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Priming the Tip of the Tongue: Effects of Prior Processing on Word Retrieval in Young and Older Adults

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We test the prediction that recent processing of a word will decrease the probability of a tip-of-the-tongue state (TOT) to a general knowledge question and that semantic processing will be superior to phonological processing in improving correct recall, but not in reducing TOTs. In Experiment 1, pronunciation of answers in an ostensibly unrelated prior task increased young and older adults' correct answers to general knowledge questions and decreased TOTs uniformly across age, although older adults produced more TOTs. In Experiments 2 and 3, semantic prior processing increased correct responses to the questions, but did not reduce TOTs more than phonological processing. These results support the Transmission Deficit model in which weakened connections between lexical and phonological nodes cause TOTs. The explanation of aging effects on priming and word retrieval integrates processing and memory systems approaches.

The tip-of-the-tongue (TOT) state is a dramatic instance of retrieval failure in which one is unable to produce a word although absolutely certain that the word is known (see Brown, 1991, for a review). Virtually all naturally occurring TOTs are eventually resolved, confirming that the TOT word is in memory, although temporarily inaccessible (Burke, MacKay, Worthley, & Wade, 1991). The starting point for the present research was a previous finding that TOT targets are low-frequency words or words that have not been used for some time. Recency of use influences retrieval processes in speech production according to the Transmission Deficit model of TOTs (Burke et al., 1991). Thus, TOTs represent an intersection of speech and memory research: We investigate the effect of recent processing on TOTs using a speech production model of TOTs and an experimental method derived from a basic memory paradigm, namely, repetition priming.

The goal of the research is to test predictions concerning the locus of the TOT deficit by examining the effect of different types of prior processing on TOTs in both young and older adults. Repetition priming effects show little variation with age, especially relative to the consistent age decrement found in explicit memory tasks (Howard, 1991; Light, 1991; Mitchell, 1993). The first two experiments test both young and older adults to determine whether this age constancy in repetition priming holds for TOTs which increase quite dramatically in old age.

The Transmission Deficit model proposes that TOTs are caused by insufficient transmission of priming top-down from a lexical representation in memory to corresponding phonological representations during an attempt to produce the word (Burke et al., 1991; MacKay & Burke, 1990). Recency of prior processing is one factor postulated to affect the rate of transmission of priming; connections among representations weaken over time when a word is not used, and the strength of

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connections determines transmission rate (see MacKay, 1987). Recent use of a target word reduces the probability of TOT by increasing the transmission of priming between lexical and phonological nodes. In Experiment 1, we test the hypothesis that TOTs are reduced by recent processing of target words and in Experiments 2 and 3 the hypothesis that phonological but not semantic processing is critical because the locus of TOTs is in phonological retrieval processes. By identifying the extent to which semantic and phonological prior processing aids word retrieval, we also hope to shed some light on the mechanisms of repetition priming.

Recent Prior Experience: Repetition Priming Effects

Recent processing of a word increases the accuracy and speed of its perception or production even without awareness of a relation between the prior experience and the facilitation of performance (see e.g., Richardson-Klavehn & Bjork, 1988; Roediger, 1990; Schacter, 1987). Improved performance as a result of recent exposure to a word is seen in *perception* tasks such as lexical decision (e.g., Scarborough, Cortese, & Scarborough, 1977) and word identification (e.g., Jacoby & Dallas, 1981) and on *production* tasks such as word fragment completion (e.g., Tulving, Schacter, & Stark, 1982; Weldon, 1991), picture naming (Wheeldon & Monsell, 1992), and general knowledge questions (e.g., Blaxton, 1989; Hamann, 1990; Kelley & Lindsay, 1993).

The general knowledge questions used in repetition priming studies are typically the same type of questions used to induce TOTs in the laboratory. Previously, however, the focus has been on the increase in number of correct responses with prior processing of the target, and incorrect responses, in particular TOTs, have not been evaluated. Thus the effect of repetition priming on TOTs is unknown.

Type of Prior Processing and Repetition Priming Effects

The *transfer appropriate processing* principle postulates that the effect of prior processing on memory performance depends on the amount of overlap between the mental operations involved in the prior experience and those involved in the test (Morris, Bransford, & Franks, 1977; Tulving, 1983; Tulving & Thomson, 1973). Roediger and his colleagues have explained dissociations in the effects of variables on implicit and explicit memory performance as a consequence of the different retrieval operations involved in the two types of memory tasks (e.g., Roediger & Srinivas, 1993; Roediger, Weldon, & Challis, 1989; Srinivas & Roediger, 1990; Weldon, 1991). Explicit memory tasks are considered primarily conceptually driven because performance is improved by prior semantic processing, indicating a dependence on encoding of meaning. Implicit memory tasks are considered primarily data-driven because performance is improved by perceptual similarity between the prior experience and the test.

However, memory tasks do not depend exclusively on one type of processing (e.g., Bassili, Smith, & MacLeod, 1989; Blaxton, 1989; Weldon, 1991; Weldon & Jackson-Barrett, 1993). Roediger has suggested that data-driven versus conceptually driven represents a continuum and that implicit memory tasks vary in the extent to which they depend on the two types of processes. Consistent with this, implicit memory tasks vary in the effect of type of prior processing (Roediger, Srinivas, & Weldon, 1989). For example, Blaxton (1989) reported that performance on general knowledge questions benefited more from prior semantic than surface level processing, suggesting a greater conceptually driven component in this task. Fragment completion performance benefited more from surface rather than semantic level processing, suggesting a greater data-driven component.

The success of this approach depends on the ability to identify the different mental operations involved in a particular memory task (Graf & Ryan, 1990). The means of identifying component operations in previous studies has been primarily empirical, for example, by determining the effect of different types of processing on task performance (e.g., Roediger et al., 1989). Types of processing effects, however, have not been consistent in some tasks. For example, repetition priming in ‘‘data-driven’’ fragment completion and perceptual identification tasks was stronger with semantic than with physical prior processing (Challis & Brodbeck, 1992; Thapar & Greene, 1994). The conceptually driven versus data-driven dichotomy also neglects the role of other processes, such as phonological encoding, which are not inherently either conceptual or dependent on the physical form of the stimulus.

In the present study, we use transfer appropriate processing principles for interpreting the effects of type of prior processing, but we use a theoretical basis for identifying mental operations involved in our task of answering general knowledge questions. The identity of these operations is the basis for predictions concerning the effect of type of prior processing on correct word retrieval and TOTs. In order to clarify the basis for the predictions, we next describe briefly the underlying model of word retrieval.

Transmission Deficit Model of TOTs

The Transmission Deficit model of TOTs was developed from the Node Structure Theory (NST), an interactive activation model of language perception and production developed by MacKay (1982, 1987). Word meanings are represented in a semantic system and word sounds are represented in a phonological system. Each lexical node is unique to a specific word and is connected to phonological nodes and semantic nodes which specify the words’ phonology and meaning. A portion of the representation of the word *palindrome* is illustrated in Fig. 1. The hierarchically organized nodes which represent syllables, phonological compounds, and features for *palindrome* and the semantic nodes which represent aspects of the word’s meaning are also shared with other words with these components. For example, lexical nodes for *palindrome* and *palisade* both are connected to the stressed syllable *pal.*

Within the NST, a special mechanism activates the most primed node in a syntactic class causing retrieval of the information it represents (MacKay, 1982, 1987). This activation mechanism differs from priming which is subthreshold excitation that prepares a node for activation and is similar in some respects to spreading activation in other models. The strength of connections between nodes determines the rate and amount of priming transmitted between them and thus is an important determinant of what information in memory becomes available. Connections between nodes become stronger or more efficient with use, increasing the rate and amount of priming transmitted across connections between frequently activated nodes (MacKay, 1982, 1987).

Word retrieval in response to a general knowledge question starts with activation of semantic nodes representing features of meaning corresponding to the question. These semantic nodes transmit priming across connections to lexical nodes and the lexical node receiving the greatest amount of priming will be activated. Activation of the lexical node gives access to further semantic information about the word and a feeling of knowing, but production of the word requires activation of phonological nodes at the lowest (feature) level. TOTs occur when the lexical node for the TOT target becomes activated, but at least some phonological information remains inaccessible (unactivated) because of a transmission deficit from the lexical node to the connected phonological nodes (see Fig. 1).

Three factors influence transmission deficits within the model because they affect the strength of connections and thus the transmission of priming: *recency* and *frequency* of activation and *aging* of the subject. These factors explain empirical findings on TOTs, for example, that TOT targets are very low in normed frequency of occurrence and that TOTs increase in old age while the availability of partial information during a TOT decreases (Burke et al., 1991; Cohen & Faulkner, 1986).

Transmission deficits in the phonological system are counteracted by activation of phonological nodes which strengthens connec-

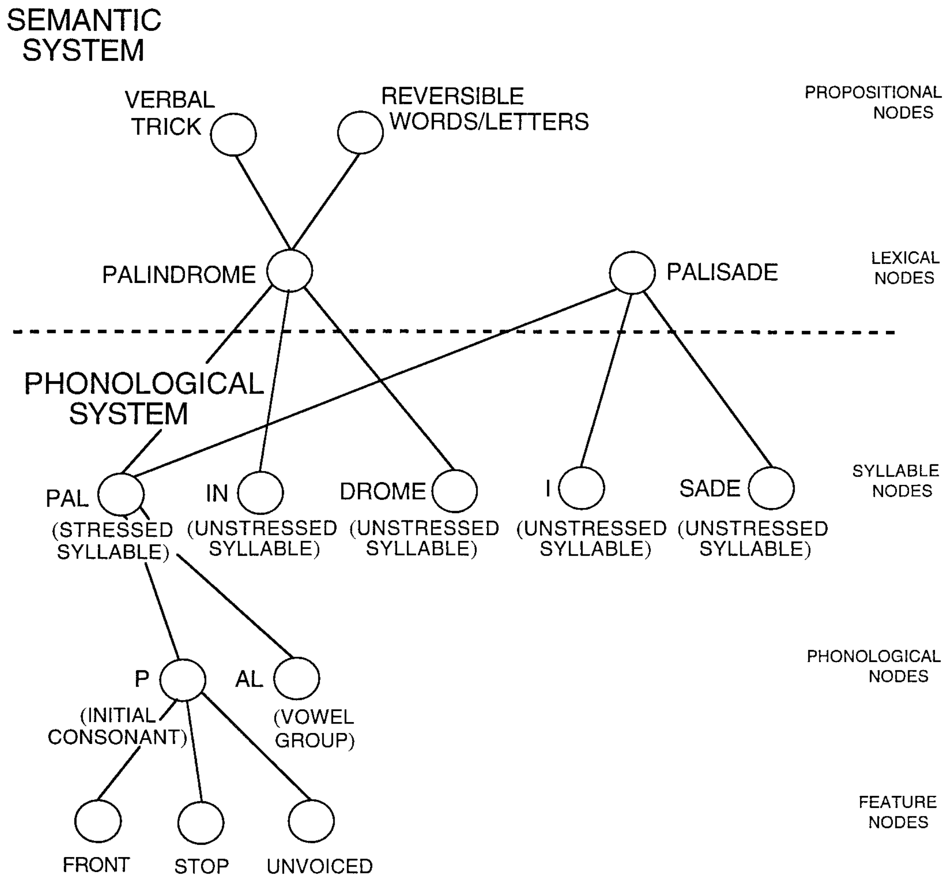

FIG. 1. A sample of nodes representing *palindrome* in the semantic and phonological systems. Many nodes necessary for producing this word have been left out to simplify the figure.

tions. This leads to the prediction, tested in Experiment 1, that pronunciation of a target word will reduce the likelihood of a subsequent TOT experience. In Experiments 2 and 3, we manipulate the nature of prior processing and examine the effect on TOTs. Because weak phonological connections cause TOTs, phonological processing of a word should reduce the likelihood of TOT and semantic processing should be irrelevant.

EXPERIMENT 1

In their analysis of the corpus of words involved in naturally occurring TOTs, Burke et al. (1991) found a relation between recent target production and probability of TOT. Proper names accounted for about 68% of all TOT targets and those that were names of acquaintances involved people who were very familiar, but who had not been contacted recently. Time since last contact with these people was longer for 65- to 75-year-old adults (M = 4.0 years) than for 18- to 21-year-olds (M = .27 years), but in both cases the names had not been used for several months or more. These data suggest that nonrecent production of a word may increase its vulnerability to a TOT state, and that age-related increases in TOTs may be related to changes in recency of production of names over the life span.

In Experiment 1, subjects were required to answer general knowledge questions following an ostensibly unrelated pronounciation task involving answers to half of the subsequent questions. Based on previous studies, we predict that prior processing will increase correct answers (e.g., Blaxton, 1989), and based on the Transmission Deficit model, we predict a reduction in TOTs as well.

Another goal of the study is to investigate the role of prior processing in the potent effects of two variables on TOTs: subject age and word class (proper names). Proper names of familiar people are more difficult to retrieve than other types of biographical information and are especially susceptible to TOTs (see Cohen & Burke, 1993). One possible explanation is that long periods of nonuse are more common for proper names than other words, as when a friend moves away or a public figure retires. In this case, the difference in frequency of TOTs between proper names and other words will be reduced in our recency condition, which equates the interval since prior processing.

Recency may also contribute to the aging effect on TOTs. Older adults report more TOTs than young adults both in the laboratory and in everyday life, especially for proper names and acquaintance names that have not been used recently (Burke et al., 1991; Cohen & Faulkner, 1986; Maylor, 1990b). Greater age makes possible very long intervals since the last use of a particular word. If an age difference in recency of use is the critical variable underlying age-related increases in TOTs, the age difference in TOTs will be reduced in the prior processing condition. In contrast, if the age difference is caused only by age-linked transmission deficits, there will be equivalent effects of prior processing across age.

Method

Subjects. Thirty undergraduates between the ages of 18 and 22 (M = 19.5 years, SD = 1.28) and 30 older adults between the ages of 64 and 82 (M = 70.6 years, SD = 4.78) participated in the experiment. Young adults were undergraduates at the Claremont Colleges and older adults lived independently in the Los Angeles area. All subjects were paid for their participation.

Vocabulary on the 50-item Primary Mental Abilities (PMA) subtest was significantly higher for older (M = 48.23) than young adults (M = 45.70), $t(58) = -3.52$, as was educational level (M = 16.93 and 13.97, respectively), $t(58) = -5.59$. There was no age difference in rating of health on a 7-point Likert scale (1, poor; 7, excellent). (All results reported as significant in this paper attained at least $p < .05$).

Materials and design. We selected from previous studies 90 general knowledge questions that were answerable with single, low-frequency words and that induced TOTs in both young and older adults (Burke & Laver, 1990; Burke et al., 1991). Common nouns answered 70 of the questions (e.g., *What is the name for a mixture of dried spices and flowers used for perfuming a room? What is the name of the nylon fabric that has two pieces that stick to each other and is used as a fastener?*) and proper nouns answered the remaining 20 questions (e.g., *What is the name of the strait between Alaska and Siberia? What is the last name of the man who assassinated Robert Kennedy?*). There were more common than proper nouns because proper names seemed more noticeable in the prior processing task and thus more likely to call attention to the relation between this task and the general knowledge questions. (Answers: *POTPOURRI, VELCRO, BERING, SIRHAN*).

The questions were divided into two lists of 45 questions each: Ten questions were answered by proper nouns and 35 questions were answered by common nouns. For each subject, one list was used for the pronunciation rating task and general knowledge task (recency condition), and the other list was used for the general knowledge task alone (baseline condition). The assignment of lists to either the recency or baseline condition was counterbalanced across subjects within each age group.

The answer sheet for the general knowledge questions consisted of seven columns. Subjects choose one of the first three columns: Column one (‘‘Know’’) was for writing the answer to the question, column two (‘‘Don’t Know’’) was checked if they did not know the answer to the question, and column three (''TOT'') was checked in the case of a TOT. If subjects checked TOT, they wrote partial phonological information (number of syllables, first letter(s)), if available, in the fourth and fifth columns, respectively. In column six, subjects wrote the correct answer to the question after the experimenter read it aloud. Subjects who checked TOT were instructed to write ''yes'' or ''no'' in column seven, depending on whether or not the correct answer read by the experimenter was the word they were trying to recall.

Procedure. Subjects were tested individually or in small groups of two to four. After completing a demographic questionnaire requesting information about age, sex, health status, and education level, subjects were given, in this order, the pronunciation rating task, a vocabulary test, and the general knowledge task.

In the pronunciation task, subjects viewed 45 words presented via overhead projector, one at a time in random order. Subjects read each word aloud as it appeared and rated the difficulty of its pronunciation on a 7-point Likert scale on the answer sheet. Each word remained on the screen for 5 s. After the pronunciation task, subjects were given 10 min to complete the PMA vocabulary test.

In the general knowledge task, subjects heard 90 questions in random order. Half of the questions were answered by the words presented in the pronunciation task, and half by words not presented in the experiment. For each question, subjects checked the appropriate column of the answer sheet. Subjects were instructed to check TOT only if they were confident that they knew the word and it was on the verge of coming back to them. Ten seconds after presenting the question, the experimenter read the correct answer to the question. Subjects who reported a TOT state were asked to indicate whether or not the correct answer was the word they were trying to recall.

Results

The analysis of Know responses included only correctly recalled answers and excluded those trials on which subjects responded Know and wrote the incorrect answer or no answer. The analysis of TOT responses excluded incorrect TOTs where the subject was attempting to recall a word other than the correct answer. Incorrect TOTs made up 4.37 and 4.67% of responses in the recency condition for young and older adults, respectively, and 6.89 and 6.22% in the baseline condition, respectively; they were not included in subsequent analyses. The proportion of Know and TOT responses were calculated for each subject and analyzed in separate ANOVAs, each with age group, condition (recency versus baseline) and word type (common versus proper noun) as variables. All analyses were on proportions, unless noted otherwise, and *M*'s are displayed as percentages.

As shown in Fig. 2 (left), there were significantly more Know responses for older than young adults, $F(1,58) = 6.90$, $MSE = .0721$, and more Know responses occurred in the recency condition than in the baseline condition, $F(1,58) = 74.90$, $MSE = .0128$. Subjects also knew a greater proportion of common nouns ($M = 44.50\%$) than proper nouns ($M = 36.75\%$), $F(1,58) = 12.80$, $MSE = .0279$. There were no significant interactions.

There were significantly more TOT responses for older than young adults, $F(1,58) = 17.53$, $MSE = .0253$, and more TOTs occurred in the baseline condition than in the recency condition, $F(1,58) = 26.13$, $MSE = .0072$ (see Fig. 2 (right)). There was a greater proportion of TOT responses for proper than common nouns, $F(1,58) = 24.06$, $MSE = .0067$. As seen in Fig. 3, there was a significant age group by word type interaction, $F(1,58) = 8.37$, $MSE = .0067$, because the age difference in TOTs was twice as big for proper names as for common nouns. Recency did not interact with either age group or word type.

TOTs can occur only when a word is not immediately recalled and thus variables that increased Know responses (e.g., old age, recency, common names) reduced the opportunity for TOTs. We adjusted for differences in opportunity for TOT by calculating TOTs

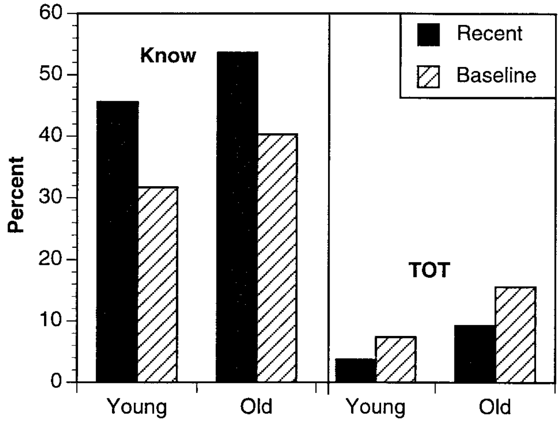

FIG. 2. Percentage of Know and TOT responses as a function of age and prior processing condition in Experiment 1.

as a proportion of unsuccessful retrievals, that is, the number of trials minus the number of correct Know responses (Brown, 1991; Burke et al., 1991). This allowed us to determine, for example, if the reduction in absolute number of TOTs in the recency condition was because there was less opportunity for TOTs in this condition. The ANOVA on these data, however, yielded the same pattern of significant effects as above. There were relatively more TOTs for older than young adults, $F(1,58) = 28.74$, $MSE = .0485$ and more for the baseline than the recency condition, $F(1,58) = 13.98$, $MSE = .0124$ (for the baseline and recency conditions, young adults' Ms = 10.8 and 6.8% and older adults' Ms = 26.1 and 20.4%, respectively). Again, there is no evidence that the recency effect differed by age, $F(1,58) = .26$. There were more TOTs for proper than common names $F(1,58) = 12.91$, $MSE = .0166$, with a significant age by word type interaction, $F(1,58) = 5.90$, $MSE = .0166$ (for common names and proper names,

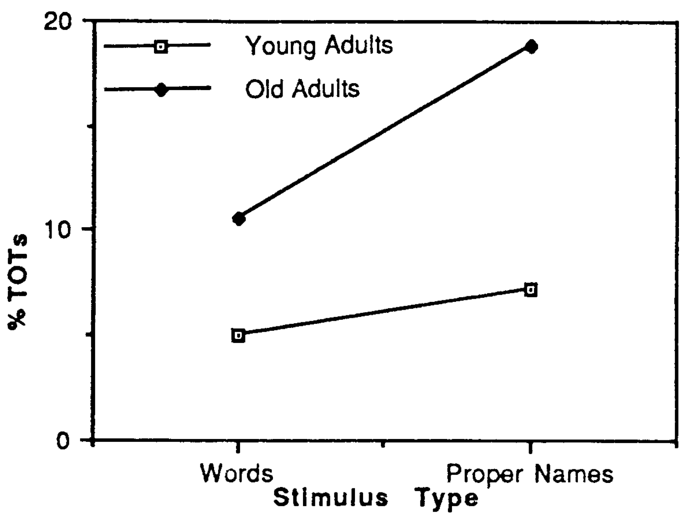

FIG. 3. Percentage of TOT responses for proper versus common names for each age group in Experiment 1.

young adults' M's = 8.1 and 10.0% and older adults M's = 19.3 and 29.3%).

The mean number of correct phonological characteristics reported in a TOT state was calculated separately by age group and recency condition. We excluded 4 older subjects and 10 young subjects who did not report at least one TOT in both conditions. Older adults reported fewer characteristics per TOT than did young adults, $F(1,44) = 43.69$, $MSE = .2920$, ($M = .09$ and .83, respectively). There was no effect of recency condition $F(1,44) = .07$, and no interactions.

Discussion

Prior processing of target words reduced the frequency of TOT states by almost 50% for both young and older adults. This effect was not because prior processing reduced the opportunity for TOTs by increasing correct recall: Prior processing also reduced the proportion of trials without correct recall that were TOTs. These findings are consistent with the hypothesis that TOT states are more likely for words that have not been produced recently and support the Transmission Deficit model in which recent production of a word strengthens connections between lexical and phonological nodes, thus reducing the probability of a TOT.

Can the age-related increase in TOTs be explained by age differences in recency of use? There was no evidence for this hypothesis in the absence of an age by recency interaction in the analysis of TOTs, either with TOTs as a proportion of all trials or as a proportion of trials without correct recall. If the age difference in TOTs was because older adults possess a greater number of nonrecently used words in their lexicons than young adults, then recent processing should have at least narrowed the age difference, but it did not.

Consistent with previous findings, young adults reported considerably more partial phonological information during TOTs than older adults (Burke et al., 1991; Maylor, 1990a). In the Transmission Deficit model, partial phonological information is retrieved when only some of the phonological nodes for producing a word are suffering a transmission deficit and a portion of the remaining phonological nodes become activated, providing the basis for partial recall. Thus the age difference in partial information is consistent with age-linked transmission deficits that decrease the availability of partial phonological information in old age by reducing the transmission of priming within the phonological system. Inasmuch as prior processing reduced TOTs by strengthening connections among phonological nodes, it is surprising that there was no effect on the availability of phonological information when TOTs persisted. One possible explanation is that prior processing strengthened primarily the connections from lexical nodes to the first level of phonological nodes, and these connections are the locus of TOTs, whereas lower level connections are critical for partial information. We return to this issue under General Discussion (below).

Proper names produced more TOTs than common nouns and the age difference in TOTs was more pronounced for proper names. We found no evidence that the special difficulty of proper names was related to recency of use because the difference in TOTs for common and proper nouns was comparable in the recency and baseline conditions. It has also been proposed that the difficulty in retrieving proper names reflects fundamental differences in the semantic representation of common and proper names, and in view of the present findings, this may be a more viable approach (see Burke et al., 1991; Cohen, 1990; Cohen & Burke, 1993).

As in previous research, prior processing increased correct recall of a word (Know responses) in answer to a general knowledge question (e.g., Blaxton, 1989). This faciliatory effect was age constant, which is consistent with evidence suggesting that repetition priming effects show little decline with age (Howard, 1991; Light, 1991; Mitchell, 1993). In the next experiment we isolate conceptual and perceptual processes involved in the priming effect and age differences may emerge in conceptual priming. It has been suggested that there are age-related declines in conceptual processes involved in word retrieval (Craik & Jennings, 1992). Moreover, age-related deficits in conceptually driven priming would be consistent with transfer appropriate processing explanations of implicit–explicit memory dissociations such as those found in old age: Deficits in conceptual processes produce explicit memory declines, whereas intact data-driven processes preserve implicit memory.

EXPERIMENT 2

General knowledge questions have been categorized as a primarily conceptually driven task because correct recall increases more following processing that directs attention to semantic features rather than to physical features of the target (Blaxton, 1989; Hamann, 1990; Roediger et al., 1989). For example, Hamann (1990) found that correct answers to general knowledge questions increased more after an orienting task requiring a like–dislike rating of the target than after a judgment about vowels in common with a previous word. Within the transfer appropriate processing framework, this is because the overlap in processes is greater between the like–dislike orienting task and the test than between the vowel orienting task and test.

In the NST model, phonological processes are critical for word retrieval in tasks such as general knowledge questions. Activation of semantic propositions leads to activation of a lexical node and the knowledge that a word is known; priming spreads from the lexical node and usually produces activation of the appropriate phonological nodes followed by a correct response. If, however, activated semantic propositions transmit insufficient priming for activation of a lexical node, a Don't Know response will be produced. If there is sufficient semantic priming to activate the correct lexical node, but there is a deficit in phonological activation, a TOT response will be produced. Thus, TOTs provide a means of isolating phonological processes within a conceptually driven task. Applying transfer appropriate processing logic, prior phonological processing will reduce TOTs while prior semantic processing will be irrelevant to the frequency of TOTs because it does not affect phonological retrieval operations.

In Experiment 2, we evaluated the effects of prior semantic and phonological processing on correct answers and TOTs to general knowledge questions. Subjects in the recency group performed three processing tasks before the test, namely, rating the pleasantness, number of syllables, or number of capital letters in a visually presented target word. Pleasantness rating requires greater conceptual processing than the other two tasks and thus is expected to improve recall the most by strengthening connections between lexical and semantic nodes. If older adults have deficits in conceptual encoding during word retrieval (e.g., Craik & Jennings, 1992), then the pleasantness task should induce less conceptual processing in older than younger adults, and thus a smaller improvement in correct responses.

Because reading familiar words is an automatic process (e.g., Stroop, 1935), and because even silent reading involves phonological encoding (e.g., Daneman & Stainton, 1991), we assumed that phonological processing would occur in all three tasks. Thus, we predicted that all three types of processing would reduce TOTs relative to a baseline group that received no task prior to the questions. Prior conceptual processing is not predicted to reduce the likelihood of TOT any more than the other two tasks because TOT is a consequence of weak phonological connections to the lexical node, not weak semantic connections. These connections would be unaffected by conceptual processing. On the other hand, however, if either explicit phonological processing or conceptual processing reduces TOTs, than the syllable and conceptual task will yield fewer TOTs than the case task.

A third group of young and older subjects received the three processing tasks, but was tested on explicit cued recall. Explicit recall has consistently been shown to vary with type of prior processing and thus this group provided a check on the effectiveness of our prior processing manipulation in the event that it had no effect on implicit recall.

Method

Design. Young and older adults were randomly assigned to one of three groups: Knowledge-Recency, Knowledge-Baseline, or Explicit Memory. For the first two groups, the test was general knowledge questions and for the third group the test was cued episodic recall. In the Knowledge-Recency and Explicit Memory groups, prior judgments about pleasantness, syllables, or case were varied within subjects. The 90 words in this orienting task were answers to the 90 general knowledge questions presented later to the Knowledge groups, and to the 90 word stems presented later for cued-recall to the Explicit Memory group. In the Knowledge Baseline group, the general knowledge questions were presented with no preceding task.

Subjects. Fifty-four undergraduates of the Claremont Colleges between the ages of 17 and 24 ($M = 19.6$ years, $SD = 1.38$) and 55 older adults from the Los Angeles area between the ages of 64 and 79 ($M = 70.84$ years, $SD = 3.87$) participated in the experiment. In each age group, there were 24 subjects in the Knowledge-Recency group, 12 subjects in the Explicit Memory group, and 18 young and 19 old subjects in the Knowledge-Baseline group. Older adults were paid for their participation and younger adults either were paid or received credit for a course requirement.

Older adults scored higher than young adults on the Nelson–Denny 25-item multiple choice vocabulary test (M's = 20.98 and 17.63, respectively), $t(106) = -5.81$, and had higher education levels (M's = 16.60 and 13.85 years, respectively), $t(107) = -7.22$. There was no age difference in rating of health.

Materials. Ninety general knowledge questions answered with single, low frequency words were selected from the same sources as in Experiment 1. Sixty-six of these questions were answered with common nouns, and 24 questions were answered with proper names of people or places. The questions were divided into three lists of 30 questions each: eight questions were answered by proper nouns and 22 questions were answered by common nouns. For each subject in the Knowledge-Recency and Explicit Memory groups, each of the three lists was matched with one of the three incidental tasks, with assignment of lists to task counterbalanced over subjects.

In the Explicit Memory condition, young subjects received 90 three-letter stems and older adults received 90 four-letter stems. For target words of only four letters, both young and older adults received three-letter word stems. The longer stems for older adults were necessary to avoid floor effects revealed in pilot tests with three-letter stems.

The answer sheet for the orienting task required subjects to rate pleasantness, syllables, or number of capital letters on a 5-point Likert scale for each of 90 words. The answer sheet for the Knowledge groups was similar to the one used in Experiment 1. However, subjects were not required to write partial phonological information after reporting a TOT.

Procedure. Subjects were tested individually or in small groups of two or three. First, they completed the demographic questionnaire used in Experiment 1. Next, subjects in the Knowledge-Recency and Explicit Memory groups viewed 90 words presented via overhead projector, one at a time and in random order. Each word appeared with one of three instructions. When the word was preceded by the ''Pleasantness'' instruction, subjects considered the meaning of the word and rated its pleasantness on a 5-point Likert scale. When the target word was preceded by the ''Syllables'' instruction, subjects decided how many syllables, between one and five, were in the word. When the word was preceded by the instruction ''Case,'' subjects counted the number of capital letters, between one and five, in the word. Each word was presented for approximately 5 s. After the orienting task, subjects were given 10 min to complete the Nelson–Denny vocabulary test.

Subjects in the Knowledge-Recency condition were then asked 90 general knowledge questions, in random order, whose answers were the words presented in the orienting task. All instructions and procedures for the general knowledge questions were the same as those in Experiment 1. Subjects in the Explicit Memory condition were given a stem-completion test instead of general knowledge questions for all words appearing in the orienting task.

Subjects in the Knowledge-Baseline condition did not participate in the orienting task. They completed only the demographic questionnaire, the vocabulary test, and the general knowledge questions, in that order.

Results

Type of processing effects in the Knowledge-Recency group. The initial analysis evaluated the effect of the different orienting tasks and excluded the Baseline condition. The proportion of Know and correct TOT responses were calculated as in Experiment 1 and analyzed in separate ANOVAs with age and type of orienting task (pleasantness, syllables, or case) as variables. Incorrect TOTs made up 7.08 and 4.03% of the responses in the Pleasantness condition for young and older adults, respectively, 6.67 and 5.83% in the Syllable condition, and 6.94 and 5.14% in the Case condition. The proportion of incorrect TOTs was marginally higher for young than older adults, $F(1,46) = 3.24$, $p < .08$, $MSE = .0085$. Incorrect TOTs were not included in subsequent analyses.

Figure 4 (left) shows mean percentage of Know responses for each of the three orienting conditions for each age group. There was a main effect of orienting condition, $F(2,92) = 16.13$, $MSE = .0153$, with more Know responses in the pleasantness than the syllable or case conditions, t's(47) = 4.61 and 5.99, respectively, and more Know responses in the syllable than the case condition $t(47) = 2.26$. There were no age effects or interactions.

Figure 4 (right) shows mean percentage of TOT responses by age and orienting condition. No effects approached significance in ANOVAs with TOT as proportion of all trials and with TOT as a proportion of trials without the correct answer (all F's < 1.0). We added proper versus common nouns as a variable to determine whether TOTs were affected by a variable other than type of prior processing, thereby eliminating the possibility of floor effects. There was no main effect of word type, but the age by word type interaction approached significance with TOTs as a proportion of all trials, $F(1,46) = 3.42$, $p < .07$, $MSE = .0061$, and was significant with TOTs as a proportion of trials without the correct answer, $F(1,43) = 4.11$, $MSE = .0191$. Older adults produced TOTs on a greater proportion of all trials for proper than common names ($M = 11.5$ and 9.1%, respectively, $t(23) = 1.76$, $p < .05$), whereas there was no difference between proper and common names for young adults ($M = 8.3$ and 9.3%, respectively).

Repetition effects. The effect of prior processing on performance was evaluated by comparing the Knowledge-Recency group with the Knowledge-Baseline group. In one set of analyses, proportion of responses was averaged across the three orienting task conditions in the Recency group and compared to performance of the Baseline group in age by group ANOVAs, separately for Know and TOT responses. In a second set of analyses, performance in each orienting task condition was compared to performance of the Baseline group via t tests, separately for Know and TOT responses within each age group. Significance level was set at .015 for the t tests.

There were more Know responses in the Recency group than in the Baseline group, $F(1,81) = 28.75$, $MSE = .0205$ (see Fig. 4). There were no age effects or interactions. For young adults, t tests revealed more Know responses for the Pleasantness, Syllables, and Case conditions than for the Baseline group, t's(40) = 4.10, 4.34, and 3.24, respectively. Similarly, for older adults, more Know responses occurred for the Pleasantness and Syllables condition than for the Baseline group, t's(41) = 3.76 and 2.71, respectively.

For TOT responses, there were significant effects of age, $F(1,81) = 5.85$, $MSE = .0068$, group, $F(1,81) = 10.52$, $MSE = .0068$, and

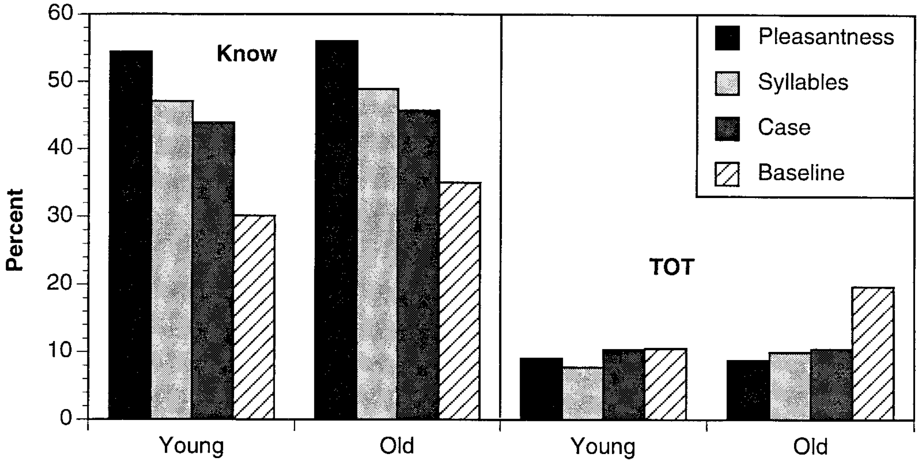

FIG. 4. Percentage of Know and TOT responses as a function of age and prior processing condition in Experiment 2.

an age by group interaction, $F(1,81) = 5.77$, $MSE = .0068$. As seen in Fig. 4, Recency and Baseline groups did not differ in TOTs for younger adults, $t(40) = -.81$, but prior processing did reduce TOTs for older adults, $t(41) = -3.26$. An ANOVA with TOT as a proportion of trials without the correct answer showed a similar effect of age, $F(1,81) = 8.00$, $MSE = .0176$, and an age by group interaction, $F(1,81) = 4.09$, $MSE = .0176$. Again, the Recency and Baseline groups did not differ in the proportion of incorrect responses that were TOTs for younger adults ($M = 17.7$ and 15.6%, respectively), but prior processing did reduce TOTs for older adults ($M = 20.5$ and 30.0%, respectively), $t(41) = -2.03$. Finally, t tests between baseline and each orienting task condition using the proportion of trials that were TOTs revealed no significant differences for young adults. For older adults, however, a smaller proportion of TOTs occurred in the Pleasantness, Syllables, and Case conditions than in the Baseline group, t's$(41) = -3.44$, -2.95, and -2.96, respectively.

Explicit memory condition. Proportion correct cued recall was significantly affected by orienting task in both age groups, $F(2,44) = 40.18$, $MSE = .0082$, with the pleasantness condition ($M = 33.5\%$) producing better recall than the syllable condition ($M = 20.6\%$) $t(23) = 5.34$, or case condition ($M = 10.1\%$), $t(23) = 7.21$, and the syllable condition producing better recall than the case condition, $t(23) = 4.05$. Age effects are not meaningful because older adults received longer stem cues than younger adults.

Discussion

Type of prior processing affected explicit recall and Know responses for general knowledge questions. In general, the pleasantness task improved correct responding more than the other two tasks, with comparable effects across age. The frequency of TOTs, however, was unaffected by type of prior processing: All three orienting tasks reduced TOTs relative to the baseline condition for older adults, but not young adults. The older adults' data provide no evidence that processing beyond silent reading of the word was effective in reducing TOTs. The effect of word type (common vs proper names) in the orienting task conditions for older adults suggests that their TOTs were not at floor. The older adults' data are consistent with the hypothesis that TOTs are caused by weak connections in the phonological system and are thus unaffected by semantic processing. However, this interpretation is challenged by the young adults' surprising results in which the priming effect obtained in Experiment 1 was eliminated. There is some evidence that this null effect of prior processing reflected a response bias which inflated TOT responses for younger adults in the Recency group.

First, older adults produced more TOTs than young adults in the Baseline group, consistent with Experiment 1 and previous research (Burke et al., 1991), but in the Recency group TOT frequency was as high for young adults as for older adults. Second, the percentage of TOTs for older adults was similar in Experiments 1 and 2 in the baseline condition (15.6 and 19.8%, respectively) and in the recency conditions (9.5 and 9.7%, respectively). This is unsurprising because there was considerable overlap in the questions for the two experiments and the subjects were from the same population. For young adults, although the percentage of TOTs was similar in the baseline condition in Experiments 1 and 2 (7.4 and 10.6%, respectively), there was a 2.5-fold increase in TOTs in the recency conditions from Experiment 1 to Experiment 2 (3.70 and 9.08%, respectively).

Young adults may have been more likely to respond TOT in the recency conditions in Experiment 2 because answers to all the questions appeared in the orienting task, whereas in Experiment 1 only 50% of the answers appeared in the orienting task. Some young subjects spontaneously commented that they knew all the answers had been presented earlier, whereas the older adults seemed unaware of this connection. Thus, instead of reporting Don't Know, young subjects may have been biased to report TOT because they knew they had seen the word earlier. In this case, any decrease in TOTs because of recent presentation was counteracted by an increase in TOTs from some young subjects who felt that they must know the answer because they had just seen it. Consistent with this interpretation, young adults in the Recency group had marginally more incorrect TOTs (where the correct answer was not the word they were trying to recall) than older adults, a result not found in previous studies (Experiment 1; Burke et al., 1991).

Although awareness that answers had been presented may have affected TOT judgments, there is no evidence that conscious episodic recall actually improved young adults' performance. If this were the case, TOTs would be lowest in the condition producing relatively high episodic recall, namely, the pleasantness condition. Moreover, Know responses would be relatively higher for young than older adults in the recency compared to the baseline condition, inasmuch as this strategy was used by young but not older adults. There was, however, no such age by recency interaction.

Experiment 3

In Experiment 3 we attempted to reduce young adults' awareness of prior presentation of target words by returning to a within-subject design in which only 50% of questions had answers presented in the orienting task. We also added a feeling-of-knowing (FOK) rating on TOT trials to measure whether prior processing increased FOK. If subjects are aware of the relation between prior processing and the general knowledge questions, this should increase their FOK.

Method

Subjects. Participants were 40 undergraduates from the Claremont Colleges between the ages of 17 and 26 ($M = 19.38$), with a mean Nelson–Denny vocabulary score of 17.53, and a mean educational level of 14.35 years. They were either paid or received credit for a course requirement.

Design and materials. Eighty-eight general knowledge questions were selected from the same sources as in Experiments 1 and 2. Sixty-eight of those questions were answered with common nouns and 20 were answered by proper nouns. The questions were divided into four lists of 22 questions each: In each list, 5 questions were answered by proper nouns and 17 questions were answered by common nouns. For each subject, one list was assigned to the Pleasantness task, one to the Syllables task, and the remaining two lists to the Baseline condition (no orienting task). The assignment of list to condition was counterbalanced across subjects. The response sheets for the orienting task and the general knowledge questions were similar to those used in the previous experiments except for the addition of a FOK rating for TOT responses on a 1 to 7 scale.

Procedure. Subjects completed the demographic questionnaire and then the orienting task in which they viewed 44 words presented one at a time in random order via overhead projector. Each word was preceded by a Pleasantness or Syllables instruction and subjects indicated their response on the 5-point Likert scale on the answer sheet.

Subjects next completed the vocabulary measure, and then the 88 general knowledge questions in random order. All other instructions and procedures regarding the general knowledge question phase of the test were the same as in Experiments 1 and 2.

Results

The proportion of Know and correct TOT responses were calculated as in Experiments 1 and 2 and analyzed in separate ANOVAs with condition (Pleasantness, Syllables, or Baseline) as a variable. Incorrect TOTs made up 5.68, 6.59, and 7.16% of responses in the Pleasantness, Syllable, and Baseline conditions, respectively; they were not included in subsequent analyses.

As in Experiment 2, Know responses showed a main effect of condition, $F(2,78) = 24.33$, $MSE = .0137$, with more Know responses in the Pleasantness condition than in the Syllable or Baseline conditions, t's$(39) = 2.92$ and 6.41, respectively, and more Know responses in the Syllable condition than in the Baseline condition, $t(39) = 4.14$, (see Fig. 5 (left)).

As shown in Fig. 5 (right), condition affected TOT responses, $F(2,78) = 8.01$, $MSE = .0019$, with more TOTs occurring in the Baseline condition than in the Pleasantness or Syllable conditions, t's$(39) = -3.79$ and -3.28, respectively. There was no difference in TOTs between the Pleasantness and the Syllable conditions, $t < 1.0$. To test whether TOTs were at floor after prior processing, we compared TOTs for proper versus common names, combining the Pleasantness and Syllable conditions because there were only five proper names in each condition. There were more TOTs for proper than common names (M's = 8.00% and 6.18%, respectively), a marginally reliable effect, $t(39) = 1.40$, $p = .087$. We also evaluated whether prior processing decreased TOTs because it increased Know responses, thereby reducing opportunity for TOTs. An ANOVA on TOTs as a proportion of trials without correct recall yielded the same pattern as above: a significant effect of condition, $F(2,78) = 3.30$, $MSE = .0060$, with a greater proportion of TOTs in the Baseline condition ($M = 15.1\%$) than in the Pleasantness ($M = 10.9\%$), $t(39) = -2.61$, or Syllable conditions ($M = 11.8\%$), $t(39) = -2.10$.

The average FOK was virtually identical for TOTs in the Pleasantness ($M = 4.85$), Syllables ($M = 4.90$), and Baseline ($M = 5.03$) conditions, $F(2,36) = .10$, providing no evidence that prior processing increased FOK. To evaluate the accuracy of FOK, we analyzed whether FOK was related to whether or not the subject was attempting to retrieve the correct TOT word which was provided by the experimenter after each TOT response. For each subject, gamma correlations were calculated between FOK and the outcome (correct or incorrect) of each TOT, and then averaged over subjects ($M = -.31$). The average gamma was significantly different from zero, $t(35) = -4.25$, indicating that higher FOK ratings were related to increased correct TOT responses.

Discussion

Using a design in which only half of the target words were presented prior to the general knowledge questions, we replicated the reduction in TOTs by recent processing shown for both age groups in Experiment 1 and for older adults in Experiment 2. The pattern of results for correct Know responses also replicated Experiments 1 and 2: Prior processing improved recall relative to the baseline condition with a greater effect for the pleasantness

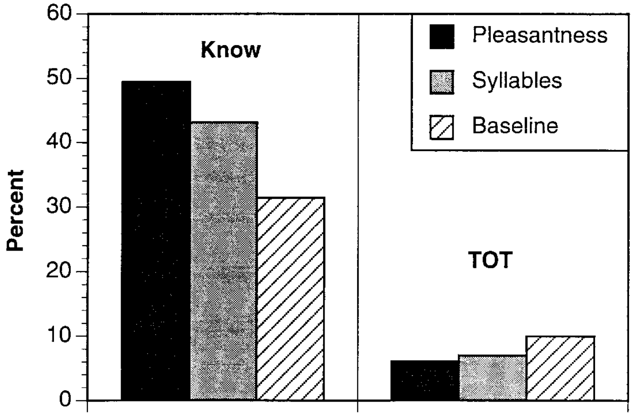

FIG. 5. Percentage of Know and TOT responses as a function of prior processing condition for young adults in Experiment 3.

than the syllables orienting task. Type of prior processing did not, however, affect TOTs, replicating Experiment 2. It is unlikely that this null effect is caused by floor effects in the prior processing conditions because proper names elicited marginally more TOTs than common names in these conditions.

Could the effect of prior processing on TOTs be contaminated by an episodic retrieval strategy used to resolve TOT states? Two aspects of the results are inconsistent with such strategies. First, the type of processing manipulation used in Experiment 3 was shown in Experiment 2 to produce the typical effect of superior episodic recall following the pleasantness compared to the syllables orienting task. Thus an episodic strategy should produce more TOT resolutions for pleasantness than syllables, but there was no difference in proportion of TOTs between these conditions. Second, it seems likely that strategies based on awareness that the answers had been presented would enhance confidence that the answer was known and thus increase FOK ratings after prior processing. However, FOK ratings were stable across prior processing and baseline conditions. These arguments do not, however, apply to the prior processing effect on Know responses because pleasantness increased responses more than syllables and there were no FOK ratings. Episodic search strategies seem an unlikely explanation of these prior processing effects because older adults showed the same effects on Know responses in Experiment 2, but no indication of being aware of the relation between the prior task and the questions.

General Discussion

This research tested predictions of the Transmission Deficit model concerning the effect of recent processing on probability of TOT. Experiment 1 demonstrated that recent pronunciation of a word increased its retrieval in response to a general knowledge question and reduced its vulnerability to a TOT state, with equivalent effects for young and older adults. Experiments 2 and 3 investigated the loci of prior processing effects by varying the type of processing required for the prior task. Semantic processing increased correct responses to general knowledge questions for both young and older adults, but showed no benefit in reducing TOTs over the phonological processing assumed to occur in all the processing tasks. We consider now the implications of our findings for the mechanisms involved in TOTs, repetition priming, and aging effects on word retrieval and memory.

Locus of TOTs and Repetition Priming

Our findings are consistent with the Transmission Deficit model concerning the cause of TOTs, namely, that weakened connections among phonological representations of a word transmit insufficient priming for activation of the required phonology. These connections are strengthened by production of the word, either overtly or silently, reducing the likelihood of TOTs. This mechanism explains why naturally occurring TOTs disproportionately involve low frequency words or names of people who have not been contacted recently (Burke et al., 1991) and why resolution of TOTs is aided by phonological priming (Brennen, Baguley, Bright, & Bruce, 1990; Meyer & Bock, 1992).

Our results extend to older adults the previous findings that young adults' prior processing of the answer increases correct responses to general knowledge questions (Kelley & Lindsay, 1993) and more so with semantic processing than surface level processing (e.g., Blaxton, 1989; Hamann, 1990). Semantic processing strengthens connections among semantic representations of the word, facilitating lexical access in the subsequent questions. It does not, however, provide any benefit over phonological processing in improving retrieval of the phonological information that is inaccessible in the TOT state.

These results also shed some light on the locus of repetition effects in word production more generally. Monsell and his colleagues have argued that repetition priming effects in picture naming are localized in the connections between word meaning and phonology and lexical access is essential (Monsell, Matthews, & Miller, 1992). Wheeldon and Monsell (1992) reported that prior production of a concrete noun in response to a definition speeded naming of a picture of the same object (e.g., *sun*), but picture naming was unaffected by prior production of a homophonic word (e.g., *son;* cf. Weldon, 1991). In the latter case, prime and target shared phonology but not lexical nodes.

Within the Transmission Deficit model, phonological similarity between nonidentical prime and target words would, *in principle*, reduce the probability of TOTs by strengthening phonological connections, thus facilitating retrieval of phonology. This prediction is not necessarily incompatible with the Wheeldon and Monsell (1992) naming latency findings because phonological deficits causing TOTs are unlikely for the common objects they used, e.g., *sun, toe, bell.* The high frequency of use of such words would maintain the strength of phonological connections; testing this prediction requires measuring the effect of phonologically similar primes on TOTs for low frequency words, and the predicted priming effect has been found (James & Burke, 1994; Meyer & Bock, 1992).

Within the NST architecture (see MacKay, 1987) the most likely place for phonological deficits causing TOTs is consistent with Monsell's locus for the repetition priming effect: the connections from lexical nodes to phonological nodes. This is because more connections converge on lower level than higher level phonological nodes, on average, and thus lower level nodes would be activated more frequently. This produces stronger connections that may be asymptotically high in strength and less sensitive to repetition priming effects. For example, the node for initial consonant *p* (see Fig. 1) would be activated for production of any of the hundreds of words with this initial sound; the node for initial syllable *pal* would be activated to produce any of the 20 or so words with this initial syllable. However, the lexical node for *palindrome* would be activated only for production of a single word, *palindrome,* and only when this occurred would the connection to *pal* be strengthened. In sum, the greater the number of connections converging on a phonological node the more often it will be activated, on average, strengthening connections. Thus, lower level phonological nodes shared by a large number of connections are an unlikely site for repetition priming effects and for the transmission deficits which cause TOTs.

Aging, Multiple Memory Systems, and Specific Processes

Our results show a pattern of age differences in TOT frequency and age constancy in repetition priming effects. TOTs were more frequent for older than young adults both when there were age differences in number of correct answers to questions (Experiment 1) and when there were not (Baseline condition, Experiment 2). The one exception was in the prior processing condition in Experiment 2, but here we concluded that young adults' TOT responses were inflated because of a response bias induced by awareness that the answers had been presented previously. Note that such awareness on the part of young but not older adults could not be the source of age differences in TOTs because awareness appeared to inflate, not decrease, TOTs, and age differences in TOTs were found in the baseline group in Experiment 2 where awareness was not an issue. Moreover, age-related increases in TOTs have been found consistently for naturally occurring TOTs (Burke et al., 1991; Cohen & Faulkner, 1986) and experimentally induced TOTs (Burke et al.; Maylor, 1990b). The present findings provide no evidence that these increases are caused by age differences in recency of use because recent processing did not reduce the size of the age difference in TOT frequency. Moreover, older adults' reduced access to partial phonological information was unaffected by recency.

The age-related decline in word retrieval represented by TOTs is notable because performance based on semantic memory is otherwise relatively immune to aging effects (e.g., Mitchell, 1989). For example, our older adults scored consistently higher than younger adults on vocabulary tests and showed comparable improvement in Know responses with the semantic orienting task. Semantic priming effects in word recognition are at least as large in older as young adults (Howard, 1988; Laver & Burke, 1993).

Under the multiple memory systems account (e.g., Schacter, 1992; Tulving & Schacter, 1990), age-related impairment on explicit memory[1] tasks and age constancy in implicit memory tasks supports the view that different brain systems underlie explicit and implicit memory. Repetition priming effects in our general knowledge task would be located in a semantic memory system (Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991; Schacter, 1992; Tulving & Schacter, 1990) which is immune to aging. This conclusion, however, is incompatible with the finding of age-related increases in TOTs, a deficit occurring within a semantic memory system.

The transfer appropriate processing framework focuses on specific processes rather than memory systems. This approach, however, also does not easily account for the present pattern of findings and has had difficulty, in general, accounting for implicit–explicit memory dissociations between subject groups, most notably amnesics versus normals. Within this framework, deficits in conceptually driven processes are the basis for amnesics' explicit memory impairment, but contrary to this, amnesics show preserved priming on conceptually driven implicit tasks (Roediger et al., 1989). Likewise with older adults, deficits in conceptually driven, but not data-driven, processes would explain the common finding of impaired explicit memory and preserved repetition priming. In the present study, however, we find no evidence for age-related deficits in conceptually driven priming.

The Transmission Deficit model postulates an age-linked deficit in a specific process that is distributed across memory systems, but whose functional effect depends on structural features of the memory system. This model differs from other proposals for distributed transmission deficits in old age (e.g., Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1988) because the functional effect of deficits varies with the architecture of the memory system involved in performance. In particular, transmission deficits impair mental operations involving nodes that have one-to-one connections. Speech production depends

[1] Age differences in explicit memory are one of the most consistent findings in cognitive aging (e.g., Burke & Light, 1981; Craik & Jennings, 1993). We did not systematically assess age-related declines in explicit memory, but in Experiment 2 cued recall for older adults, but not younger adults, was at floor when the same retrieval cues were used across age (e.g., initial letters of the target word). To improve recall of older adults, we gave them longer retrieval cues than those for young adults.

on transmission of priming along single connections in the phonological system (see Fig. 1), making it vulnerable to transmission deficits, as in TOTs. In contrast, priming in the semantic system typically involves a large number of converging connections. For example, semantically related words typically share a number of propositions so that semantic priming summates across these many shared connections compensating for an age-linked transmission deficit (MacKay & Burke, 1990; Laver & Burke, 1993).

Repetition priming is preserved in old age because it is based on strengthening existing connections in memory. Age-related transmission deficits reflect age differences in asymptotic connection strength, whereas the short-term change in strength produced by prior processing is age constant so that repetition priming effects are equivalent across age. Explicit memory, however, involves additional processes necessary for forming new connections required for conscious recollection. Within this model, sustained transmission of priming is required for new connection formation and age-related decrease in transmission of priming impairs new connection formation (MacKay, 1990; MacKay & Abrams, in press; MacKay & Burke, 1990; cf. Howard, Fry, & Brune, 1991).

Summary

We have argued that TOTs serve to isolate phonological processes within a conceptually driven task and that repetition priming in this task involves multiple dimensions of encoding, not just a perceptual–conceptual continuum. Specification of processes was aided by a model of speech production which describes phonological and semantic retrieval processes for a task like question answering (see, e.g., Dell, 1986; MacKay, 1987). Thus, models of the task are helpful in revealing the complexity of processes involved in repetition priming effects. We have also argued that the pattern of preserved semantic and repetition priming and increased TOTs in old age is not handled well by multiple memory system approaches in which aging impairs one memory system but not another or by processing approaches in which aging impairs one type of process but not another. Age-related deficits in transmission of priming can account for the observed pattern of age effects, but only by considering the architecture of the memory system involved. Thus we concur with other investigators in calling for an integration of the multiple memory systems and processing approaches (Roediger & Srinivas, 1993; Shimamura, 1993).

References

Bassili, J. N., Smith, M. C., & MacLeod, C. M. (1989). Auditory and visual word-stem completion: Separating data-driven and conceptually driven processes. *The Quarterly Journal of Experimental Psychology,* **41**A, 439–453.

Blaxton, T. (1989). Investigating dissociations among memory measures: Support for a transfer-appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **15,** 657–668.

Brennen, T., Baguley, T., Bright, J., & Bruce, V. (1990). Resolving semantically induced tip-of-the-tongue states for proper nouns. *Memory and Cognition,* **18,** 339–347.

Brown, A. S. (1991). The tip of the tongue experience: A review and evaluation. *Psychological Bulletin,* **109,** 204–223.

Burke, D. M., & Laver, G. (1990). Aging and word retrieval: Selective age deficits in language. In E. A. Lovelace (Ed.), *Aging and cognition: Mental processes, self-awareness and interventions* (pp. 281–300). Amsterdam: North Holland.

Burke, D., & Light, L. (1981). Memory and aging: The role of retrieval processes. *Psychological Bulletin,* **90,** 513–554.

Burke, D. M., MacKay, D. G., & Worthley, J. S., & Wade, E. (1991). On the tip of the tongue: What causes word finding failures in young and older adults? *Journal of Memory and Language,* **30,** 542–579.

Challis, B. H., & Brodbeck, D. R. (1992). Level of processing affects priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **18,** 595–607.

Cohen, G. (1990). Why is it difficult to put names to faces? *British Journal of Psychology,* **81,** 287–297.

Cohen, G., & Burke, D. M. (1993). A review of memory for proper names. *Memory,* **1,** 249–264.

Cohen, G., & Faulkner, D. (1986). Memory for proper names: Age differences in retrieval. *British Journal of Developmental Psychology,* **4,** 187–197.

Craik, F. I. M., & Jennings, J. (1992). Human memory. In F. I. M. Craik & T. A. Salthouse (Eds.), *The* *handbook of aging and cognition* (pp. 51–110). Hillsdale, NJ: Lawrence Erlbaum.

DANEMAN, M., & STAINTON, M. (1991). Phonological recoding in silent reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **17,** 618–632.

DELL, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review,* **93,** 283–321.

GRAF, P., & RYAN, L. (1990). Transfer-appropriate processing for implicit and explicit memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **16,** 978–992.

HAMANN, S. (1990). Levels-of-processing effects in conceptually driven implicit tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **16,** 970–977.

HOWARD, D. V. (1988). Aging and memory activation: The priming of semantic and episodic memories. In L. L. Light & D. M. Burke (Eds.), *Language, memory and aging* (pp. 77–99). New York: Cambridge Univ. Press.

HOWARD, D. V. (1991). Implicit memory: An expanding picture of cognitive aging. In K. W. Schaie (Ed.), *Annual review of gerontology and geriatrics* (Vol. 11, pp. 1–22). New York: Springer.

HOWARD, D. V., FRY, A. F., & BRUNE, C. M. (1991). Aging and memory for new associations: Direct versus indirect measures. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **17,** 779–792.

JACOBY, L. L., & DALLAS, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General,* **110,** 306–340.

JAMES, L. E., & BURKE, D. M. (1994, April). *Resolving the tip of the tongue: The role of phonological priming.* Paper presented at the Cognitive Aging Conference, Atlanta.

KEANE, M. M., GABRIELI, J. D. E., FENNEMA, A. C., GROWDON, J. H., & CORKIN, S. (1991). Evidence for a dissociation between perceptual and conceptual priming in Alzheimer's disease. *Behavioral Neuroscience,* **105,** 326–342.

KELLEY, C. M., & LINDSAY, D. S. (1993). Remembering mistaken for knowing: Ease of retrieval as a basis for confidence in answers to general knowledge questions. *Journal of Memory and Language,* **32,** 1–24.

LAVER, G. D., & BURKE, D. M. (1993). Why do semantic priming effects increase in old age? A meta-analysis. *Psychology and Aging,* **8,** 34–43.

LIGHT, L. L. (1991). Memory and aging: Four hypotheses in search of data. *Annual Review of Psychology,* **42,** 333–376.

MACKAY, D. G. (1982). The problems of flexibility, fluency, and speed–accuracy trade-off in skilled behavior. *Psychological Review,* **89,** 483–506.

MACKAY, D. G. (1987). *The organization of perception and action: A theory for language and other cognitive skills.* New York: Springer-Verlag.

MACKAY, D. G. (1990). Perception, action and awareness: A three body problem. In W. Prinz & O. Neumann (Eds.), *Relationships between perception and action* (pp. 269–303). Berlin: Springer-Verlag.

MACKAY, D. G., & ABRAMS, L. (in press). Language, memory and aging: Distributed deficits and the structure of new versus old connections. In J. E. Birren & W. K. Schaie (Eds.), *Handbook of the psychology of aging: Fourth Edition.* San Diego: Academic Press.

MACKAY, D. G., & BURKE, D. M. (1990). Cognition and aging: New learning and the use of old connections. In T. M. Hess (Ed.), *Aging and cognition: Knowledge organization and utilization* (pp. 213–263). Amsterdam: North Holland.

MAYLOR, E. A. (1990a). Age, blocking and the tip of the tongue state. *British Journal of Psychology,* **81,** 123–134.

MAYLOR, E. A. (1990b). Recognizing and naming faces: Aging, memory retrieval and the tip of the tongue state. *Journal of Gerontology: Psychological Sciences,* **45,** 215–225.

MEYER, A. S. & BOCK, K. (1992). The tip-of-the-tongue phenomenon: Blocking or partial activation? *Memory and Cognition,* **20,** 715–726.

MITCHELL, D. B. (1989). How many memory systems? Evidence from aging. *Journal of Experimental Psychology: Learning, Memory and Cognition,* **15,** 31–49.

MITCHELL, D. B. (1993). Implicit and explicit memory for pictures: Multiple views across the lifespan. In P. Graf & M. E. J. Masson (Eds.), *Implicit memory: New directions in cognition, development, and neuropsychology* (pp. 17–48). Hillsdale, NJ: Lawrence Erlbaum.

MONSELL, S., MATTHEWS, G. H., & MILLER. D. C. (1992). Repetition of lexicalization across languages: A further test of the locus of priming. *The Quarterly Journal of Experimental Psychology,* **44**A, 763–783.

MORRIS, C. D., BRANSFORD, J. D., & FRANKS, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior,* **16,** 519–533.

MYERSON, J., HALE, S., WAGSTAFF, D., POON, L. W., & SMITH, G. A. (1990). The information-loss model: A mathematical theory of age-related cognitive slowing. *Psychological Review,* **97,** 475–487.

RICHARDSON-KLAVEHN, A., & BJORK, R. A. (1988). Measures of memory. *Annual Review of Psychology,* **39,** 475–543.

ROEDIGER, H. L., III (1990). Implicit memory: Retention without remembering. *American Psychologist,* **45,** 1043–1056.

ROEDIGER, H. L., III, & SRINIVAS, K. (1993). Specificity of operations in perceptual priming. In P. Graf & M. E. J. Masson (Eds.), *Implicit memory: New direc-*

tions in cognition, development, and neuropsychology (pp. 17–48). Hillsdale, NJ: Lawrence Erlbaum.

Roediger, H. L., III, Srinivas, K., & Weldon, M. S. (1989). Dissociations between implicit measures of retention. In S. Lewandowsky, J. C. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 67–84). Hillsdale, NJ: Lawrence Erlbaum.

Roediger, H. L., III, Weldon, M. S., & Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 3–41). Hillsdale, NJ: Lawrence Erlbaum Associates.

Salthouse, T. A. (1988). Initiating the formalization of theories of cognitive aging. *Psychology and Aging,* **3,** 3–16.

Scarborough, D. L., Cortese, C., & Scarborough, H. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance,* **3,** 1–17.

Schacter, *D. L. (1992). Understanding implicit memory. American Psychologist,* **47,** 559–569.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory and Cognition,* **13,** 501–518.

Shimamura, A. P. (1993). Neuropsychological analyses of implicit memory: History, methodology, and theoretical interpretations. In P. Graf & M. E. J. Masson (Eds.), *Implicit memory: New directions in cognition, development, and neuropsychology* (pp. 265–285). Hillsdale, NJ: Lawrence Erlbaum.

Srinivas, K., & Roediger, H. L., III (1990). Classifying implicit memory tests: Category association and anagram solution. *Journal of Memory and Language,* **29,** 389–412.

Stroop, J. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology,* **18,** 624–643.

Thapar, A., & Greene, R. L. (1994). Effects of level of processing on implicit and explicit tasks. *Journal of Experimental Psychology: Learning, Memory and Cognition,* **20,** 671–679.

Tulving, E. (1983). *Elements of episodic memory.* Oxford: Clarendon Press.

Tulving, E., & Schacter, D. L. (1990). Priming and human memory systems. *Science,* **247,** 301–306.

Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **8,** 336–342.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review,* **80,** 352–373.

Weldon, M. S. (1991). Mechanisms underlying priming on perceptual tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **17,** 526–541.

Weldon, M. S., & Jackson-Barrett, J. L. (1993). Why do pictures produce priming on the word-fragment completion test? A study of encoding and retrieval factors. *Memory and Cognition,* **21,** 519–528.

Wheeldon, L. R., & Monsell, S. (1992). The locus of repetition priming of spoken word production. *The Quarterly Journal of Experimental Psychology,* **44**A, 723–761.

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