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# A reevaluation of semantic versus nonsemantic processing in implicit memory

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A number of investigations have purported to demonstrate that semantic processing does not produce a memorial advantage over nonsemantic processing on implicit tests, as contrasted with the typical advantage of semantic over nonsemantic processing on explicit tests. A review of 166 outcomes from 38 studies that have manipulated processing on implicit tests reveals that on 131 occasions (79%), priming was greater following semantic than it was following nonsemantic processing. This difference was found in both perceptual and conceptual implicit memory tests, as well as in within- and between-subjects designs. It suggests that implicit tests reflect the involvement of both conceptual and perceptual processes. Although explicit contamination may account for some of the processing difference in implicit tests, the pervasiveness of the phenomenon, especially in perceptual implicit tests, makes it an unlikely account for the entire effect.

Human memory can be measured without requiring conscious recollection. In recent years, a number of tasks that tap such "implicit" or "indirect" memory have been developed, and this area of investigation has accounted for a prodigious amount of research (see Graf & Masson, 1993; Richardson-Klavehn & Bjork, 1988; Roediger, 1990; Schacter, 1987). In general, implicit memory is measured by tests on which subjects are not instructed to recollect their prior exposure to the items. This does not mandate that subjects be unaware that some test items have been presented previously, only that they not consciously use this information in responding. In contrast, explicit memory tests require subjects to actively remember the prior information at the time of test (Schacter, Bowers, & Booker, 1989). The measures used in implicit memory tests, along with their results, have included decreased relearning time, lowered perceptual threshold, faster naming and reading latencies, and increased likelihood of word-puzzle solutions (word fragments, word stems, and anagrams).

An important issue in the implicit memory literature, one that forms the focus of the present review, is the impact of different levels of processing on priming. Although the term "levels" is technically inappropriate because it implies an ordinal scale of measurement from the nonsemantic to the semantic (T. O. Nelson, 1977), it is ubiquitous in the literature, so we will abide by convention and use it throughout this paper. The literature on explicit memory tests is rife with demonstrations that a nonsemantic level of processing, wherein subjects focus on physical aspects of the stimulus, yields poorer retention than a semantic level, wherein subjects respond to a meaningful dimension of the stimulus (Craik & Lockhart, 1972; Craik & Tulving, 1975; Lockhart & Craik, 1990). In contrast to this, a number of recent investigations using implicit memory tests claim to have found no effect of variations in levels of processing. This null outcome has attained the status of an established "fact," as reflected in the summary statement by Richardson-Klavehn and Bjork (1988): "There are now numerous demonstrations that traditional encoding manipulations, while producing strong effects on performance in a direct test, do not affect the extent of repetition effects in an indirect test" (p. 493).

Recent statements suggest a continuation of this impression: "virtually every study of the effect of level of processing has determined that it has ... no effect on implicit tasks" (Hamann, 1990, p. 971); "levels of processing do not seem to affect implicit memory performance" (Hirshman, Snodgrass, Mindes, & Feenan, 1990, p. 635); "a number of experiments have shown that manipulations intended to change level of processing during initial encoding have no influence on ... implicit memory" (Perruchet & Baveux, 1989, p. 77); "a number of factors ... have no effect on implicit memory. These include the level of processing of target items" (Parkin, Reid, & Russo, 1990, p. 507). This opinion has even made its way into a recent memory textbook (Baddeley, 1990, pp. 208–209).

We take issue with the conclusion that the level of processing has *no* effect on implicit tasks. Our paper is not the first to point this out (cf. Roediger & McDermott, 1993). Chiarello and Hoyer (1988), as well as Challis and Brodbeck (1992), conducted a meta-analysis of prior research in which nonsemantic tasks consistently led to poorer implicit test performance than did seman-

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tic tasks. However, there are several limitations to the previous reviews. First, the number of studies (4 and 11, respectively) and the number of empirical outcomes (11 and 35, respectively) evaluated were limited. In addition, the implicit tasks examined in these reviews consisted primarily of word-stem completion, word-fragment completion, and perceptual identification. One purpose of the present review, then, is to broaden the range of studies evaluated. A second purpose is to further examine two issues raised by Challis and Brodbeck (1992). One involves levels of processing differences as a function of input condition (between- vs. within-subjects designs) and the other concerns the type of implicit test (perceptual vs. conceptual). Both of these will be examined in detail after a consideration of the entire corpus of data.

## OVERVIEW OF LEVELS OF PROCESSING STUDIES

The types of tasks used in the studies are described below. The abbreviation next to each task is used in the summary of the investigations listed in the Appendix. The *nonsemantic* tasks include the following:

count ascending and descending letters (asc/dsc)
rate the clarity of a speaker's voice (clarity)
count the consonants in word (conson)
compare word pairs on consonants *and* vowels (con/vow)
copy a pair of words (in writing; copy)
look for a cross on a picture (cross)
count enclosed letters (encl)
rate letter font readability (font)
note whether an object is facing left or right (leftright)
search for designated letter(s) (letter)
can object be drawn with a continuous line? (line)
name a word or picture (naming)
identify 2 letters not in a word (notlet)
rate pitch of speaker's voice (pitch)
judge object size (size)
count syllables in word (syllab)
count t-junction letters (t-jun)
identify typecase of word, upper/lower (typecase)
look for vertical line on a picture (vertline)
compare vowels in word pairs (vowel)

*Semantic tasks*, in contrast, have included the following:

word identifies animate or inanimate object (animate)
categorize words (cat/word)
rate concreteness (concrete)
free associate (free/ass)
name and answer question concerning use (function)
rate meaningfulness (meaning)
name picture (naming)
identify what object resembles (obj/rsmb)
rate pleasantness (or liking) (pleasant)
rate words on either pleasantness or imagery (pleas/ imag)
rate portability of object (portab)
relate two words to each other (relate)
generate sentence to include two words (sent/gen)
read words in a defining sentence (sent/read)

The studies included in this summary adhere to the original levels of processing paradigm: (1) subjects were required to evaluate one type of stimulus (e.g., words, objects) in two or more different ways, and (2) subjects were not informed about a subsequent memory test. The first criterion excludes studies on the generation effect, because the nature of the stimulus differs between "generate" and "read" conditions (Blaxton, 1989; Gardiner, 1988; Gardiner, Dawson, & Sutton, 1989; Jacoby, 1983; Winnick & Daniel, 1970): In the "read" condition, the subject is shown the word, whereas in the "generate" condition, the subject must produce it. As Hamann (1990) notes, "better performance on a task in one condition than in the other could be due to the elaborative variable, the seen-unseen variable, or an interaction of these two variables" (p. 976). The second criterion excludes studies (Greene, 1990) or conditions (Bowers & Schacter, 1990) in which incidental versus intentional input conditions are used to represent different levels of processing. Although a parallel could be drawn between the nonsemantic level of processing and incidental learning conditions, and between the semantic level of processing and intentional learning conditions, these studies confound input processing with test expectation. In studies where level of processing was manipulated *within* incidental and intentional conditions (Roediger, Weldon, Stadler, & Riegler, 1992), we used only the incidental conditions for the present comparisions.

The Appendix lists, first, those studies in which perceptual tasks were used, and, second, those carried out with conceptual implicit memory tests. Srinivas and Roediger (1990) differentiate these two types of tests by suggesting that perceptual tests "rely heavily on the match of perceptual features between learning and test episodes," whereas conceptual tests "require the encoded meaning of concepts for successful recollection" (p. 390). The implicit memory tasks considered to be *primarily* perceptual are word-fragment and word-stem completion, fragmented words, and word identification. These have been so identified by Blaxton (1989, 1991) and Srinivas and Roediger (1990) according to the following criterion: a "generate" condition will yield *poorer* performance than a "read" condition with perceptual implicit tests and *better* performance than a "read" condition in conceptual implicit tasks. Category-item generation, general knowledge, and free association have been defined as conceptual tests (Roediger & McDermott, 1993), but the status of several tasks remains to be determined (anagram solution, picture naming, picture drawing). For the sake of simplicity, we separated the tasks that were clearly perceptual from those that were not, and we will refer to the latter group as conceptual, although the degree of conceptual involvement appears to vary considerably from task to task (see Rajaram & Roediger, 1993; Roediger & McDermott, 1993; Roediger & Srinivas, 1993).

Whenever possible, the levels of processing effect was broken down within each study into separate subconditions, such as number of repetitions (Challis & Brodbeck, 1992; Schacter & McGlynn, 1989), type of stimuli (Schacter, Cooper, & Delaney, 1990; Srinivas & Roediger, 1990), combinations of input and test stimulus (Graf & Ryan, 1990), and retention interval (Chiarello & Hoyer, 1988; Squire, Shimamura, & Graf, 1987). When both recall and recognition tests were given (Besson, Fischler, Boaz, & Raney, 1992; Graf & Mandler, 1984; Hashtroudi, Ferguson, Rappold, & Chrosniak, 1988; Light & Singh, 1987), recall was used to represent the explicit test. When more than two processing tasks were used (Jacoby & Dallas, 1981; Musen, 1991; Schacter & McGlynn, 1989), only two conditions were selected to represent the most typical semantic and nonsemantic conditions.[1]

The Appendix shows the experiment number from the published study, the type of subjects tested, whether the semantic and nonsemantic levels of processing tasks were manipulated between (B) or within (W) subjects, the type of semantic and nonsemantic processing tasks, the type of implicit and explicit tests, and the semantic and nonsemantic performance levels for both implicit and explicit tests. Priming was routinely computed by subtracting performance in the baseline from the priming condition, except in conditions for which base rates were not provided. In some cases, the results are expressed as a difference in percent correct; in other cases, the results are expressed as latencies.

The *implicit* tests in the Appendix are abbreviated as follows:

word stem completion (WS): the first letters of the word are provided at test (ALCOHOL is tested by ALC____)

auditory word-stem completion (AWS): same as WS, except that test stimuli are auditory

word fragment completion (WF): some letters of the word are provided at test (ALCOHOL is tested by _LC_H__)

fragmented word solution (FW): letters of the word are incompletely presented at test (ALCOHOL is tested by ALCOHOL, but with chunks missing from the letters)

anagram solution (AS): generate a word from letter combination (ALCOHOL is tested by LACHOLO)

word identification (WI): visual word identification

auditory word identification (AWI)

picture naming (PN): label a picture verbally

free association (FA): provide a single word association

picture drawing (PD): draw a figure following a brief exposure

object decision (OD): decide whether pictured object is possible or impossible

category generation (CG): produce members (exemplars) of conceptual categories

general knowledge (GK): answer general knowledge questions

The *explicit* tests in the Appendix are cued recall (CR), free recall (FR), recognition (RC), visual word-stem completion (WS), auditory word-stem completion (AWS), word-fragment completion (WF), fragmented word (FW), and general knowledge (GK). The last five tests use the same format as the implicit tests described above, with the exception that the instructions emphasize remembering the prior input list to produce solution words.

## META-ANALYSIS OF LEVELS OF PROCESSING STUDIES

In most published investigations on levels of processing, the same conclusion is echoed: Level of processing has *no* effect on implicit memory tests. A closer scrutiny of these outcomes, however, leads to the opposite conclusion. The 38 studies in the Appendix yielded 166 outcomes comparing semantic and nonsemantic processing in implicit tests. Of these, 131 outcomes (79%) revealed less priming in the nonsemantic than in the semantic condition, 31 (19%) produced more priming in the nonsemantic than in the semantic condition, and 4 (2%) yielded equivalent priming in nonsemantic and semantic conditions. For the statistical comparison, the number of outcomes with less priming in the nonsemantic condition than in the semantic condition was compared with chance (the equivalent outcomes were divided evenly). Thus, a chi-square goodness-of-fit test to compare this outcome (133/33) against a chance split (83/83) revealed a significant difference [$\chi^2(1) = 61.45$; a significance level of .05 is used for all statistical tests]. The chi-square test will be used in subsequent analyses in the same manner as applied here: to compare the number of studies with nonsemantic < semantic processing against a 50–50 split. The difference between semantic and nonsemantic processing in the implicit tasks was statistically significant in over half of the individual outcomes, and these are noted by an asterisk (*) in the effect column. In investigations with multiple outcomes (e.g., Carroll, Byrne, & Kirsner, 1985), if the level of processing main effect was significant and did not interact with the second variable (e.g., age), this is noted by a dagger (†) in the effect column. The absence of an asterisk or a dagger in the effect column means either a nonsignficant difference, or that the difference was not tested. Of the 38 studies in the Appendix, 33 included *explicit* as well as implicit memory tests, and these studies yielded a total of 115 outcomes. As one would expect (Craik & Lockhart, 1972), test performance under the nonsemantic level of processing was less than test performance under the semantic level of processing in nearly all (112, or 97%) of the outcomes.

Contrary to the conclusions of most researchers exploring levels of processing in implicit memory tests, the pattern of outcomes suggests an impact of levels of processing on implicit memory performance, albeit less frequently (79%) than in the explicit memory tests (97%). A serious difficulty in prior priming studies with levels of processing may be statistical power, and increasing sample size may be necessary to provide the sufficient statistical sensitivity to detect weak effects. However, a statistical test is essentially a substitute for empirical replication in that it mathematically predicts the likelihood that a particular outcome will be repeated under similar circumstances. The consistency in the pattern of outcomes in the Appendix overrides the individual statistical outcomes.

In their review of the levels of processing effects in implicit memory research, Challis and Brodbeck (1992) discuss several issues, including the difference between perceptual and conceptual implicit tests, and between- and within-subject manipulations of levels of processing. Here we will consider both of these points in relation to the present meta-analyses.

**Perceptual Versus Conceptual Implicit Tests**

Recent research suggests that implicit tasks are not exclusively perceptual, as previously assumed, but that different implicit tasks vary in the degree to which they involve conceptual and perceptual processing (Hirshman et al., 1990; Srinivas & Roediger, 1990; Weldon, 1991). When Srinivas and Roediger (1990) compared several different implicit memory tests, they found that both conceptual and perceptual factors combine in different proportions to elicit priming. Hamann (1990), as well as Srinivas and Roediger (1990), view the conceptual and perceptual influences on implicit memory performance as a matter of degree, rather than a dichotomy, with the demands of the specific encoding and retrieval tasks determining the extent of involvement of each type of processing.

The prior analyses of levels of processing effects in implicit tasks included a mixture of both perceptual and conceptual tests (Challis & Brodbeck, 1992). If the significant effect in implicit tasks is due to the combination of conceptual and perceptual factors, then examining *only* perceptual tests should eliminate the advantage of semantic over nonsemantic processing. Of the 38 studies in the Appendix, 29 used a bona fide perceptual implicit test. Of the 124 outcomes from these studies, 94 (or 76%) yielded poorer performance in the nonsemantic than in the semantic processing condition on the implicit test. Priming with nonsemantic processing was greater than with semantic in 26 outcomes, with no difference in 4 instances. This pattern differed significantly from chance [$\chi^2(1) = 37.29$], suggesting that the levels of processing difference in implicit tests occurs even when only perceptual tasks are considered. For the conceptual implicit tasks, there were 42 outcomes from 12 studies, and 37 (88%) revealed poorer performance in the nonsemantic condition than in the semantic condition (nonsemantic was higher than semantic 5 times). This outcome was also significantly different from chance [$\chi^2(1) = 24.38$]. A direct comparison of perceptual and conceptual studies with respect to the proportion of outcomes where the nonsemantic condition resulted in less priming than the semantic condition revealed no significant difference [$\chi^2(1) = 1.84$]. In summary, the levels of processing difference in implicit tests exists for both conceptual and perceptual tests, and the magnitude of the effect is similar for both types of tests.

**Fragmentary Processing in Nonsemantic Levels of Processing**

A second methodological issue raised by Challis and Brodbeck (1992) is whether the stimulus is processed as a whole or as fragmented parts under nonsemantic processing instructions. Since all implicit tests require producing, completing, or identifying a whole stimulus, a level of processing effect may be due in part to the difference between adequate holistic stimulus processing in the semantic condition and fragmented stimulus processing in the nonsemantic condition. Most nonsemantic tasks do focus on the individual letters in words (vowels, consonants, ascenders, descenders, t-junctions, enclosures, etc.) or parts of pictures (find a cross, locate a vertical line) and the three studies that used whole-stimulus processing do not provide sufficient data to resolve this issue (Graf & Ryan, 1990; Musen, 1991; Schacter et al., 1990).

If whole-stimulus processing is *not* occurring in nonsemantic levels of processing tasks involving fragmentary analysis, then significant priming should occur *less often* under the nonsemantic than under the semantic level. This is not the case. Priming under the implicit test conditions was tested against chance in most studies, and a significant difference is indicated in the table by an asterisk (*) to the right of the priming score. As with the tests reported above, if a main effect of priming was presented, and if it did not interact with processing condition, this is designated by a dagger (†). Significant priming occurred in both the nonsemantic and the semantic conditions 72 times, in only the semantic condition 5 times, and in only the nonsemantic condition 4 times. If subjects were inadequately processing the whole word in the nonsemantic condition, the majority of which involved fragmentary analyses, it seems unlikely that frequency of significant priming would be equivalent in both semantic and nonsemantic conditions on a subsequent indirect test.

**Between- Versus Within-Subjects Designs**

Related to the issue of incomplete word processing, a subject's "set" to process only fragmented portions of the input stimulus under nonsemantic processing should be tempered in within-subjects (mixed-list) designs. Since all semantic levels of processing tasks demand complete stimulus processing, when subjects are forced to alternate between semantic and nonsemantic processing, they should be more likely to engage in whole-stimulus processing in the nonsemantic condition as well. This issue was addressed empirically by Challis and Brodbeck (1992). Using a word-fragment completion task, they discovered a significant levels of processing difference with a between-subjects design in Experiment 1 but no such difference with a within-subjects design in Experiment 2. Exploring this issue further, they discovered that significant levels of processing effects did occur in a within-subjects design *if* semantic and nonsemantic tasks were separated by blocks. The effect in the between-subjects design resulted from depressed performance in the nonsemantic relative to the semantic condition, suggesting carry-over effects from semantic to nonsemantic encoding conditions in the standard mixed-processing within-subjects levels of processing design.

In the present data set, the implicit data were examined separately for between- and within-subjects levels of processing designs (note that some studies had both between- and within-subjects manipulations: Challis & Brodbeck, 1992; Graf & Mandler, 1984). To minimize the likelihood of explicit contamination, only studies with perceptual implicit tests were considered (Schacter et al., 1989). For *between-subjects* designs, there were 78 outcomes from 18 studies, and a significant majority (56, or 72%) revealed less priming in the nonsemantic than in the semantic condition [$\chi^2(1) = 17.55$; 19 outcomes showed more priming in the nonsemantic than in the semantic condition, and 3 revealed no difference]. For *within-subjects* designs, there were 46 outcomes from 10 studies and a significant majority (38, or 84% had less priming in the nonsemantic than in the semantic condition [$\chi^2(1) = 17.89$; 7 outcomes showed more priming in the nonsemantic than in the semantic condition, and 1 revealed no difference]. A direct comparison of between- and within-subjects designs, with respect to the proportion of outcomes where the nonsemantic condition resulted in less priming than the semantic condition did, revealed no significant difference [$\chi^2(1) = 1.69$]. In summary, both mixed and unmixed levels of processing designs yielded a significant majority of outcomes where nonsemantic processing produced less priming than did semantic processing, and the proportion of these outcomes was similar for both types of designs.

## Summary

Levels of processing effects exist in implicit as well as explicit tests of memory. The analyses suggest that a robust effect is found in both conceptual and perceptual implicit tests, as well as in both between- and within-subjects designs. Furthermore, the proportion of studies revealing the standard levels of processing effect is similar in conceptual and perceptual tests, and in between- and within-subjects designs. The possible fragmentary stimulus processing in the nonsemantic condition (versus whole-stimulus processing in semantic conditions) does not appear to be a viable explanation of the levels of processing difference in implicit tests, because significant priming occurred in 90% of the cases when such a test was made. Investigators should refrain from making unqualified references to dissociations between semantic–nonsemantic levels of processing and implicit–explicit memory as support for *or* against a particular theoretical stance. Instead, more research needs to be focused on the manner in which variations in processing conditions differentially influence performance in implicit versus explicit tests.

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## NOTES

1. Jacoby and Dallas (1981) used two different nonsemantic tasks: letter identification and rhyme generation. We selected letter identification because it was more commonly used as a nonsemantic task across other studies. Mussen (1991) also used two different nonsemantic tasks: line counting and figure duplication. Line counting was selected because, like the semantic task (verbal label generation), it was mental. The other nonsemantic task, figure duplication, not only was physical but also required considerably more time to complete, compared with either the line-counting or the verbal label generation task. Finally, Schacter and McGlynn (1989) used three different semantic tasks: reading two defining sentences (one for each word pair), reading one sentence frame including both words of a pair, and generating a synonym for each word. We selected the sentence frame condition, because this was used consistently throughout all four of their experiments. The defining sentence and synonym generation conditions were only used in Experiments 1 and 2.

**APPENDIX**
**Details of Levels of Processing (LOP) Studies: Subjects, Design, Encoding Tasks, Implicit and Explicit Test Means, and LOP Effect**

| | | | | Encoding Tasks | | Implicit Test | | | | Explicit Test | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study | Exp. | Subjects | Design | NonSem | Sem | Test | NonSem | Sem | Effect | Test | NonSem | Sem | Effect |
| | | | | | Perceptual Tasks | | | | | | | | |
| Besson, Fischler, Boaz, | 1A | coll | W | con/vow | animate | WF (rel) | 27 | 31 | +† | RC | 45 | 72 | + |
| & Raney, 1992 | 1A | coll | W | con/vow | animate | WF (unrel) | 02 | 11 | +† | RC | 41 | 63 | + |
| | 1B | coll | W | con/vow | animate | WF (rel) | 17 | 22 | + | WF | 23 | 33 | + |
| | 1B | coll | W | con/vow | animate | WF (unrel) | 02 | 06 | + | WF | 04 | 08 | + |
| Bowers & Schacter, 1990 | 1 | coll | W | t-jun/encl | pleasant | WS | 16* | 26* | + | WS | 19 | 47 | + |
| Carroll, Byrne, | 4 | 7-yr | B | cross | portab | WI | 25† | 26† | + | | | | |
| & Kirsner, 1985 | | | | | | | | | | | | | |
| Challis & Brodbeck, | 1 | coll | B | asc/dsc | pleas/imag | WF (X1) | 13 | 28 | +† | | | | |
| 1992 | 1 | coll | B | asc/dsc | pleas/imag | WF (lag0) | 18 | 28 | +† | | | | |
| | 1 | coll | B | asc/dsc | pleas/imag | WF (lag10) | 18 | 34 | +† | | | | |
| | 1 | coll | B | asc/dsc | pleas/imag | WF (lag30) | 18 | 35 | +† | | | | |
| | 2 | coll | W | asc/dsc | pleasant | WF | 24 | 26 | + | | | | |
| | 3 | coll | W | asc/dsc | pleasant | WF (mix) | 25* | 28* | +* | | | | |
| | 3 | coll | W | asc/dsc | pleasant | WF (blk) | 16* | 26* | +* | | | | |
| | 3 | coll | B | asc/dsc | pleasant | WF | 18* | 29* | + | | | | |
| | 4 | coll | W | asc/dsc | pleasant | WF (mix) | 20 | 21 | + | | | | |
| | 4 | coll | W | asc/dsc | pleasant | WF (blk) | 17 | 31 | +* | | | | |
| Chiarello & Hoyer, 1988 | 1 | coll | B | vowel | pleasant | WS (0m) | 52 | 47 | −† | WS | 47 | 72 | + |
| | 1 | coll | B | vowel | pleasant | WS (13 m) | 28 | 34 | +† | WS | 29 | 52 | + |
| | 1 | coll | B | vowel | pleasant | WS (46 m) | 21 | 36 | +† | WS | 21 | 41 | + |
| | 1 | older | B | vowel | pleasant | WS (0 m) | 26 | 38 | +† | WS | 33 | 56 | + |
| | 1 | older | B | vowel | pleasant | WS (13 m) | 18 | 29 | +† | WS | 02 | 36 | + |
| | 1 | older | B | vowel | pleasant | WS (46 m) | 23 | 28 | +† | WS | −1 | 29 | + |
| Graf & Mandler, 1984 | 1 | coll | B | vowel | pleasant | WS | 31 | 37 | + | FR | 09 | 36 | + |
| | 2 | coll | B | vowel | pleasant | WS | 11 | 18 | + | RC | 22 | 76 | + |
| | 3 | coll | W | vowel | pleasant | WS (1st) | 18 | 20 | + | WS | 08 | 41 | + |
| | 3 | coll | W | vowel | pleasant | WS (2nd) | 18 | 35 | + | WS | 06 | 40 | + |
| Graf, Mandler, & Haden, | 1 | coll | B | vowel | pleasant | WS | 22 | 25 | + | FR | 08 | 30 | + |
| 1982 | | | | | | | | | | | | | |
| Graf & Ryan, 1990 | 3 | coll | B | font | pleasant | WI (pp) | 18† | 19† | + | RC | 40 | 76 | + |
| | 3 | coll | B | font | pleasant | WI (ps) | 10† | 14† | + | RC | 30 | 59 | + |
| | 3 | coll | B | font | pleasant | WI (ss) | 20† | 18† | − | RC | 44 | 66 | + |
| | 3 | coll | B | font | pleasant | WI (sp) | 13† | 21† | + | RC | 27 | 72 | + |
| Graf & Schacter, 1985 | 1 | coll | B | vowel | relate | WS (same-u) | 10* | 38* | +† | CR | 00 | 35 | + |
| | 1 | coll | B | vowel | relate | WS (diff-u) | 08* | 11* | +† | | | | |
| | 1 | coll | B | vowel | relate | WS (same-r) | 09* | 28* | +† | CR | 09 | 67 | + |
| | 1 | coll | B | vowel | relate | WS (diff-r) | 11* | 15* | +† | | | | |
| Graf, Squire, & Mandler, | 1 | inpat | W | vowel | pleasant | WS | 36 | 50 | +† | FR | 13 | 36 | + |
| 1984 | 1 | alcoh | W | vowel | pleasant | WS | 24 | 31 | +† | FR | 10 | 40 | + |
| | 1 | depres | W | vowel | pleasant | WS | 28 | 44 | +† | FR | 16 | 47 | + |
| | 2 | alcoh | W | vowel | pleasant | WS (0 m) | 22 | 33 | +† | RC | 04 | 61 | + |
| | 2 | alcoh | W | vowel | pleasant | WS (15 m) | 10 | 27 | +† | RC | 09 | 59 | + |
| | 2 | alcoh | W | vowel | pleasant | WS (120 m) | −5 | 02 | +† | RC | 04 | 46 | + |
| | 2 | inpat | W | vowel | pleasant | WS (0 m) | 19 | 17 | −† | RC | 23 | 43 | + |
| | 2 | inpat | W | vowel | pleasant | WS (15 m) | 02 | 17 | +† | RC | 00 | 54 | + |
| | 2 | inpat | W | vowel | pleasant | WS (120 m) | −3 | 05 | +† | RC | 12 | 28 | + |
| Hashtroudi, Ferguson, | 2 | coll | W | vowel | pleasant | FW | 15* | 19* | + | FW | 07 | 30 | + |
| Rappold, & | | | | | | | | | | | | | |
| Chrosniak, 1988 | | | | | | | | | | | | | |
| Horton, Smith, Barghout, | 3 | coll | B | vowel | pleasant | WF | 37* | 51* | + | FR | 40 | 54 | + |
| & Connolly, 1992 | 3 | coll | B | vowel | pleasant | WF | 28* | 37* | + | FR | 26 | 41 | + |
| Jacoby & Dallas, 1981 | 1 | coll | W | letter | meaning | WI (yes) | 13† | 15† | + | RC | 51 | 95 | + |
| | 1 | coll | W | letter | meaning | WI (no) | 16† | 18† | + | RC | 49 | 78 | + |
| Java & Gardiner, 1991 | 1 | coll | W | letter | free/ass | WS | 21† | 19† | − | WS | 19 | 48 | + |
| | 1 | older | W | letter | free/ass | WS | 14† | 18† | + | WS | 13 | 25 | + |
| Jelicic & Bonke, 1991 | 1 | coll | B | vowel | pleasant | WS | 31 | 42 | +* | FR | 13 | 36 | + |
| Johnston, Hawley, | 6&7 | coll | B | vowel | naming | WI (msec) | 189* | 357* | + | RC | 06 | 26 | + |
| & Elliott, 1991 | | | | | | | | | | | | | |
| Light, LaVoie, | 1 | coll | B | syllab | pleasant | WI (vis) | 18† | 23† | + | RC | 40 | 78 | + |
| Valencia-Laver, | 1 | coll | B | syllab | pleasant | WI (aud) | 08† | 12† | + | RC | 38 | 76 | + |
| Owens, & Mead, 1992 | 1 | older | B | syllab | pleasant | WI (vis) | 15† | 16† | + | RC | 31 | 65 | + |
| | 1 | older | B | syllab | pleasant | WI (aud) | 09† | 08† | − | RC | 32 | 60 | + |
| Light & Singh, 1987 | 1 | coll | B | vowel | pleasant | WS | 24† | 29† | +† | FR | 07 | 33 | + |
| | 1 | older | B | vowel | pleasant | WS | 17† | 24† | +† | FR | 04 | 16 | + |

**APPENDIX (Continued)**

| | | | | Encoding Tasks | | Implicit Test | | | | Explicit Test | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study | Exp. | Subjects | Design | NonSem | Sem | Test | NonSem | Sem | Effect | Test | NonSem | Sem | Effect |
| | 3 | coll | B | vowel | pleasant | WI (80%) | 11† | 16† | + | FR | 10 | 33 | + |
| | 3 | coll | B | vowel | pleasant | WI (65%) | 14 | 15 | + | | | | |
| | 3 | coll | B | vowel | pleasant | WI (50%) | 04 | 04 | 0 | | | | |
| | 3 | older | B | vowel | pleasant | WI (80%) | 09† | 12† | + | FR | 09 | 21 | + |
| | 3 | older | B | vowel | pleasant | WI (65%) | 14 | 17 | + | | | | |
| | 3 | older | B | vowel | pleasant | WI (50%) | 07 | 05 | − | | | | |
| Lupker, Harbluk, & Patrick, 1991 | 1 | coll | B | vowel | sent/gen | WS | 18* | 24* | + | WS | 22 | 41 | + |
| Micco & Masson, 1991 | 1 | coll | B | copy | sent/gen | WS (same) | 17 | 16 | − | WS | 11 | 33 | + |
| | 2 | coll | B | copy | relate | WS (same) | 27 | 31 | + | | | | |
| Naito, 1990 | 1&2 | 6-yr | W | letter | cat/word | WF | 22* | 22* | 0 | FR | 05 | 05 | 0 |
| | 1&2 | 8-yr | W | letter | cat/word | WF | 19* | 20* | + | FR | 09 | 20 | + |
| | 1&2 | 11-yr | W | letter | cat/word | WF | 23* | 21* | − | FR | 08 | 22 | + |
| | 1&2 | 21-yr | W | letter | cat/word | WF | 21* | 22* | + | FR | 14 | 31 | + |
| D. L. Nelson, Schreiber, & Holley, 1992 | 1 | coll | B | vowel | concrete | WF (small) | 27 | 31 | + | WF | 30 | 49 | + |
| | 1 | coll | B | vowel | concrete | WF (large) | 29 | 31 | + | WF | 27 | 36 | + |
| | 1 | coll | B | vowel | concrete | WS (small) | 36 | 35 | − | WS | 25 | 46 | + |
| | 1 | coll | B | vowel | concrete | WS (large) | 30 | 32 | + | WS | 15 | 36 | + |
| Park & Shaw, 1992 | 1 | coll | B | letter | pleasant | WS (2) | 01 | 02 | + | WS (2) | 03 | 09 | + |
| | 1 | coll | B | letter | pleasant | WS (3) | 07 | 08 | + | WS (3) | 09 | 21 | + |
| | 1 | coll | B | letter | pleasant | WS (4) | 11 | 12 | + | WS (4) | 16 | 36 | + |
| | 1 | older | B | letter | pleasant | WS (2) | 01 | 01 | 0 | WS (2) | 02 | 03 | + |
| | 1 | older | B | letter | pleasant | WS (3) | 05 | 07 | + | WS (3) | 08 | 09 | + |
| | 1 | older | B | letter | pleasant | WS (4) | 09 | 12 | + | WS (4) | 09 | 18 | + |
| Roediger, Weldon, Stadler, & Riegler, 1992 | 1 | coll | W | asc/dsc | pleasant | WF | 23 | 20 | − | WF | 31 | 51 | + |
| | 1 | coll | W | asc/dsc | pleasant | WS | 16 | 13 | − | WS | 16 | 59 | + |
| | 1 | coll | W | asc/dsc | pleasant | WF | 13 | 01 | − | WF | 42 | 36 | − |
| | 1 | coll | W | asc/dsc | pleasant | WS | 05 | 03 | − | WS | 51 | 43 | − |
| Rueckl & Olds, 1993 | 1 | coll | B | naming | meaning | WI (sim) | 18† | 16† | − | | | | |
| | 1 | coll | B | naming | meaning | WI (x1) | 23† | 22† | − | | | | |
| | 1 | coll | B | naming | meaning | WI (x3) | 25† | 31† | + | | | | |
| Schacter & Church, 1992 | 1 | coll | B | pitch | cat/word | AWI (same) | 13† | 23† | +† | RC | 44 | 84 | + |
| | 1 | coll | B | pitch | cat/word | AWI (diff) | 11† | 18† | +† | RC | 39 | 80 | + |
| | 2 | coll | B | pitch | cat/word | AWI (same) | 20† | 23† | + | RC | 29 | 65 | + |
| | 2 | coll | B | pitch | cat/word | AWI (diff) | 21† | 16† | − | RC | 30 | 62 | + |
| | 3 | coll | B | pitch | pleasant | AWS (same) | 15† | 31† | +† | AWS | 39 | 66 | + |
| | 3 | coll | B | pitch | pleasant | AWS (diff) | 10† | 20† | +* | AWS | 39 | 62 | + |
| | 4 | coll | B | clarity | meaning | AWS (same) | 28† | 31† | + | AWS | 22 | 54 | + |
| | 4 | coll | B | clarity | meaning | AWS (diff) | 20† | 18† | − | AWS | 22 | 51 | + |
| | 5 | coll | B | clarity | meaning | AWS (same) | 10† | 10† | 0 | | | | |
| | 5 | coll | B | clarity | meaning | AWS (diff) | 07† | 08† | + | | | | |
| Schacter, Cooper, & Delaney, 1990 | 2 | coll | B | leftright | obj/rsmb | OD (pos-1) | 12† | 01 | − | RC | 48 | 69 | + |
| | 2 | coll | B | leftright | obj/rsmb | OD (pos-2) | 13† | 06 | − | RC | | | |
| | 2 | coll | B | leftright | obj/rsmb | OD (imp-1) | −5† | −6 | − | RC | 19 | 38 | + |
| | 2 | coll | B | leftright | obj/rsmb | OD (imp-2) | 0† | −4 | − | RC | | | |
| | 3 | coll | B | size | obj/rsmb | OD (pos-1) | 09† | 10† | + | RC | 31 | 62 | + |
| | 3 | coll | B | size | obj/rsmb | OD (pos-2) | 08† | 06† | − | RC | | | |
| | 3 | coll | B | size | obj/rsmb | OD (imp-1) | −2† | −7† | − | RC | 24 | 46 | + |
| | 3 | coll | B | size | obj/rsmb | OD (imp-2) | −6† | 09† | + | RC | | | |
| Squire, Shimamura, & Graf, 1987 | 2 | coll | W | vowel | pleasant | WS (0m) | 30 | 46 | +† | RC | 79 | 98 | + |
| | 2 | coll | W | vowel | pleasant | WS (2h) | 17 | 18 | +† | RC | 75 | 91 | + |
| | 2 | coll | W | vowel | pleasant | WS (4d) | 16 | 21 | +† | RC | 74 | 85 | + |
| | 2 | alcoh | W | vowel | pleasant | WS (0m) | 27 | 39 | +† | RC | 81 | 96 | + |
| | 2 | alcoh | W | vowel | pleasant | WS (2h) | 04 | 14 | +† | RC | 67 | 90 | + |
| | 2 | alcoh | W | vowel | pleasant | WS (4d) | 11 | 14 | +† | RC | 66 | 78 | + |
| | 3 | coll | W | vowel | pleasant | WF (0m) | 38 | 43 | +† | RC | 80 | 99 | + |
| | 3 | coll | W | vowel | pleasant | WF (2h) | 18 | 33 | +† | RC | 76 | 97 | + |
| | 3 | coll | W | vowel | pleasant | WF (4d) | 17 | 24 | +† | RC | 70 | 90 | + |
| | 3 | alcoh | W | vowel | pleasant | WF (0m) | 19 | 45 | +† | RC | 74 | 97 | + |
| | 3 | alcoh | W | vowel | pleasant | WF (2h) | 03 | 15 | +† | RC | 64 | 92 | + |
| | 3 | alcoh | W | vowel | pleasant | WF (4d) | 09 | 20 | +† | RC | 69 | 90 | + |
| Srinivas & Roediger, 1990 | 2 | coll | B | conson | pleasant | WF (vis) | 13† | 21† | +* | | | | |
| | 2 | coll | B | conson | pleasant | WF (aud) | 09† | 11† | + | | | | |
| | 3 | coll | B | syllab | pleasant | WF (pic) | 07 | 00 | − | | | | |
| | 3 | coll | B | syllab | pleasant | WF (vis) | 18 | 16 | − | | | | |
| | 3 | coll | B | syllab | pleasant | WF (aud) | 09 | 08 | − | | | | |

**APPENDIX (Continued)**

| | | | | Encoding Tasks | | Implicit Test | | | | Explicit Test | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study | Exp. | Subjects | Design | NonSem | Sem | Test | NonSem | Sem | Effect | Test | NonSem | Sem | Effect |
| | | | | Conceptual, Mixed, and Not-Yet-Determined Tasks | | | | | | | | | |
| Buller (cited in | 1 | 3-yr | W | naming | function | CG | 04 | 21 | + | | | | |
| Graf, 1990) | 1 | 4-yr | W | naming | function | CG | 14 | 18 | + | | | | |
| | 1 | 5-yr | W | naming | function | CG | 12 | 22 | + | | | | |
| Carroll, Byrne, | 1 | coll | B | cross | animate | PN (msec) | 35† | 28† | − | RC | 69 | 81 | + |
| & Kirsner, 1985 | 2 | coll | B | cross | portab | PN (msec) | 50† | 33† | − | | | | |
| | 3 | 5-yr | B | cross | portab | PN (msec) | 33† | 73† | + | RC | 24 | 69 | + |
| | 3 | 7-yr | B | cross | portab | PN (msec) | 28† | 70† | + | RC | 58 | 96 | + |
| | 3 | 10-yr | B | cross | portab | PN (msec) | 30† | 57† | + | RC | 64 | 99 | + |
| Challis & Sidhu, 1993 | 3 | coll | W | letter | meaning | GK (x1) | 04 | 07 | + | GK | 20 | 38 | + |
| | 3 | coll | W | letter | meaning | GK (x4) | 07 | 17* | + | GK | 21 | 53 | + |
| | 3 | coll | W | letter | meaning | GK (x16) | 09* | 20* | + | GK | 33 | 60 | + |
| Curfman, 1989 | 1 | coll | B | vertline | animate | PN (msec) | 39* | 76* | + | RC | 58 | 65 | + |
| Hamann, 1990 | 1 | coll | W | vowel | pleasant | GK | 14* | 34* | +* | | | | |
| | 1 | coll | W | vowel | pleasant | CG | 09* | 23* | +* | | | | |
| | 2 | coll | W | vowel | pleasant | CG (10m) | 06* | 16* | +* | | | | |
| | 2 | coll | W | vowel | pleasant | CG (30m) | 01 | 12* | +* | | | | |
| | 2 | coll | W | vowel | pleasant | CG (90m) | 03 | 06 | + | | | | |
| Hamberger & Friedman, | 1 | young | W | typecase | animate | CD (msec) | 12† | 29† | +† | | | | |
| 1992 | 1 | middle | W | typecase | animate | CD (msec) | 08† | 29† | +† | | | | |
| | 1 | older | W | typecase | animate | CD (msec) | 02† | 30† | +† | | | | |
| Java, 1992 | 1 | coll | W | notlet | free/ass | AS | 14† | 05† | − | RC | 39 | 85 | + |
| | 1 | older | W | notlet | free/ass | AS | 07† | 11† | + | RC | 11 | 67 | + |
| Knight, 1988 | 1 | coll | B | vertline | animate | PN (msec) | 38 | 56* | + | RC | 44 | 57 | + |
| | 2 | coll | B | vertline | animate | PN (msec) | 15 | 18 | + | RC | 13 | 26 | + |
| Musen, 1991 | 1 | coll | B | line | obj/rsmb | PD | 07* | 13* | + | RC | 42 | 89 | + |
| D. L. Nelson, Schreiber, | 4 | coll | B | vowel | concrete | FA (large) | 23 | 30 | + | CR | 40 | 60 | + |
| & Holley, 1992 | 4 | coll | B | vowel | concrete | FA (small) | 39 | 46 | + | CR | 55 | 77 | + |
| Schacter & McGlynn, | 1 | coll | B | con/vow | sent/read | FA | 04 | 14* | +* | CR | 11 | 38 | + |
| 1989 | 2 | coll | B | con/vow | sent/read | FA (x2) | 02 | 14* | +† | CR | 09 | 45 | + |
| | 2 | coll | B | con/vow | sent/read | FA (x4) | 04* | 16* | +† | CR | 15 | 66 | + |
| | 2 | coll | B | con/vow | sent/read | FA (x8) | 05* | 25* | +† | CR | 19 | 79 | + |
| | 3 | coll | B | con/vow | sent/read | FA | 14* | 20* | +* | CR | 14 | 32 | + |
| | 4 | coll | B | con/vow | sent/read | FA (x2) | 01 | 27 | +† | CR | 04 | 71 | + |
| | 4 | coll | B | con/vow | sent/read | FA (x4) | 01 | 29 | +† | CR | 08 | 82 | + |
| | 4 | coll | B | con/vow | sent/read | FA (x8) | 01 | 32 | +† | CR | 18 | 88 | + |
| Srinivas & Roediger, | 2 | coll | B | conson | pleasant | CG (vis) | 02 | 14 | +† | | | | |
| 1990 | 2 | coll | B | conson | pleasant | CG (aud) | 03 | 13 | +† | | | | |
| | 2 | coll | B | conson | pleasant | AS (vis) | 16 | 26 | +* | | | | |
| | 2 | coll | B | conson | pleasant | AS (aud) | 20 | 18 | − | | | | |
| | 3 | coll | B | syllab | pleasant | AS (pic) | 03 | 01 | − | | | | |
| | 3 | coll | B | syllab | pleasant | AS (vis) | 11 | 14 | +* | | | | |
| | 3 | coll | B | syllab | pleasant | AS (aud) | 05 | 09 | +* | | | | |

Note—Exp., experiment number. Design: W, within subjects, B, between subjects. NonSem, nonsemantic; Sem, semantic. LOP, level of processing; + indicates positive LOP effect; − indicates reversed LOP effect; 0 indicates no LOP effect; * indicates priming or LOP effect was statistically reliable by the authors' report; † indicates priming or LOP main effect was statistically reliable in conjunction with a nonsignificant interaction. Means are in percentages unless milliseconds are indicated under the implicit test column. For other abbreviations, see text.

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