure

The procedure of Experiment 3a was similar to that for Experiment 1a. At study, stimuli were presented in a manner designed to emphasize the conceptual associative aspects of each item. Participants were asked to think of the specified item (e.g., “Think of a frog” or “Think of a cake”). They were then required to respond yes or no verbally to a question about whether the item was associated to a cue word. For target items, the correct answer was always yes (e.g., frog, “Does it go with the word green?”). This ensured that the associative link between the target item and the cue was positively activated at study. For fillers, the correct answer was always no (e.g., cake, “Does it go with the word calendar?”).

For each trial at test, participants were read a cue word (e.g., green or jewelry), and were asked to generate the first five items that came to mind that were associated with that word. All five responses were recorded and the number of times a target was produced when it had been studied (primed) and unstudied (baseline) was scored. On the post-test memory strategies questionnaire, none of the Grade 5 or adult participants reported deliberately trying to recall study list items.

Experiment 3a: Results

Performance on the study questions was evaluated in order to confirm that the associations between target and cue words were familiar to all participants, and that
there was no response bias to say either “yes” or “no.” In all age groups, accuracy was at least 18.4 out of 20 for targets and 18.8 for filler items.

The test phase responses consisted of the five items generated in response to each associative cue. These were coded to give the number of primed (studied) targets and the number of baseline (unstudied) targets produced. The maximum score in each condition was 20.

Table 6 presents mean primed and baseline scores, and also includes priming scores. Trend analysis on the baseline scores revealed no significant linear trend with age, $F < 1$, $MSE = 0.45$. When examining the implicit memory scores (i.e., priming = primed − baseline) as a function of age, it can be seen that there was no developmental increase for conceptual associative priming and trend analysis confirmed that there was no significant linear trend with age, $F < 1$, $MSE = 3.84$.

Comparison of Experiments 1a (category cues) and 3a (associative cues). Experiment 1a found that category-based conceptual implicit memory increased strongly with age, whereas Experiment 3a failed to find any such development for associate-based conceptual implicit memory. As noted in the Method section above, however, 8 of the 40 target items used in Experiment 1a needed to be changed in Experiment 3a. Thus, it could perhaps be argued that the conflicting results found in the two conceptual priming experiments were due to the partially different stimulus sets used, and not the associative vs. categorical nature of the relationship to the cue. For this reason, the data from both Experiments 1a and 3a were recoded to include only stimuli that were tested in both experiments (i.e., the 32 overlapping items). Fig. 2 presents these recoded priming scores.

Trend analysis conducted on the recoded data of Experiment 1a still found a significant linear trend with increasing age, $F(1, 56) = 16.13$, $MSE = 2.59$, $p < .01$. Analysis of the recoded priming scores of Experiment 3a again found no linear effect of age, $F(1, 56) < 1$, $MSE = 2.98$. A two-way ANOVA was then conducted on the priming data from Experiments 1a and 3a and the interaction between Age group

<table>
<thead>
<tr>
<th>Age group</th>
<th>Kindergarten</th>
<th>Grade 3</th>
<th>Grade 5</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studied</td>
<td>3.93 (1.94)</td>
<td>5.00 (2.17)</td>
<td>3.73 (1.28)</td>
<td>4.00 (2.10)</td>
</tr>
<tr>
<td>Unstudied</td>
<td>0.33 (0.49)</td>
<td>0.33 (0.72)</td>
<td>0.67 (0.82)</td>
<td>0.33 (0.62)</td>
</tr>
<tr>
<td>Priming</td>
<td>3.60 (2.03)</td>
<td>4.67 (2.35)</td>
<td>3.07 (1.22)</td>
<td>3.67 (2.06)</td>
</tr>
</tbody>
</table>

Mean number of target items generated in response to the associative cue for studied (primed) and unstudied (baseline) items. Scores are out of 20. Priming calculated as studied − baseline. Standard deviations are given in brackets.
and Experiment was found to be significant, $F(3, 112) = 3.91$, $MSE = 2.79$, $p < .02$, confirming the difference in pattern. Given that there were now no item differences between these two sets of data, these analyses confirm the conclusion that conceptual priming in a category generation task increases with age, but that conceptual priming in an associate generation task for the same items is developmentally stable. These results are consistent with the idea that implicit memory improves with age only when the underlying knowledge base is developing.

**Experiment 3b: Explicit memory**

Experiment 3b assessed the development of explicit memory for associate-based information, using an associate cued recall task. Only two age groups were tested (Kindergarten and adults). Unlike the recognition memory task used in Experiment 2b, this cued recall task is likely to involve the use of strategies. Thus, it might be expected that explicit memory performance in Experiment 3b would improve with age, despite the stable underlying knowledge base. Given that all other aspects of Experiment 3b were the same as the implicit version in Experiment 3a, any development found here would clearly dissociate implicit and explicit memory (unlike much of the previous developmental literature on implicit vs. explicit memory which confounded the nature of retrieval with the type of processing undertaken).
Method

Participants

The 30 participants comprised 15 children from Kindergarten (age range 5–6 years) and 15 adults (age range 18–38 years, $M = 22.2$). Twenty three were female, seven were male.

Materials/procedure

All materials were identical to those used in Experiment 3a. The procedure for Experiment 3b was also identical, with the exception of the change to an explicit cued recall task at test. Participants were given the associative cue (e.g., green) and asked to recall the corresponding target item from the study list, with no time limit on response. As in Experiment 1b, memory was tested only for the 20 target cues.

Experiment 3b: Results

Study phase responses confirmed that Kindergarten children knew that the target items were associated with their relevant cues, with an accuracy of at least 18 out of 20 in both age groups. Accuracy for filler items was also at least 18.8 out of 20 for both age groups.

At test, explicit memory scores in the associate cued recall task were calculated as the number of correctly recalled target items minus falsely recalled baseline items (false recall of target items was again zero for all participants). Results showed strong age-related development of explicit memory. Recall performance was more than twice as good for adults ($M = 16.53$, $SD = 2.97$) as for Kindergarten children ($M = 7.33$, $SD = 2.99$), and this difference was highly significant, $t(28) = 8.45$, $p < .01$.

Comparison of Experiment 3a (implicit) and 3b (explicit). In the present experiment, age-related development of conceptual associative explicit memory was found, with adults showing substantially better cued recall than Kindergarten children. In contrast, Experiment 3a failed to find any such development of associate-based conceptual implicit memory. This pattern is illustrated in Fig. 3. Using Kindergarten and adult groups only, a $2 \times 2$ between groups ANOVA confirmed the steeper developmental trend in the explicit memory condition relative to the implicit memory condition by showing a significant interaction between Age group and Memory condition, $F(1, 56) = 47.86$, $MSE = 6.54$, $p < .001$. This finding confirms the dissociation between explicit and implicit memory for associate-based conceptual information.

Comparison of Experiment 1b (category cue) and 3b (associative cue). The explicit memory development for associative information found in Experiment 3b was then compared to the explicit memory development for category-based information found in Experiment 1b. Data in Experiments 1b and 3b were recoded to include only the
Fig. 3. Comparison of implicit (Experiment 3a) and explicit (Experiment 3b) memory performance of associate-based information as a function of age group. Maximum score is 20.

Fig. 4. Recoded cued recall scores as a function of age group for both Experiment 1b (category-based) and 3b (associate-based). Maximum score is 20.
32 stimuli that were common to both experiments. Fig. 4 presents cued recall scores for the results of both Experiment 1b and 3b for these items. Using an independent samples t test on the recoded data of Experiment 1b, it was found that adult participants \(M = 12.07, SD = 2.9\) still recalled significantly more category exemplars than Kindergarten children \(M = 6.73, SD = 2.8\), \(t(28) = 7.21, p < .01\). Analysis of the recoded associative recall scores of Experiment 3b, also revealed significantly higher recall scores in adults \(M = 12.80, SD = 3.1\) than Kindergarten children \(M = 5.67, SD = 2.2\), \(t(28) = 5.11, p < .01\). Further, an ANOVA found no two-way interaction between Age group and Experiment, \(F(1,56) = 1.57, MSE = 7.74, p > .2\). Thus, results show that strong development of explicit memory occurred for both category-based conceptual information (Experiment 1b) and associative-based conceptual information (Experiment 3b).

**Experiment 3 Discussion**

Experiment 3 examined memory for associate-based conceptual information. With respect to implicit memory, we found no effect of age on priming (Experiment 3a). This result supports our contention that implicit memory improves with age if, and only if, the underlying knowledge base develops with age. It contradicts, however, the processing account idea that implicit memory might develop for conceptual information per se (Komatsu et al., 1996; Perez et al., 1998; Perruchet et al., 1995).

With respect to explicit memory, we observed strong age-related development (Experiment 3b). In terms of a “four factors” approach, we have previously discounted any basic capacity increase for explicit memory (see Experiment 2) and, in the present case, there were no knowledge base developments. This therefore leaves the observed improvement as being attributable to the development in strategic processing across childhood.

Finally, results of Experiment 3 demonstrated a clear implicit–explicit dissociation in development. Given the close matching of the implicit and explicit tasks, this dissociation could not be attributed to confounds with other factors (e.g., perceptual vs. conceptual processing, or stable vs. developing knowledge base). Given that implicit memory is not influenced by strategic factors at any age, we argue that this dissociation has its origin in differential reliance of implicit and explicit retrieval on strategy use and/or metamemory.

**Discussion**

In previous developmental studies, the standard finding has been that explicit memory improves across childhood, but implicit memory does not. In attempting to explain this dissociation, researchers have used theories appropriated from the adult literature on implicit memory. The theoretical framework of the more established developmental explicit memory literature has largely been ignored. A major
advance of the present study, therefore, has been its adoption of a developmentally
driven framework. This approach has produced important new empirical findings,
with corresponding implications for theories of implicit and explicit memory, both
in children and in adults.

Evaluating current theories of developmental implicit–explicit dissociations

Two theories of implicit–explicit dissociations in children have been considered in
the previous literature. The results of the present study have contradicted both of
these proposals.

The memory systems account (e.g., Naito, 1990) suggested that explicit memory
performance improves throughout childhood because there is a late-developing ex-
licit system, while implicit memory performance is stable from approximately 3
years of age because an implicit system matures early. While it is difficult to measure
an underlying system directly, the pattern of behavioral dissociation in the previous
literature was at least consistent with this account. In the present study, however, we
showed that implicit memory performance can develop “late” (i.e., increase even be-
yond 10 years of age), while intact explicit memory can emerge “early” (i.e., reach
adult levels in 5-year-olds). These results clearly discount a memory systems theory,
at least in any version where systems are proposed to differ in rate of maturation la-
ter than 5 years of age.

The alternative perceptual vs. conceptual processing account (e.g., Blaxton, 1989)
suggested that the standard developmental dissociation between implicit and explicit
memory is attributable to confounds with the perceptual (appearance-based) vs. con-
ceptual (meaning-based) nature of processing. Even in the previous literature, several
findings were inconsistent with this interpretation. When the nature of processing
was well-matched between the implicit and explicit versions of the task—for exam-
ple, category generation vs. category-cued recall (Perruchet et al., 1995; Perez et al.,
1998)—dissociations between the development of implicit and explicit memory were
still obtained. Our own results further contradict the processing account. In Exper-
iment 3, we used associate-generation for the implicit task and associate-cued recall
for the explicit task, and again obtained a clear dissociation; we also showed in Ex-
periment 3 that the use of conceptual processing is not sufficient to ensure develop-
ment of implicit memory. Thus, while it is true that many standard implicit tests are
perceptual in nature while many standard explicit tests are conceptual in nature—
and that this type of confound should generally be avoided—the processing
account is not able to explain developmental dissociations between implicit and
explicit memory.

Interpretation of developmental dissociations in terms of the “four factors” approach

In the present research, we have found that implicit and explicit memory show
complex patterns of childhood development. The two forms of long-term memory
sometimes behave in the same fashion and sometimes dissociate. Moreover, each form shows age-related development under some circumstances and not under
others. These patterns suggest the presence of complex interactions between several factors. Taking our results in conjunction with the previous literature, the likely role of each of the traditional four factors (basic capacity, knowledge base, strategies, and metamemory) in the childhood development of implicit and explicit memory can be summarized as follows.

We have argued that the factors contributing to explicit memory development beyond 5 years of age include: changes in the underlying knowledge base; development in strategic processing (strategy use and metamemory); but not an increase in basic memory capacity. In Experiment 1b, explicit memory development was found using a cued-recall task for category-based conceptual information, with a developing underlying knowledge base. In Experiment 2b, explicit memory showed no development when examined using a recognition task, following simple perceptual encoding, and using a stable knowledge base (i.e., information about object form). In Experiment 3b, the knowledge base tested (conceptual associate-based) was stable, yet explicit memory in a cued-recall task improved with age. Thus, we conclude that age-related improvement is possible when the underlying knowledge base is developing. Improvement is also possible when the underlying knowledge base is stable, as long as the retrieval task allows strategic processing. With respect to a basic capacity, however, we observed no age-related improvement in explicit memory when the experimental paradigm minimized the contributions of other known developmental factors (including disallowing knowledge base changes, and strategic processing at encoding, and strategic processing at retrieval; Experiment 2b).

In contrast to explicit memory, it appears that the only traditional factor contributing to implicit memory development is development in the underlying knowledge base. In Experiment 1a, priming was found to increase across a broad age range when stimuli were atypical category exemplars, namely, items for which previous literature has shown that underlying conceptual knowledge develops even into adolescence. In Experiment 2a, when implicit memory was examined using a degraded picture-naming task, priming remained developmentally stable for knowledge that was argued to have reached adult levels by 5 years of age (i.e., perceptual information about object form). In Experiment 3a, the information tested (conceptual associate-based) was again stable in the underlying knowledge base, and implicit memory

\[ \text{In all present experiments, the study and test phase activated the same form of knowledge about an item. Thus, our conclusion that implicit memory improves with age when the underlying knowledge base is developing was derived from a situation in which category knowledge for atypical exemplars was the relevant domain at both encoding and retrieval. In further experimental work not included here, we have disentangled the contributions of each phase, by assessing priming in two study-test mismatch conditions. Age-related development was weak or absent when category confirmation at study preceded object identification at test (Kindergarten} = 1.47; \text{Adults} = 2.20; \text{scores out of 20), and also when object orientation decision at study preceded category exemplar generation at test (Kindergarten} = 1.20; \text{Adults} = 2.60; \text{scores out of 20). This argues that, to obtain strong age-related development of implicit memory (see Table 1), it is necessary to access developing aspects of knowledge about the target item at both encoding and retrieval.} \]
failed to develop with age. This latter result formed a striking contrast to that obtained in Experiment 1a, despite the use of many common target items in the two experiments, and despite the use of very similar tasks (category generation vs. associate generation).

In terms of implicit–explicit dissociations, we can now address why previous studies have consistently found strong explicit memory development coupled with no implicit memory development. We suggested in the introduction that all but one of these studies (Perruchet et al., 1995) employed material for which there was probably little or no change in the underlying knowledge base across the age range tested. Our own results argue that such conditions do not allow development of implicit memory, but still allow development of explicit memory due to the contribution of strategic processing. We therefore propose that the major factor in developmental dissociations between implicit and explicit memory—in our own Experiment 3 as well as in the previous literature—is their differential reliance on strategic processing at retrieval.

Implications for adult theories of implicit and explicit memory

In the introduction, we discussed a number of approaches for thinking about how differences between implicit and explicit memory should be explained, in adults as well as in children. The idea that explicit–implicit dissociations reflect conceptual vs. perceptual processing confounds has been thoroughly discounted, both developmentally and in adults. Each of the other theories reviewed, however, has empirical evidence supporting it, and so a brief comment on how our developmental results are to be integrated into adult theories is appropriate.

First, we wish to emphasize that our rejection of a memory systems approach to implicit–explicit differences applies specifically to the developmental version in which an implicit system is said to be intact by about age 5 years, while an explicit system matures well beyond this age. In adults, it is clear from amnesia and brain imaging studies that implicit and explicit memory do rely on different systems in the sense of utilizing physiologically distinct brain regions. Unfortunately, the “systems” terminology encourages the idea that the functional role of these regions is to provide different storage locations for “implicit memories” and “explicit memories.” It is this storage location idea that (falsely) suggests that basic capacities for memory (i.e., amount of storage room) could increase at different rates for implicit and explicit tasks. We suggest, in contrast, that the functional role of the physiological differences is more likely to lie in other aspects of memory performance. These might include differences in strategic processing (Jacoby, 1991) or perhaps in access to spatio-temporal information (McKone & French, 2001) between implicit and explicit memory.

Second, we have argued that, in children, strategic processing differences are a major source of implicit–explicit dissociations. Interestingly, this idea is consistent with the existence of an age-related dissociation at the other end of the lifespan. Beyond approximately 60 years of age, implicit memory remains stable but explicit memory performance declines (e.g., Hashtroudi, Chrosniak, & Schwartz, 1991;
Light, Singh, & Capps, 1986). Many authors (for review, see Hertzog & Hultsch, 2000) have argued that older adults fail to use their metamnemonic skills effectively to control learning, or to update strategies appropriately for cognitive performance. This is much like the situation in childhood, where young children may be able to implement a strategy on instruction, but fail to do so spontaneously (e.g., Flavell, Beach, & Chinsky, 1966). Thus, a lack of effective strategy use provides a likely explanation of why it is that explicit memory performance is poor in both children and in the elderly, while implicit memory performance remains good at all ages.

Finally, our results in children have supported a clear role for the knowledge base in implicit memory. In terms of adult theories, the “knowledge base” corresponds most directly to an ongoing debate (e.g., Bowers, 2000) about the role of pre-existing vs. novel representations in supporting priming. Our developmental results argue that pre-existing representations do play an important role in priming. However, this is not a simple “activation” theory (cf. Graf & Mandler, 1984) in which items with a pre-existing representation (i.e., in the knowledge base; such as real words) show priming while items without a pre-existing representation (i.e., not in the knowledge base; such as nonwords) do not. In our experiments all items were, in themselves, familiar even to the youngest age group tested, and the relevant “change in the knowledge base” was presumed to involve some sort of internal structural development with age, such as stronger connections of atypical exemplars to a category label, or richer connections to other exemplars from the same category. Our conclusion that the knowledge base affects implicit memory should, of course, be considered jointly with the fact that pre-experimental knowledge also affects explicit memory. Thus, in general, we suggest that theories of memory need to continue to incorporate the fact that memory for one specific exposure to a target item is formed with reference to what is known pre-experimentally about that item.

How do changes in the knowledge base lead to increases in implicit memory?

We have argued that implicit memory can improve with age when the underlying knowledge base is simultaneously undergoing development. The question that naturally arises from this statement is how do changes in the knowledge base lead to increases in priming? We would presume that the basis for this development is similar to that underlying improvements in children’s explicit memory performance. For example, many explicit memory researchers believe that knowledge is represented as a network in semantic memory (for review, see Bjorklund, 1987). Such a network consists of nodes that are connected together. During development, the number of items (i.e., nodes) a child knows increases, as do the number and strength of the connections between them. When children are highly familiar with items in the knowledge base, the richer knowledge structures provide better retrieval cues between items. This enhances explicit memory performance, and we see no reason to assume that it would not also affect implicit memory. Indeed, as suggested in the introduction, specific mechanisms by which richer knowl-
edge could affect priming are available within both activation/modification theories (Bowers, 2000) and episodic/instance theories (Logan, 1990; Roediger & McDermott, 1993) of implicit memory.

Further implications of the knowledge base approach in children

The idea that implicit memory is associated with underlying knowledge has two further implications for developmental research. First, it predicts that in future studies of priming in children, it should be possible to demonstrate age-related increases even for perceptual materials: while much perceptual knowledge is well established by 5 years, some domains (particularly learning to read English words, and perhaps recognition of objects in highly unusual views) do improve beyond this age. We might also predict that a child expert in a given domain might exhibit more priming than even an adult, if that adult has little or no relevant background knowledge (cf. studies of child chess experts in short-term memory; Chi, 1978).

Second, and more generally, we suggest that the relationship between underlying knowledge and priming can be turned around, such that priming can be used as a measure of the development of knowledge in children. In fact, the use of memory tasks as a method of assessing the state of the knowledge base is quite common in the developmental literature, but researchers have tended to use explicit memory tasks for this purpose. In face recognition, for example, it is generally assumed that the age-related improvement in recognition memory reflects an age-related development in underlying perceptual knowledge about faces (e.g., Carey, 1980; Carey, Diamond, & Woods, 1980; Johnston & Ellis, 1995). The arguments made in the present paper, however, demonstrate that this is not necessarily the case: the development could well be attributable to older subjects’ better use of strategic processing (e.g., “This face looks like my friend Bill, so I will rehearse the name Bill, Bill, Bill”). Given independent evidence (see Gilchrist & McKone, in press) that perceptual processing of faces is mature by 6 years of age, we might predict that implicit memory measures should show no development and, indeed, Ellis et al. (1993) found that priming for faces did not improve over the age range of 5–11 years. Thus, we argue that explicit memory tasks do not provide a suitable measure of the state of underlying knowledge at different ages. Implicit memory tasks can provide a purer measure for this purpose.

Acknowledgments

The research presented in this paper was based on the first author’s doctoral dissertation, which was conducted at the School of Psychology, The Australian National University. Correspondence concerning this article should be addressed to Kristina Murphy, who is now at the Centre for Tax System Integrity, Research School of Social Sciences, The Australian National University, Acton, ACT 0200, Australia.
Appendix A

Stimuli used in Experiments 1 and 2

<table>
<thead>
<tr>
<th>Category</th>
<th>Targets</th>
<th>List A</th>
<th>Generation strength(%)</th>
<th>List B</th>
<th>Generation strength(%)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exemplar 1</td>
<td></td>
<td></td>
<td>Exemplar 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generation</td>
<td></td>
<td></td>
<td>Generation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>strength(%)</td>
<td></td>
<td></td>
<td>strength(%)</td>
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<td></td>
</tr>
<tr>
<td>toys</td>
<td>kite</td>
<td>—</td>
<td></td>
<td>puppet</td>
<td>3.8</td>
<td>P</td>
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<td>Goofy</td>
<td>—</td>
<td></td>
<td>Care Bear</td>
<td>—</td>
<td>A</td>
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<td>swimsuit</td>
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<td>P</td>
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<td>cymbals</td>
<td>9.7</td>
<td>B&amp;M</td>
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<td></td>
<td>slingshot</td>
<td>4.1</td>
<td>B&amp;M</td>
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<tr>
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<td></td>
<td>sticky tape</td>
<td>—</td>
<td>A</td>
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<td>bowl</td>
<td>20.6</td>
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<td>heel</td>
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<td>P</td>
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<td>astronaut</td>
<td>—</td>
<td>B&amp;M</td>
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<td></td>
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<td>rollerblade</td>
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<td></td>
<td>flippers</td>
<td>3.1</td>
<td>P</td>
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<td>stairs</td>
<td>9.4</td>
<td></td>
<td>chimney</td>
<td>1.6</td>
<td>P</td>
</tr>
</tbody>
</table>

Mean = 7.5
Mean = 6.5

Note. P, sourced from Posnansky (1978), B&M, sourced from Battig and Montague (1969), and A, developed by the first author.

Filler items (study phase)

Suitcase, pipe, coathanger, umbrella, anchor, envelope, flag, candle, snowman, cake, cigarette, handbag, ashtray, helmet, basket, bottle, whistle, lock, sandwich, and pram.
**Filler category cues (conceptual test phase)**

Moods, places one can live, crimes, girl’s names, boy’s names, things you can read, Australian cities, diseases, types of music, weather phenomena, materials, drinks, trees, relatives, metals, jewelry, colors, precious stones, countries, and flowers.

**Stimuli used in Experiment 3**

<table>
<thead>
<tr>
<th>Associate</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>List A</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Exemplar 1</strong></td>
</tr>
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<td>makeup</td>
<td>lips</td>
</tr>
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<td>toaster</td>
</tr>
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<td>Goofy</td>
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<td>stockings</td>
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<td>recess</td>
<td>hopscotch</td>
</tr>
<tr>
<td>battle</td>
<td>arrow</td>
</tr>
<tr>
<td>green</td>
<td>frog</td>
</tr>
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<td>stapler</td>
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<tr>
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</table>

**Filler items (study phase)**

As for Experiments 1 and 2.

**Filler associate cues (conceptual test phase)**

As for filler category cues in Experiments 1.

**References**


