On the Tip of the Tongue: What Causes Word Finding Failures in Young and Older Adults?

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This paper develops a new theory of the tip of the tongue (TOT) phenomenon. Within this interactive activation model of speech production, TOTs occur when the connections between lexical and phonological nodes become weakened due to infrequent use, nonrecent use, and aging, causing a reduction in the transmission of priming. Predictions of the theory were examined using retrospective questionnaires, diary procedures, and a laboratory word retrieval task. In Study 1, young, midage, and older adults recorded naturally occurring TOTs in structured diaries during a four-week interval in their everyday life. TOT targets were infrequent words in the language, and proper names, the largest category of TOT targets, were the names of acquaintances who had not been contacted recently, especially for older adults. Persistent alternates, i.e., incorrect words that came repeatedly to mind, shared phonology and grammatical class with TOT targets, and delayed TOT resolution. Older adults experienced more TOTs, but fewer persistent alternates. An influence of expectations on these age differences was ruled out by responses to the retrospective questionnaires, which indicated no age differences in expected number of TOTs. In Study 2, basic results for age and persistent alternates were replicated in the laboratory for experimenter-selected TOT targets. The experimental study also demonstrated that proper names of famous people are especially vulnerable to TOTs in older adults. © 1991 Academic Press, Inc.

Processes underlying the selection and production of words have attracted considerable attention within cognitive psychology. The tip of the tongue (TOT) phenomenon offers a special opportunity for investigating these processes because it involves a selective failure of word retrieval: A TOT word is in the lexicon of the afflicted person but is temporarily inaccessible. The present paper develops a new theory of TOTs and tests implications of this theory in two complementary studies. Study 1 examined spontaneous TOTs of subjects trained to record TOTs in a structured diary as they occurred during everyday life. Studies of naturally occurring speech errors have stimulated development of basic theories of language production, and Study 1 follows in this tradition (e.g., Dell, 1986; Fay & Cut-
about TOTs and to make predictions that are relevant to the present studies.

Language Production in the NST

The memory system in the NST consists of a vast network of processing units called nodes. The nodes considered here are organized hierarchically and have symmetrical connections: A bottom-up connection implies a corresponding top-down connection and vice versa. Speech production uses three hierarchically related systems of nodes, illustrated in Fig. 1 for the word frisbee. The semantic system represents concepts underlying words, phrases and propositions. For example, the lexical node representing frisbee in the semantic system contains no phonological information, but is connected to nodes in the phonological system representing a hierarchy of units such as syllables, consonant clusters, vowels, and phonological features. Phonological nodes represent types, not tokens, and so are connected to all lexical nodes whose words include that phonological component. These type-based and hierarchical aspects of phonological representations capture important characteristics of TOTs. Finally, nodes in the phonological system are connected to nodes in the muscle movement system for producing overt speech (See Fig. 1).

The model postulates two fundamentally different processes, priming and activation, and differences between these two processes are important for explaining TOTs. Activation is necessary to consciously retrieve information a node represents, is all-or-none, and does not spread, unlike the concept of spreading activation in other network theories (e.g., McClelland & Rumelhart, 1981). Priming or subthreshold excitation prepares a node for possible activation and an activated node primes all nodes connected to it. However, whereas activation proceeds hierarchically (i.e., top-down and left-to-right) in production, priming spreads in parallel to all connected
nodes at both higher and lower levels. Priming summates temporally across a single connection and spatially across different simultaneously active connections to the same node. Finally, repeated activation of a node over a prolonged period results in satiation, a temporary decrement in how rapidly the node can transmit priming. Satiation underlies phenomena such as the verbal transformation effect, perceptual and motor adaptation, and the semantic satiation effect (see MacKay, 1987).

Activation is always sequential and requires a special class of activating mechanisms known as sequence nodes. Each sequence node connects with every node in a domain, which is a set of nodes that all share the same syntactic function or sequential privileges of occurrence in words and sentences. The domains for the nodes in Fig. 1 are indicated in parentheses, for example, (noun) for frisbee and (initial consonant group) for the phonological compound fr. When a sequence node is activated it repeatedly multiplies priming of all nodes within a domain so that whatever node begins with the most priming will reach threshold first and become activated. This domain-based activation captures important features of TOTs and speech errors such as word substitutions. For example, word substitutions occur if the node for an intended word has acquired less priming than some other node in its domain when
the activating mechanism is applied. Only words in the same domain as the target are candidates for retrieval, accounting for the "sequential class regularity" in all types of substitution errors (e.g., Dell, 1986; Stemberger, 1985; MacKay, 1979).

During normal, error-free word finding, the translation of thought into speech begins with activation of a propositional node representing a concept in the semantic system, such as, say, *They were throwing a frisbee*. Activating this propositional node transmits priming to the lexical node for *frisbee*, so that it becomes activated as the most primed node in its domain when its activation mechanism (sequence node) is applied. Priming then spreads from the lexical node to connected phonological nodes. Retrieving the complete phonology for *frisbee* requires activation of nodes at all levels of the phonological system, including phonological feature nodes. Phonological nodes corresponding to the target word are normally activated because top-down priming from activated lexical nodes normally suffices to ensure that these phonological nodes are the most primed in their domains.

**The Basic Cause of TOTs: The Transmission Deficit Hypothesis**

The NST represents a detailed example of a general class of TOT explanations that we label the Transmission Deficit hypothesis (Bowles, Obler, & Poon, 1989; Cohen & Faulkner, 1986; Yaniv & Meyer, 1987). The basic cause of TOTs in the NST is a deficit in the transmission of priming across critical connections required for producing the target word. When a TOT occurs, a lexical node in the semantic system becomes activated, giving access to semantic information about the target word, but at least some phonological information remains inaccessible because insufficient priming is transmitted to enable activation of connected phonological nodes. Within the NST, three factors influence this transmission deficit: frequency of use, recency of use, and aging.

**Frequency of Use**

Connections between nodes become stronger or more efficient with use. When a node has frequently been activated over the course of a lifetime, the rate and amount of priming transmitted across its connections increases (MacKay, 1981; 1982). This frequency factor explains why naturally occurring (Stemberger & MacWhinney, 1986) and experimentally induced (MacKay, 1970) phonological speech errors are more likely for low than high frequency words. The stronger connections from lexical to phonological nodes for high frequency words tend to reduce phonological errors, which occur when another, inappropriate node in a phonological domain acquires more priming than the correct node when the activating mechanism is applied. The frequency factor also explains why word substitutions are more likely for low than high frequency words (Stemberger, 1984) and why object naming is faster for high than low frequency names (Huttenlocher & Kubicek, 1983; Oldfield & Wingfield, 1965).

TOTs arise when connections to some or all of the phonological nodes for rarely used words become so weak that they transmit insufficient priming to enable activation. Thus, we predict that TOTs in Study I will involve low frequency words more often than high frequency words. This effect of frequency on TOTs has often been suggested (e.g., Ellis, 1985), but it has never been tested.

**Aging**

According to MacKay and Burke (1990), aging weakens connections within the entire network of nodes, reducing the rate and amount of priming transmitted across connections (see Salthouse, 1988, for a related view). MacKay and Burke demonstrated that such a transmission deficit can account for well-established, age-linked declines in the learning of new information (e.g., Burke & Ligh, 1981) and in the general
speed of mental operations (e.g., Salts-thouse, 1985). This Transmission Deficit hypothesis predicts increased frequency of TOTs for older adults because an age-linked weakening of connections will reduce transmission of priming from lexical nodes to connected phonological nodes, thereby reducing the likelihood of phonological activation.

Recency of Use

Whereas the frequency factor defines the increase in strength of connections with use, the recency factor defines the decay of this strength over time with nonuse. Connections to phonological nodes of words that have not been used recently can become so weak that they transmit insufficient priming to enable activation. The NST therefore predicts that spontaneous TOTs should involve words that have not been used recently. Although it is well known that recency improves recall of newly learned information (e.g., Baddeley, 1990), effects of recency on TOTs for words learned long ago have never been examined.

The recency factor suggests another reason why TOTs might increase with age. As age increases so does the opportunity for a longer interval since the last use of a word. For example, time-since-use for the name of a high school teacher will be greater in older adults simply by virtue of their greater age. Thus, older adults may experience more TOTs because the interval since they last tried to use a TOT word is greater than in young adults, a hypothesis that has never been tested. An additional prediction, based on age deficits in learning new information, is that older adults will experience more TOTs for recently learned names. To test these predictions in Study 1, we gathered recency information for acquaintance names involved in TOTs, recording how long our subjects knew these acquaintances and how recently they had contact with them.

Characteristics of TOTs: Established Findings and New Predictions

This section reviews the main characteristics of TOTs that have been investigated in the past and shows how these characteristics relate to the processing architecture of the NST and the three factors discussed above. We also generate new predictions regarding these characteristics which provide a framework for the remainder of the paper.

Partial Phonological Information

The availability of partial phonological information is a striking characteristic of TOTs. Subjects can typically specify the number of syllables, the stress pattern, and the initial and final sounds or letters of an otherwise irretrievable target during both naturally occurring TOTs (Cohen & Faulkner, 1986; Woodworth, 1938) and experimentally induced TOTs (Brown & McNeill, 1966; Kohn, Wingfield, Menn, Goodglass, Berko Gleason, & Hyde, 1987; Koriat & Lieblich, 1974; Rubin, 1975). However, subjects’ reports of final letters of TOT words may be attributable to guessing based on general knowledge of English morphology (Kohn et al., 1987; see also Koriat & Lieblich, 1975).

How can we recall parts of a word when we cannot say what the word is? Only some of the phonological nodes for producing a word may be suffering a transmission deficit due to infrequent or nonrecent use. Some subset of the remaining phonological nodes may in fact become activated, providing a basis for partial recall.

Why do some aspects of phonology (number of syllables, stress pattern, and initial sound) become available during TOTs and not others (say, exact number of sounds)? This availability pattern reflects the top-down and left-to-right sequence of node activation within the phonological system during production. Nodes are organized at each level into domains with common sequential properties, e.g., stressed
first syllable, initial consonant. The order in which domains are activated is determined by sequence nodes which code syntactic rules in the semantic system and phonological rules in the phonological system (MacKay, 1987). Until a sequence node activates a node in its domain, it will inhibit sequence nodes governing domains that follow it. Thus, initial phonological segments are activated before later segments within the phonological system. TOT’s result when phonological feature nodes receive insufficient priming to become activated. Information about number of syllables is more likely to become available than the complete phonology for a word because syllable nodes are activated before phonological feature nodes (see Fig. 1). Similarly, initial segments of a word are activated first and are more likely to be retrieved than final segments. What is less likely in the NST is retrieval of later but not initial phonological segments. Further, an age-linked transmission deficit predicts that availability of partial information should decrease with age because retrieval of phonological information depends on transmission of priming from lexical nodes.

**Feeling-of-Knowing (FOK)**

People in the TOT state are typically certain that they “know” the desired word, even though they cannot, for the moment, bring it to mind (James, 1890; Brown & McNeill, 1966). The accompanying sense of imminent retrieval has been characterized as “something like the brink of a sneeze” (Brown & McNeill, 1966, p. 326), and has been quantified via feeling-of-knowing (FOK) ratings. For subjects in the TOT state, FOK rating correlates positively with probability of target recall (e.g., Gruneberg & Monks, 1974; Gruneberg & Sykes, 1978; Read & Bruce, 1982), and recognition (e.g., Butterfield, Nelson, & Peck, 1988; Hart, 1965; Nelson, Gerler, & Naren, 1984), and correlates negatively with time for target identification (Goodglass, Wingfield, & Wayland, 1989; Nelson et al., 1984; Nelson, Leonesio, Lanwehr, & Naren, 1986) and lexical decision (Yaniv & Meyer, 1987).

How can we accurately judge that we know a word (FOK) when we cannot say the word? The distinction between semantic and phonological nodes is essential for explaining this and other characteristics of TOTs. Activating a lexical node indicates that the word is known and provides one basis for FOK. Activating its connected semantic propositions provides another basis for FOK and enables the rich descriptions of the meaning of the target word given by subjects in the TOT state (Cohen & Faulkner, 1986; Read & Bruce, 1982). Finally, activating a lexical node can prime and enable activation of some phonological nodes, providing a third basis for FOK.

Similar factors underlie our ability to reject other, inappropriate words that come to mind instead of the target. In William James’ (1890) memorable description, “It is a gap that is intensely active...” If wrong names are proposed to us, this singularly definite gap acts immediately so as to negate them (p. 251).” The “active gap” corresponds to the phonological nodes that cannot be activated, and “wrong names” are rejected because they do not fit the already activated semantic and phonological information. For example, conflicting propositions within the semantic system rather than conflicting phonology will enable rejection of words that are phonologically similar to the TOT word.

How can a general transmission deficit affect activation of phonological nodes without also affecting activation of semantic or lexical nodes (the basis for FOK)? This pattern follows from two characteristics of the NST: summation of priming and the processing architecture. Priming summates temporarily across a single connection and spatially across several simultaneously active connections to the same node. Thus, when connections from more than one active node converge on the same node, its rate of summation and asymptotic
level of priming increases. In language production, priming from many semantic nodes converges onto a single lexical node, summing across these connections. Phonological nodes cannot benefit from a corresponding summation process in production because top-down priming diverges from a single lexical node to many phonological nodes (see Fig. 1). The summation of priming that occurs during production can therefore compensate for a general transmission deficit at the lexical level, but not at the phonological level. Thus, because activation is based on a most-primed-wins principle, semantic and lexical nodes will sometimes be activated, giving high F0K, even though phonological nodes cannot be activated due to a general transmission deficit.

**Persistent Alternates**

Subjects in the TOT state often report that a word related to the target comes repeatedly and involuntarily to mind (Reason & Lucas, 1984). These recurring responses have been called “blockers” (Reason & Lucas, 1984) or “interlopers” (Jones, 1989), but we use a more descriptive or theoretically neutral label here: “persistent alternates.”

How do persistent alternates come initially to mind? The sample of nodes in Fig. 2 illustrates how a persistent alternate such as *charity* is retrieved instead of the TOT

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**Fig. 2.** Illustration of the spread of priming preceding retrieval of persistent alternates. *Chastity* is the TOT target and *charity* is the alternate that comes repeatedly to mind. The arrows represent the spread of bottom-up and top-down priming to *charity* through nodes shared with *chastity*. Many nodes necessary for producing these words have been left out to simplify the figure.
target chastity within the NST. Chastity is connected with propositions such as "is a virtue" and "take a vow of," so that when the lexical node for chastity becomes activated, the lexical node for charity becomes primed via semantic propositions that it shares with chastity, e.g., "is a virtue." Now, the TOT for chastity originated as a transmission deficit. Some of its phonological nodes receive too little priming to enable activation, whereas others such as the node for the initial consonant cluster ch do receive sufficient priming and in fact become activated. These activated phonological nodes now transmit priming bottom-up to all lexical nodes containing these components, including, charity. Unactivated nodes pass on second-order priming to all lexical nodes containing these elements, so that, for example, ity may also contribute to the priming of charity, albeit weakly. Top-down and bottom-up priming therefore summate on charity. Following repeated activation and satiation of the lexical node for chastity (but not the connected phonological nodes), charity may be the most primed lexical node in the (noun) domain and become activated. This enables full retrieval of its phonology (which is not suffering transmission deficit). Thus, persistent alternates are a consequence of transmission deficit rather than its cause.

Under the NST, TOT targets and persistent alternates should share several attributes, a prediction we test in both studies. The automatic spread of priming between levels during lexical selection increases the probability of retrieving words that share semantic, morphological and phonological components with the intended word. Alternates will also share syntactic class with the target because activation occurs by lexical domain (syntactic class) and repeated attempts to retrieve the TOT target will yield alternates only in that domain. This prediction links TOTs to a fundamental phenomenon in speech errors, namely that words substituted in error virtually always belong to the same syntactic class as the intended word (Fay & Cutler, 1977; MacKay, 1979; Stemberger, 1985).

As a consequence of the processing architecture of the theory, target-alternate similarity is expected to be age constant. However, older adults may report more TOTs but fewer alternates because the transmission deficit that causes TOTs also reduces bottom-up priming to the lexical nodes for alternates, making activation of an alternate less likely.

Why do persistent alternates come repeatedly and involuntarily to mind? The spread of priming to phonologically similar words is automatic and involuntary, and once an alternate is activated it becomes easier to activate in the future because recent use increases the linkage strength of connections and enables more efficient transmission of priming. Thus we also predict that alternates will increase the time required for retrieval of the target. For the target to regain its most-primed status, satiation of the target lexical node must dissipate over time, and the increase in linkage strength due to recent activation of the alternate must decay over time.

Resolution of TOTs

Subjects sometimes attempt to resolve TOTs using retrieval strategies, for example, thinking of contextual information such as the last time they had seen a target person or place, or going through the alphabet letter by letter as a cue to the TOT word (Read & Bruce, 1982). This latter strategy seems especially likely to aid resolution when the first speech sound of the target is unavailable (as in Gruneberg & Monks, 1974). Nonetheless, although subjects in the TOT state can describe aspects of the target as they become available (e.g., Kohn et al., 1987), access to this partial information, and to the target itself, involves retrieval processes that are themselves unavailable to awareness or conscious control (Goodglass et al., 1989; cf., Nisbett & Wilson, 1977). Consistent with this, studies of naturally occurring TOTs report spontane-
ous resolutions or pop-ups, where a TOT target pops into mind at a time when conscious attention is directed elsewhere (Cohen & Paulkner, 1986; Reason & Lucas, 1984).

The NST provides no mechanism for causing pop-ups directly: Because the weak connections that originally cause TOTs reflect factors such as low production frequency, non-recent use, and aging, there is no reason to expect pop-ups to reflect spontaneous recovery in these particular connections. However, pop-ups could arise from an inadvertent boost in priming to the phonological nodes suffering from transmission deficit. For example, if the critical phonological components occur accidentally during internal speech or everyday language comprehension, the full phonology of the TOT word may become available and enable the word to pop into mind. This "inadvertent cuing" account of pop-ups is consistent with Yaniv and Meyer’s (1987) explanation of incubation effects in both problem solving and language production. The inadvertent cuing account is also consistent with E. A. Schegloff’s (personal communication, June 24, 1990) tape recorded data on the resolution of a naturally occurring TOT for the name Ojai (a small town in California). Frustration associated with the TOT led to the utterance, "Oh hell" (pronounced oh-hell), that immediately triggered recall of the missing target (pronounced oh-hi). Under the theory, the phonological similarity of "Oh hell" and "Ojai" together with their difference in domain enabled retrieval of the TOT word rather than repeated retrieval of "Oh hell" as a persistent alternate (see Brown, 1991, for a similar example).

The present account of pop-ups makes several predictions that we test in Study 1. On the assumption that the extent of transmission deficit determines both FOK and pop-up time, TOTs with high FOK should be associated with reduced pop-up times. Also, pop-ups should take longer for older than for young adults because greater similarity between input and the TOT word should be required to overcome age-linked transmission deficits, which affect a larger number of phonological nodes in the case of older adults.

**Types of Words Involved in TOTs**

Certain types of words are clearly more difficult to recall than others. Newly encountered proper names are particularly problematic: The same acoustic word form is more difficult to recall as a proper name, as in, "This is Mr. Baker" than as an occupation name, as in, "This man is a baker" (McWeeny, Young, Hay, & Ellis, 1987; see also Cohen & Paulkner, 1986). Older adults’ ratings of their ability to remember names is lower than young adults’ (Cohen & Paulkner, 1984; Martin, 1986), although it is unclear if this applies to very familiar names as well as newly learned names. In Study 1 and Study 2 we determine what types of words are most commonly involved in TOTs. For reasons outlined in the General Discussion, the NST predicts that proper names will be more vulnerable to TOTs than common names.

**Predictions Based on the Inhibition Hypothesis**

The Inhibition hypothesis represents another general and widely accepted class of TOT explanations that is quite different from the Transmission Deficit hypothesis. Under the Inhibition hypothesis, TOTs arise when another word blocks retrieval of the TOT word (Baddeley, 1982; Brown, 1979; Jones, 1989; Jones & Langford, 1987; Meringer & Meyer, 1895; Reason & Lucas, 1984; Roediger, 1974; Roediger & Necely, 1982), perhaps because lexical nodes inhibit one another in proportion to their own activation level. For example, language production models such as Stemberger (1985) postulate such between-word inhibitory processes to augment the difference in activation levels among lexical nodes (as in McClelland & Rumelhart, 1981) so that "the poor get poorer and the rich get
richer" until the most activated word is selected for production. Thus, when semantic information activates two or more words to varying extents and an alternate word more so than the target word, a TOT will occur because the more highly activated alternate will inhibit the target and make it inaccessible (see, e.g., Baddeley, 1982; Jones, 1989).

We developed several predictions based on the Inhibition hypothesis that contrast with predictions based on the Transmission Deficit hypothesis. If TOTs increase with age, persistent alternates, the cause of TOTs under the Inhibition hypothesis, should also increase with age. Moreover, under the widely held assumption that FOK reflects the level of activation of a word in memory (e.g., Nelson et al., 1984), the Inhibition hypothesis predicts that occurrence of a persistent alternate should decrease FOK for the target word that it inhibits. Pop-up time is also relevant to the Inhibition hypothesis because if persistent alternates inhibit TOT targets then occurrence of a persistent alternate should increase pop-up time for the target.

**General Methodological Issues**

Predictions regarding TOTs can be investigated in three basic ways: retrospective questionnaires, diary studies, and laboratory word retrieval tasks. With retrospective questionnaires, subjects estimate how many TOTs they experience per week or month in everyday life (e.g., Cohen & Faulkner, 1986; Sunderland et al., 1986). With diaries, they record on-line information about TOTs as they occur over, say, a month of daily living (Reason & Lucas, 1984). In word retrieval tasks, subjects answer questions designed to induce TOTs (e.g., Brown & McNeill, 1966; Kohn et al., 1987). Because each of these methods has both strengths and weaknesses, we argue that a combination of all three methods is needed to provide a rich and convergent database for testing our predictions.

Retrospective questionnaires can provide information about subjects' expectations regarding TOTs (e.g., how often and with what kinds of words), which is important because expectations could influence both diary and lab-induced TOTs. However, because retrospective questionnaires rely on subjects' memory for their TOTs over extended periods, this procedure is prone to error and is insufficient onto itself, especially when studying populations with memory deficits (e.g., older adults; cf. Baddeley, 1989).

Diary procedures provide a valuable corpus of naturally occurring TOT targets and persistent alternates. As in studies of speech errors (MacKay, 1980), records of naturally occurring TOTs are necessary to establish the critical variables to include or control in a laboratory study. However, diary investigations of age differences must evaluate whether one group of subjects, say, older adults, are more diligent in recording TOTs, or are more likely to use words susceptible to TOTs or persistent alternates.

Laboratory studies of TOTs enable control of stimulus variables such as word type and environmental variables such as distracting events. However, they also suffer from limitations that have been underestimated in the past. For example, it is difficult to include in laboratory studies variables that differ in unknown ways from subject to subject such as acquaintance names, which, as we will see, are a common source of naturally occurring TOTs, especially among older adults. Also, laboratory studies are subject to artifact from the selection of target words because, for example, the selected words may be inherently more conducive to TOTs for older than younger adults.

One methodological problem that applies to both laboratory and diary methods is the "fragmentary data problem" (Brown & McNeill, 1966), namely, that the amount of data contributed varies among subjects and among TOT target words. Such fragmentary data create problems for statistical
analyses. We followed Brown & McNeill's prescriptions for dealing with these problems: to report the data very fully and to analyze them in more than one way. Like Brown and McNeill, we find that TOT states are "much the same from word to word and subject to subject (p. 328)," despite variability among words and subjects in susceptibility TOTs.

**STUDY 1: NATURALLY OCCURRING TOTs**

In the first phase of Study 1, 130 young, mid-age, and older adults completed a retrospective questionnaire in which they estimated how frequently they experienced TOTs with various characteristics. In the next phase, the same subjects used structured diaries to record information about TOTs as they occurred spontaneously during a 4-week interval in their everyday life. By comparing expectations about TOTs reported in the retrospective questionnaires to the information about TOTs recorded on-line in the diaries, we hoped to evaluate whether expectations biased the diary reports.

The diary data yielded a sizeable corpus of TOT words and persistent alternates, and this data base allowed us to examine aspects of TOT words such as frequency of use, recency of use, syntactic class, and variation with age. Other information about TOT states recorded in the diaries allowed us to test predictions about effects of age on resolution time and relations between persistent alternates, resolution, and characteristics of TOTs, such as the availability of partial information.

**Method**

**Subjects**

Participants were 50 older adults, 30 mid-age adults, and 50 young adults, with equal numbers of men and women in each age group. Table 1 shows background information for each group. All subjects were native speakers of English and reported short-term plans compatible with accurate maintenance of a TOT diary for 28 consecutive days: Excluded from the study were people who had scheduled, for example, vacations or surgery during that period. Mid-age and older adults lived in the community and were highly educated, with more years of education than young adults, all of whom were undergraduates, $F(2,127) = 24.38, MSe = 4.11$. The Wechsler Adult Intelligence Scale (WAIS) vocabulary subtest and digit span showed a commonly observed age pattern: Mid-age and older adults scored significantly higher on vocabulary than young adults, $F(2,124) = 6.73, MSe = 47.22$, but significantly lower on digit span, $F(2,124) = 20.33, MSe = .90$. The Boston Naming Test was administered to the two older groups, and their scores were close to perfect (maximum = 60) for both age groups, indicating naming proficiency. (All results reported as significant in this paper attained at least $p < .05$).

**Materials**

The retrospective questionnaire asked subjects to estimate how often they experienced TOTs (per month), what types of words their TOTs involved, what aspects of

| TABLE 1 | **BACKGROUND CHARACTERISTICS OF SUBJECTS IN STUDY 1** |
|---|---|---|---|---|---|---|---|---|
| | **Age** | **Education*** | **WAIS Vocabulary** | **Boston Naming Test** | **Digit Span** |
| | M | SD | M | SD | M | SD | M | SD |
| Young | 19.4 | 1.2 | 13.7 | 1.1 | 67.1 | 6.6 | — | — |
| Mid-age | 38.7 | 3.3 | 16.7 | 2.1 | 72.6 | 4.6 | 58.2 | 1.6 |
| Older | 71.0 | 4.1 | 15.8 | 2.6 | 71.0 | 8.1 | 57.1 | 4.6 |

* Education in years.
TOT words they could usually recall, what retrieval strategies they found helpful, what proportion of their TOTs were successfully resolved, and how concerned they were about TOTs compared to other memory errors.

The diary contained 11 questions to be answered about each TOT experience as it occurred. The questions concerned the type of word involved (e.g., name of person, place, object), characteristics of the word that entered awareness (e.g., sound, number of syllables, when last encountered), and strategies used to resolve the TOT (e.g., consult dictionary, search memory alphabetically, think of meaning of word). Seven-point scales were provided for rating at TOT onset the FOK, the certainty of eventual recall, and the familiarity of the TOT word (1 = low; 7 = high). Space was provided for subjects to indicate any alternate word that came repeatedly to mind, to note each attempt to think of the TOT word, and to indicate the correct word when a TOT was successfully resolved, along with the time interval between TOT onset and resolution. Subjects selected one of three ways whereby a resolved TOT finally came to mind: by a memory search strategy, by consulting a person or book, or by popping up on its own.¹

For a random subset of 10 subjects in each age group, two questions were added for each TOT. One question concerned the context in which the TOT occurred, i.e., when thinking, talking, or writing, and the other concerned the subject’s physical and mental state at the time of the TOT: Subjects rated how worried, excited, fatigued, and sick they felt on a 7-point scale (1 = less than usual; 7 = more than usual).

Procedure

One of the authors (JW) interviewed each subject individually at the beginning and end of their 4-week interval. In the initial interview, the subject heard a description of the TOT state and, once a clear definition was established, filled out the retrospective questionnaire. Next, subjects practiced filling in the diary by recalling a recent TOT from their own experience or by analyzing a hypothetical TOT provided by the experimenter. Instructions emphasized that subjects should keep the diary nearby at all times, begin filling in the diary the moment a TOT occurred, answer all questions in the diary for each TOT experienced over the 4-week period, and continue recording information relevant to a TOT whether or not it was ultimately resolved or new TOTs occurred. Subjects were told to contact the experimenter for assistance or for additional diaries (ensuring that the forms available did not limit the number of TOTs reported).

In the final interview at the end of four weeks, the experimenter collected each diary, administered the naming, vocabulary, and digit span tests, and reviewed the diary entries with the subject to ensure legibility, to clarify meanings for ambiguous terms, and to account for or fill in missing data. For subjects recording information on the context of TOTs, the final interview also clarified, when necessary, whether a TOT occurred in a formal context as in writing an assigned paper or newspaper article, or in an informal context as in gossiping with a friend. Finally, subjects who experienced TOTs for acquaintance names were asked four additional questions: how long they knew each acquaintance, frequency of contact with him or her, most recent contact, and how well they knew the acquaintance on a 1 to 7 scale. Subjects were then paid for their participation ($20 for midage and older subjects and $10 plus course credit for young adults).

Results

Retrospective Responses

These data were particularly interesting for the absence of age differences. Subjects

¹ The diary and the retrospective questionnaire are available from the authors.
in the three age groups anticipated having about the same number of TOTs: Mean estimates of TOT frequency on a 1 (never) to 7 (very frequently) scale were 4.38 for young adults, 3.97 for midage adults, and 4.36 for older adults, and estimated TOTs per month were 3.04, 3.20, 3.22, respectively, both $F$’s < 1.0. Estimated percent of unresolved TOTs was virtually identical for the three age groups at 11–12%. However, responses to two questions showed age differences that paralleled those observed in the diary data. The percent of subjects reporting that they usually recalled the sound of TOT words decreased with age, 68% of young, 43% of midage, and 28% of older adults, $x^2 = 16.26$. Also, unlike other resolution strategies such as going through the alphabet, the “relax and direct attention elsewhere” strategy increased with age: More older (78%), than midage (60%) or young (56%) adults reported using this strategy, $x^2 = 5.85$.

**Diary Data**

Across all groups, subjects recorded 686 TOT experiences in their diaries, of which 653 (95%) were resolved during the four week interval. Except as indicated otherwise, both resolved and unresolved TOTs provided the basis for subsequent analyses. Consistent with the high resolution rate, overall certainty-of-recall ratings were high (5.85 out of 7), and mean FOK was close to maximum (6.48 out of 7), indicating that subjects were confident that they knew the TOT words. Familiarity ratings were also high (5.64 out of 7), indicating that subjects felt that their TOTs involved familiar words.

**Age and TOT Frequency**

Mean TOTs and percent resolved for each age group are shown in Table 2. An ANOVA on number of TOTs with sex and age as variables showed a significant effect of age, $F(2,124) = 10.63$, $MSe = 8.22$, but no effect of sex or age by sex interaction (both $F$’s < 1.0). Follow-up tests showed that midage and older adults both reported significantly more TOTs than young adults. (All follow-up tests of main effects involved the Least Significant Differences procedure unless noted otherwise.) The age difference in TOTs was unrelated to the greater education, higher vocabulary scores, and lower digit spans of older adults: A hierarchical multiple regression with WAIS vocabulary score, years of education, digit span, and age entered in that order showed no significant change in $R$-square for any variable except age which yielded a significant $R$-square change of .14. Consistent with this, the simple correlation of each of these variables with mean TOTs was significant only for age ($r = .38$).

Probability of resolution was close to ceiling and relatively unaffected by age. Although the proportion of resolutions per subject tended to increase with age (see Table 2), this trend was nonsignificant $F(2,127) = 2.80$, $MSe = .03$, $p < .07$, and the number of subjects who failed to resolve all their TOTs did not increase with age, $x^2 = .85$.

One-way ANOVA’s were used to examine relations between age and ratings of FOK, certainty-of-recall, and target familiarity, averaged across TOTs for each subject within each age group. FOK did not vary with age (see Table 3), so that the increase in TOTs with age cannot be due to an age-linked shift in the FOK criterion for deciding whether a TOT has occurred.

**TABLE 2**

<table>
<thead>
<tr>
<th>Group</th>
<th>TOTs</th>
<th>Resolutions</th>
<th>Percent of TOTs Resolved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
<td>$M$</td>
</tr>
<tr>
<td>Young</td>
<td>3.92</td>
<td>1.74</td>
<td>3.62</td>
</tr>
<tr>
<td>Midage</td>
<td>5.40</td>
<td>2.93</td>
<td>5.13</td>
</tr>
<tr>
<td>Old</td>
<td>6.56</td>
<td>3.51</td>
<td>6.36</td>
</tr>
</tbody>
</table>

*Note: Means are for TOTs per subject over a 4-week interval.*
There were significant age effects on both certainty-of-recall, \( F(2,127) = 4.99, MSe = .89 \), and familiarity, \( F(2,127) = 8.33, MSe = 1.03 \), with both showing higher ratings for midage and older adults than young adults (see Table 3). An age-linked increase in attempts to retrieve words that are less certain of recall or subjectively less familiar cannot therefore explain why TOT's increased with age.

**Type of TOT Word**

Word type was determined for all 686 TOTs because subjects indicated word type for both resolved and unresolved TOTs. TOTs were grouped into three categories: proper names (e.g., Casablanca), names of objects (e.g., algae), and abstract words (e.g., idiomatic). The abstract word category contained mainly non-object nouns, adjectives, verbs, a few phrases, and one adverb. The corpus contained no TOTs involving closed class or function words. TOTs involving proper names were more common (62%) than TOTs involving object names (12%) and abstract words (23%).

Table 4 shows the mean number of TOTs for the three word classes as a function of age. As can be seen, TOTs for proper names and object names increased with age, whereas TOTs for abstract words decreased with age. An ANOVA on the number of TOTs in each category for each age group showed significant effects for age, \( F(2,127) = 10.77, MSe = 2.71 \), for word category, \( F(2,254) = 103.67, MSe = 2.75 \), and for the age by word category interaction, \( F(4,254) = 8.96, MSe = 2.75 \). One-way ANOVAs on the number of TOT's in each category confirmed that proper name TOTs were more common for midage and older adults than for young adults, \( F(2,127) = 11.02, MSe = 5.88 \); object name TOTs were more common for older adults than for midage or young adults, \( F(2,127) = 12.59, MSe = .82 \); but the age difference for abstract word TOTs was not significant, \( F(2,127) = 2.23, MSe = 1.52, p < .12 \).

Using proportion of TOTs in each category as the dependent variable, a similar pattern emerged, except that proportionally more TOTs involved abstract words for young adults than for midage or older adults, \( F(2,127) = 9.51, MSe = .06 \). This effect may occur because the college environments of young adults provided formal situations that prompted greater use of abstract words, creating more opportunity for abstract word TOTs. To explore this, we analyzed the 184 TOTs of the 10 subjects in each age group who reported TOT context. Only 18 of these TOTs occurred in formal situations, of which 10 were for abstract words. Consistent with the view that college contexts contributed to abstract word TOTs, young adults experienced 8 of the 10 abstract word TOTs in formal situations, clearly more than any other age group.

**Subcategories of proper name TOTs.** Proper name TOTs fell into four subcategories: names of acquaintances, famous people, places, and titles of books, films, or
television shows (see Table 5). The number of TOTs in these four subcategories varied with age, $F(2,127) = 11.07, MSe = 1.46$, and subcategory, $F(3,381) = 17.59, MSe = 1.42$, with an age by subcategory interaction, $F(6,381) = 4.30, MSe = 1.42$. There were significant simple effects of age for acquaintance names, $F(2,127) = 6.94, MSe = 3.20$, and place names, $F(2,127) = 7.22, MSe = .58$, and marginal age effects for famous people, $F(2,127) = 2.52, MSe = 1.55, p < .09$, and titles, $F(2,127) = 2.93, MSe = .37, p < .06$. Follow-up tests confirmed that older adults experienced more TOTs for acquaintance and place names than midage and young adults, that midage adults experienced more TOTs for place names than young adults, and that young adults experienced more TOTs for titles than older adults.

Recency and Acquaintance Name TOTs

Recency of acquisition. To determine whether the increase in acquaintance name TOTs for older adults reflected a problem in remembering new rather than old information, we analyzed duration of acquaintance as a function of age. Table 6 shows the mean duration in years that each acquaintance was known, averaged across all subjects in each age group who reported at least one acquaintance name TOT. Older adults' quartile range shows that 75% of their acquaintance name TOTs involved people known for at least 6.71 years, suggesting that recently learned names were not a major contributor to their TOTs. Because the range of values within each age group was large and increased with age (see Table 6), we used the log of the mean for each subject to increase homogeneity of variance in the ANOVA. Duration of acquaintance varied with age, $F(2,69) = 51.97, MSe = .22$, and in follow-up tests was greater for older than either young or midage adults, and greater for midage than young adults. Consistent with this, ratings of how well known the acquaintances were varied with age, $F(2,69) = 6.59, MSe = 2.08$, with significantly higher ratings for older than young adults (see Table 6). In sum, the age-linked increase in TOTs for acquaintance names is not a consequence of the acquaintance being either briefer in duration or more recently acquired for older adults.

Recency of use. The interval since last contact with acquaintance was analyzed in the same way as duration of acquaintance (see Table 6). There were significant age effects, $F(2,66) = 9.68, MSe = .88$, and in follow-up tests, time since last contact was significantly greater for older than young and midage adults. Thus older adults had contacted their TOT acquaintances less recently than young and midage adults, suggesting that recency of use varied with age.

Frequency of Use

We used Francis and Kucera (1982) to determine the median frequency of occurrence of resolved TOT words, excluding

<table>
<thead>
<tr>
<th>Group</th>
<th>Acquaintance</th>
<th>Famous person</th>
<th>Place</th>
<th>Movie/TV/book</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>0.86</td>
<td>22</td>
<td>0.64</td>
<td>16</td>
</tr>
<tr>
<td>Midage</td>
<td>1.33</td>
<td>25</td>
<td>1.20</td>
<td>22</td>
</tr>
<tr>
<td>Old</td>
<td>2.18</td>
<td>33</td>
<td>1.10</td>
<td>17</td>
</tr>
</tbody>
</table>

Note. Percentage is of total TOTs in each age group.

Examples:
- "Cory"  
- "Carl Rogers"  
- "Nordstrom"  
- "Munsiers"  
- "Jo Hartley"  
- "Walter Matthau"  
- "Wilson College"  
- "Sound of Music"
TIP OF THE TONGUE AND AGING

TABLE 6
ACQUAINTANCE NAME TOTs

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Duration of acquaintance</th>
<th>Recency of contact</th>
<th>How well known</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>Quartile range</td>
<td>M</td>
</tr>
<tr>
<td>Young</td>
<td>23</td>
<td>1.06</td>
<td>0.26-1.52</td>
<td>0.27</td>
</tr>
<tr>
<td>Midage</td>
<td>15</td>
<td>4.16</td>
<td>0.60-6.00</td>
<td>0.38</td>
</tr>
<tr>
<td>Old</td>
<td>34</td>
<td>17.67</td>
<td>6.71-26.77</td>
<td>4.03</td>
</tr>
</tbody>
</table>

a Duration of acquaintance and recency of contact is expressed in years.
b Rated on a scale from 1 = not well to 7 = very well.

proper names and phrases. Overall, 47% of the words were so infrequent as to be unlisted in the Francis and Kucera norms. Table 7 shows the number and percent of unlisted words subclassified by age and word type. Older adults tended to have a larger proportion of unlisted words, but the χ²'s were not significant for either abstract words, χ² = 4.91, p < .10, or object names, χ² = 1.83. For TOT words that were listed, the median frequency was lower than would be expected by chance: The median frequency for all open class words in Francis and Kucera is 84 occurrences per million (Stemberger & MacWhinney, 1986), a frequency exceeded by only 11% of our listed, open class TOT words.

Partial Information about TOT Words

The mean number of reported characteristics (e.g., number of syllables, initial sound of word) per TOT for young, midage, and older adults was 2.07, 1.91, and 1.53, respectively, F(2,127) = 4.39, MSe = .86.

Follow-up tests showed that older adults recalled fewer characteristics than did the younger groups. Number of reported characteristics was related to occurrence of an alternate. Pearson correlations between TOTs with alternates (in percent) and the mean number of characteristics recalled were significant for young and older subjects, r's = .26 and .30, respectively, but not for midage subjects, r = .16.

Persistent Alternates

The percentage of TOTs accompanied by alternates differed by age, F(2,127) = 4.85, MSe = .09 (see Table 8). Follow-up tests showed that older adults reported alternates on a smaller percentage of TOTs than did young adults.

Alternates and word type. The decrease in alternates with age was not a consequence of age differences in the type of word involved in TOT's. We calculated the percentage of TOTs with alternates separately for proper names, object names, and abstract words and, as seen in Table 8, the

TABLE 7
FREQUENCY OF OCCURRENCE OF ABSTRACT AND OBJECT NAME TOT TARGETS

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of words</th>
<th>Not listed</th>
<th>Mdn frequency</th>
<th>Number of words</th>
<th>Not listed</th>
<th>Mdn frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>59</td>
<td>16 (27%)</td>
<td>11</td>
<td>12</td>
<td>6 (50%)</td>
<td>4</td>
</tr>
<tr>
<td>Midage</td>
<td>29</td>
<td>8 (28%)</td>
<td>6</td>
<td>17</td>
<td>11 (65%)</td>
<td>3</td>
</tr>
<tr>
<td>Old</td>
<td>33</td>
<td>16 (48%)</td>
<td>3</td>
<td>57</td>
<td>40 (67%)</td>
<td>2</td>
</tr>
</tbody>
</table>

a Frequency of occurrence and listings are from Francis and Kucera (1982).
b Frequency is occurrences per million words.
TABLE 8
PERCENTAGE OF TOTs WITH ALTERNATES BY AGE FOR ALL TOTs AND BY TARGET WORD TYPE

<table>
<thead>
<tr>
<th>Group</th>
<th>Percent all TOTs with alternates</th>
<th>Percent TOTs with alternates by target word type</th>
<th>Proper names</th>
<th>Object names</th>
<th>Abstract words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>67</td>
<td>60</td>
<td>88</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Midage</td>
<td>58</td>
<td>47</td>
<td>77</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>48</td>
<td>51</td>
<td>53</td>
<td>43</td>
<td></td>
</tr>
</tbody>
</table>

Note. The number of TOTs varies by target word type and age group.

percentage was smaller for older than young adults in each word type. Because many subjects did not experience TOTs for all three word types, we used a hierarchical multiple regression to evaluate the relation of age, TOT word type and their interaction (entered in that order) to the percentage of alternates. With age entered, a small but statistically significant R-square of .043 was obtained. Entering TOT word type and its interaction with age did not significantly increase the amount of explained variance. Thus, TOT word types that occurred more frequently for older adults, such as proper names, were not less likely to trigger alternates than other word types.

Alternate and TOT word similarity. We evaluated three dimensions of similarity between alternates and TOT words: syntactic class, initial phoneme, and number of syllables. Syntactic class refers to words that share the same sequential privileges of occurrence in sentences (e.g., adjectives, people’s names). Table 9 shows that almost all alternates shared syntactic class with the TOT target. We also determined the percentage of cases in which the first phoneme of the alternate and the target was identical. This was compared to a chance probability calculated as the scalar product of two vectors, one containing the proportion of each initial phoneme of the alternates and the other containing the proportion of each initial phoneme in the TOT targets (cf. Dell & Reich, 1981). The chance percentage of identical initial phonemes was between 5% and 6% for each age group, substantially less than the obtained percentages shown in Table 9. Finally, the number of syllables in alternates and TOT words were significantly correlated, r’s = .56, .39, and .56 for the young, midage, and older adults, respectively. The percentage of alternates and targets with identical numbers of syllables expected by chance (calculated from the scalar products) ranged from 21 to 25% for the three age groups, again less than the obtained percentages shown in Table 9. Thus, alternates show considerable phonological and syntactic similarity to TOT targets.

Alternates, FOK, and certainty-of-recall. Two separate ANOVAs evaluated whether

TABLE 9
PERCENTAGE OF ALTERNATES WITH CHARACTERISTICS IDENTICAL TO TOT WORDS

<table>
<thead>
<tr>
<th>Group</th>
<th>Syntactic category</th>
<th>Initial phoneme</th>
<th>Number syllables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>85.2</td>
<td>36.2</td>
<td>50.9</td>
</tr>
<tr>
<td>Midage</td>
<td>84.1</td>
<td>38.9</td>
<td>37.8</td>
</tr>
<tr>
<td>Older</td>
<td>93.0</td>
<td>32.5</td>
<td>49.1</td>
</tr>
</tbody>
</table>

Examples

<table>
<thead>
<tr>
<th>Category</th>
<th>Alternate</th>
<th>TOT word</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same syntactic</td>
<td>lobotomy</td>
<td>dichotomy</td>
</tr>
<tr>
<td></td>
<td>vibrator</td>
<td>blender</td>
</tr>
<tr>
<td></td>
<td>charity</td>
<td>chastity</td>
</tr>
<tr>
<td></td>
<td>Montecito</td>
<td>Mendocino</td>
</tr>
<tr>
<td></td>
<td>Betty Craighead</td>
<td>Betsy Crighton</td>
</tr>
<tr>
<td>Different</td>
<td>despair</td>
<td>discouraged</td>
</tr>
<tr>
<td>syntactic</td>
<td>Alistair Cooke</td>
<td>Masterpiece</td>
</tr>
<tr>
<td></td>
<td>flame</td>
<td>Theater</td>
</tr>
<tr>
<td></td>
<td>rising</td>
<td>sizing</td>
</tr>
<tr>
<td></td>
<td>manganese</td>
<td>magenta</td>
</tr>
</tbody>
</table>
TABLE 10
MEAN NUMBER AND PERCENTAGE OF RESOLVED TOTS BY AGE AND RESOLUTION METHOD

<table>
<thead>
<tr>
<th>Group</th>
<th>Memory search</th>
<th>Consulted book/person</th>
<th>Popped-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>strategy</td>
<td>M</td>
<td>%</td>
</tr>
<tr>
<td>Young</td>
<td>0.79</td>
<td>0.3</td>
<td>20</td>
</tr>
<tr>
<td>Midage</td>
<td>1.40</td>
<td>0.3</td>
<td>27</td>
</tr>
<tr>
<td>Older</td>
<td>0.76</td>
<td>0.3</td>
<td>12</td>
</tr>
</tbody>
</table>

the occurrence of an alternate affected mean ratings for FOK and certainty-of-recall. Only subjects who reported at least one TOT with an alternate and one without could be included (32 young, 24 midage, and 37 older subjects). Both ANOVAs showed age effects, but no effect of alternates on the ratings. It was not possible to determine whether alternates affected the probability of actually resolving a TOT because almost all TOTS were resolved. However, the relatively few (33) unresolved TOTS across all age groups showed no increased occurrence of alternates: 18 had alternates and 15 did not.

Resolution of TOTS: How and When

Method of resolution. An ANOVA on the number of resolved TOTS included as variables resolution method, occurrence of alternates and age. The effect of resolution method was significant, $F(2,244) = 34.72$, $MSe = 1.38$, with pop-ups the most frequent method for all ages (see Table 10), and interacted with age, $F(2,244) = 7.04$, $MSe = 1.38$. Older adults had more TOT words pop up than either young or midage adults, $F(2,124) = 10.48$, $MSe = 5.23$, and there was a marginally significant age effect for the memory search method, with midage adults resolving more TOTS via memory search than either young or older adults, $F(2,124) = 2.91$, $MSe = 1.59$, $p < .06$. Resolution method did not interact with the occurrence of alternates. The main effects of age, alternates, and their interaction were significant, consistent with the report above that TOTS increased with age, whereas alternates decreased with age.

Age differences in method of resolution may reflect age differences in attempts to use strategies to resolve TOTS. The mean number of different strategies reported for each TOT differed by age, $F(2,127) = 6.98$, $MSe = .47$, with older adults using significantly fewer strategies per TOT (1.52) than young (1.95) and midage (2.03) adults. Note, however, that older adults' decreased use of active resolution strategies cannot account for their decreased experience of persistent alternates: The frequency of TOTS with and without alternates did not interact with resolution method in the ANOVA reported above.

Time required for resolution. The interval between onset and resolution of a TOT was translated into minutes and a mean was calculated for each subject. The range of resolution times was very large and the distribution was positively skewed, so logarithms were used in all analyses. A one-way ANOVA showed a significant age effect, $F(2,124) = 4.35$, $MSe = 3.50$ with longer resolution times for older adults than either young or midage adults. The cumulative frequency distributions of resolution time in Fig. 3 illustrate this age difference clearly. A Kolmogorov-Smirnov test (Siegel, 1956) on these distributions showed a significant difference between young and older adults, $Z = 2.69$, and between midage and older adults, $Z = 1.94$.

We used hierarchical multiple regression analysis to evaluate effects of age, alternates, age by alternate interaction, method of resolution, and method of resolution by age interaction, entered in that order, on the dependent variable, time to resolve a TOT. There was a small but significant relation between age and resolution time, $R$-
Fig. 3. Cumulative frequencies of TOTs as a function of resolution time for pop-ups.

square = .031; adding alternates significantly increased R-square to .064, and adding method of resolution increased it significantly to .099. Neither interaction affected R-square. Thus, TOTs with alternates took substantially longer to resolve than TOTs without alternates in each age group: 13.3 vs. 3.8 min for the young, 12.5 vs. 4.9 min for the midage, and 51.1 vs. 15.8 min for older adults. Comparing methods of resolution across all age groups, pop-ups (M = 22.9 min) took longer than consulting an external source (M = 14.4 min) which took longer than memory searches (M = 4.3 min).

A second regression on resolution time for pop-ups only, entered age, alternates, age by alternates, word type, and age by word type in that order. With age entered, R-square was a small but significant .014, and increased significantly to .032 with the addition of alternates. As can be seen in Fig. 4, TOTs with alternates took considerably longer to resolve in each age group. No other variable had a significant effect. Another regression entering age, alternates, word type, and FOK had the same outcome as the one above and there was no significant effect of FOK. The lack of a FOK effect probably reflects the restricted range of this variable for TOTs that popped up. M = 6.57, SD = 1.00.

Subject Variables: Mental and Physical States

The rating of state at TOT onset by 10 subjects in each age group showed age differences for Worry, Excitement, and Fatigue, p < .057 or better, F’s (2,27) = 3.24, 3.19, and 3.95, respectively. In each case follow-up tests showed that mean ratings for midage adults (4.35, 4.52, 4.76, respectively) were significantly higher than for older adults (3.01, 3.12, 3.24, respectively), but neither group differed from young adults (3.88, 3.85, 4.11, respectively). Thus, midage adults were more likely than older adults to view their state at the time of

Fig. 4. Resolution time for pop-ups as a function of age and the occurrence of alternates.
the TOT as unusual. The mean ratings for Sickness did not differ for young, midage, and older adults (3.39, 3.47, 2.78, respectively).

Discussion

Analysis of our corpus of TOT words provided clear support for the predicted relation between TOTs and frequency and recency of use of the target word. For all age groups, TOTs involved abstract words and object names that occurred relatively rarely in the language, according to word frequency norms. Recency also influenced TOTs because acquaintance name TOTs involved names of people who were highly familiar but had not been contacted for at least three months, and much longer in the case of older adults. Within the NST, infrequent and non-recent use weakens connections between lexical and phonological nodes, creating a local priming decrement that causes TOTs.

Also as predicted, FOK and familiarity ratings for TOT targets were consistently high across all age groups, as observed in other studies (see Brown, 1991). Within the NST, the high FOK for older adults results from summation of priming at lexical and semantic nodes which compensates for their general age-linked transmission deficit.

Aging had a clear effect on TOTs that is consistent with this age-linked transmission deficit. Number of TOTs reported in the diaries increased with age, and this increase was evident in midage adults, 35 to 45 years old. Unlike TOTs, however, persistent alternates decreased in frequency with age, and older adults reported less information about the target word than young or midage adults. Cohen and Faulkner (1986) in their study of naturally occurring TOTs for proper names likewise reported an age-related decline in the availability of partial information, and their older subjects, like ours, explained that often during the TOT experience their “mind simply went completely blank.” The age difference in occurrence of persistent alternates does not seem to be a by-product of the type of words involved in older adults TOTs because it was obtained for each of the three main types of TOT words. This pattern of data for partial information and persistent alternates is more consistent with Transmission Deficit hypotheses than with Inhibition hypotheses as currently formulated.

Results of Study 1 suggest that two factors may conspire to reduce transmission of priming in older adults. One is a general transmission deficit resulting from aging. The other is recency because greater age makes possible very long intervals since last use of particular words. Relative to young adults, older adults had a tenfold increase in the average time since contacting acquaintances whose names triggered TOTs. Thus, older adults may have more TOTs for proper names because of a greater interval since last use of these words. On the other hand, frequency of use over the course of a lifetime almost certainly increased with age for acquaintance names (because average duration of acquaintance increased dramatically with age), and probably also for abstract words and object names as well. This age-linked increase in frequency of word use may partially compensate for transmission deficits resulting from aging and non-recent use, but clearly it does not overcome them.

Estimated TOT frequency in the retrospective questionnaires did not vary with age, effectively ruling out the hypothesis that older adults report more TOTs because they expect more TOTs. Indeed, a reporting bias in the direction of estimated TOT frequencies would have reduced the diary age differences. The hypothesis that younger adults recorded fewer TOTs because they were generally less diligent than other subjects in keeping TOT records also seems unlikely. Our young adults reported 3.9 TOTs while the same-age subjects in Reason and Lucas’s (1984) diary study reported 2.5 TOTs over four weeks, indicating that our young adults were at least as
diligent as their subjects. Moreover, our young adults recorded more alternatives and partial information per TOT than did our older adults, suggesting that young adults were more diligent than older adults, at least with respect to recording this aspect of TOTs.

Other characteristics of TOTs were age constant, consistent with our view that priming transmission varies with age, but not the processing architecture underlying TOTs. As predicted, persistent alternatives shared phonology and syntactic class with target words across all age groups. Because resolution of TOTs was effectively at ceiling, we could not determine whether alternatives influenced the probability of resolving a TOT. However, as predicted, persistent alternatives were associated with longer resolution times, contradicting the hypotheses that alternatives have no effect on retrieval (Kohn et al., 1987), or that alternatives facilitate resolution by “allowing the target specification to be sharpened up” (Cohen & Faulkner, 1986, p. 190; Brown & McNeill, 1966). This relation between alternatives and resolution time could in principle arise because longer resolution times allow more time for retrieval of an alternate. However, this argument is weakened by the fact that older adults had the longest resolution times and fewest alternatives.

Across all age groups, proper names were the most frequent type of word involved in TOTs. Newly learned names were not responsible for this proper name effect because acquaintance names in each age group were rated as familiar and had been known at least a year, on average. The proper name effect suggests that proper names are not just difficult to learn (McWeeny et al., 1987), but difficult to retrieve, even when well learned.

Proper name and object name TOTs increased in frequency with age, while abstract word TOTs decreased in relative frequency with age. The age effect for abstract words may in part reflect age differences in language use. As college undergraduates, our younger subjects may have been required to use low frequency abstract words more often than older adults. Nonetheless, the pattern contradicts the hypothesis that TOTs increase with age because vocabulary size increases with age and makes retrieval of any given word more difficult. Under this vocabulary size hypothesis, naturally occurring TOTs should more often involve members of large word classes (e.g., object names, abstract words) than members of relatively small word classes (e.g., proper names).

Pop-ups were the most common means of resolution for all ages, and, as predicted, required more time as a function of age. They were relatively more frequent for older adults, perhaps because older adults used fewer resolution strategies. With age and experience, older adults may learn that a word they are struggling to retrieve will eventually pop into mind without use of active strategies. Consistent with this interpretation, the retrospective questionnaire data suggested that older adults were more likely to adopt the strategy of “relaxing and directing attention elsewhere.” This less active approach to resolution cannot, however, account for the reduced persistent alternatives in older adults because alternatives did not occur any less frequently with pop-ups than with more active resolution methods (e.g., memory search).

**STUDY 2: EXPERIMENTALLY INDUCED TOTs**

Study 2 was a laboratory experiment designed to provide a rigorous and convergent test of four classes of effects in Study 1: the similarity of targets and persistent alternatives, the effects of age on TOTs and persistent alternatives, the proper name effect, and the relatively larger increase in proper name TOTs for older adults. The effect of age on TOTs in Study 1 could have been influenced by what words the three age groups tend to use in their everyday life. For example, if midage and older adults are more likely to produce words susceptible to
TOTs, this could produce an age-related increase in TOTs. Similarly, some peculiarity of words used by older adults might make alternates less likely or make TOTs slower to resolve. Such problems disappear when TOTs for preselected targets are induced in the laboratory.

Our subjects were a subset of the young and older adults who had participated in Study 1 several months earlier. Based on results of Study 1, 100 TOT target words were selected from five categories: abstract nouns, object names, adjectives/verbs, and the names of famous people and places. This allowed us to examine whether the names of famous people and places are in general more vulnerable to TOTs, and whether abstract words are more vulnerable to TOTs in young adults, or were just used more often by young adults in Study 1.

**Method**

**Subjects**

Participants were 21 young and 21 older adults from Study 1, matched for education and WAIS vocabulary, and selected on the basis of availability. All subject characteristics, including mean number of TOTs in Study 1, are shown in Table 11. The two groups differed significantly only in digit span and number of TOTs reported in Study 1, t's (40) = 3.65 and 3.06, respectively.

**Materials**

The targets were 100 low frequency words: 20 abstract nouns, 20 object names, 20 adjectives and verbs, 20 place names, and 20 names of famous people. The questions for inducing TOTs for these words were derived from a dictionary, an atlas, Who's Who in America, Current Biography, and general information norms (Nelson & Narens, 1980). Questions that subjects consistently answered correctly or incorrectly in pilot testing were modified or replaced.

For each target, a multiple-choice recognition test was constructed, consisting of the TOT target and three foils. Foils shared word type with the target, were semantically similar, and were derived from the same sources as the questions. The 100 targets, questions, and foils are shown in the Appendix.

**Procedure**

The experimental task was described to subjects as similar to a trivia game played on a computer. Subjects were told not to expect to get all of the answers correct because the questions were intentionally difficult to answer. Although familiar with TOT states from their earlier participation in Study 1, subjects were also read a description of the TOT state derived from Brown and McNeill (1966).

The TOT-inducing questions were presented on the monitor of an Apple II Plus computer, and for each, the subjects typed one of three possible responses on the computer keyboard: K (Know) if they felt they knew the answer, D (Don't know) if they did not feel they knew the answer, or T (TOT) if they were in a TOT state. A sequence of programmed queries shown in

<table>
<thead>
<tr>
<th>Table 11</th>
<th>Background Characteristics of Subjects in Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Age</td>
</tr>
<tr>
<td>----------</td>
<td>-----</td>
</tr>
<tr>
<td>Young</td>
<td>20.0</td>
</tr>
<tr>
<td>Old</td>
<td>71.3</td>
</tr>
</tbody>
</table>

*Education in years.*
Fig. 5 followed this initial response. The first two queries were identical for all subjects: How familiar is the word (on a 1 to 7 scale)?; How certain are you that you can recall the word?

Subsequent queries differed for subjects who initially responded Know, Don't know, or TOT. The computer presented the four-choice recognition question following both Know and Don't know responses, but after Know responses, first asked subjects to type in the correct answer to the question. After TOT responses, subjects were asked to provide, if possible: initial sound, final

---

**Fig. 5.** Sequence of questions for inducing TOTs in Study 2.
sound, number of syllables, similar sounding word, persistent alternate. The computer then asked subjects to guess the word, and if their guess was incorrect, presented a five-choice recognition question. This recognition question was the same as for Know and Don’t know responses except that “None of the Above” was added to the programmed choices for TOT responses to determine whether the TOT involved a word other than the target word. After either correct recall or a response to the multiple choice question (see Fig. 5), subjects saw the correct answer, and pressed (Return) on the keyboard to continue with the next TOT-inducing question.

In a practice session preceding the experiment, four additional TOT-inducing questions were presented and subjects were instructed to respond as follows: Know for the first question, Don’t know for the second, TOT for the third, and according to their actual state for the fourth question. Thus, subjects saw all possible sequences of programmed queries before beginning the experiment proper.

Each subject was tested individually and received the 100 TOT-inducing questions in a different random order. Subjects proceeded through the task at their own pace, but could not backtrack to earlier questions. To minimize loss of correct answers due to misspelling, the computer scored only the first three letters of any attempt to produce the answer.

Results

Age and TOT Frequency

Absolute number of TOTs. TOT responses were made on 10.9% of the trials, yielding a total of 458 TOTs. The mean number of Know, Don’t know, and TOT responses is shown by age and word type in Table 12. An ANOVA was performed separately on each response type using the five word types as a within-subject variable and age as a between-subject variable. Only the main effect of age for Don’t know responses was significant, $F(1,40) = 4.63, MSe = 53.93$, indicating that older subjects responded Don’t know less often overall. The word type effect was significant in each analysis. $F’s (4,160) = 21.74, 19.43,$ and $4.50, and MSe = 5.67, 6.08,$ and $2.29,$ for Know, Don’t know, and TOT, respectively, as was the age by word type interaction, $F’s (4,160) = 11.49, 6.80,$ and $3.86,$ respectively. $t$ tests confirmed that older adults responded Know more often and Don’t

<table>
<thead>
<tr>
<th>TABLE 12</th>
<th>MEAN NUMBER OF KNOW, DON’T KNOW, AND TOT RESPONSES TO QUESTIONS BY TARGET WORD TYPE IN STUDY 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Non-object nouns</td>
</tr>
<tr>
<td>Know responses</td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>10.3</td>
</tr>
<tr>
<td>Old</td>
<td>10.1</td>
</tr>
<tr>
<td>Don’t know responses</td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>7.8</td>
</tr>
<tr>
<td>Old</td>
<td>8.0</td>
</tr>
<tr>
<td>TOT responses</td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>1.9</td>
</tr>
<tr>
<td>Old</td>
<td>1.9</td>
</tr>
<tr>
<td>TOT responses correctly recalled or recognized</td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>1.7</td>
</tr>
<tr>
<td>Old</td>
<td>1.4</td>
</tr>
</tbody>
</table>
know less often for object names, verbs and adjectives, and place names. Older adults responded TOT significantly more often only for names of famous people.

Incorrect recognitions of TOT targets on the multiple choice test presumably indicate that the subject had in mind a word other than the target word. Such responses were less frequent than in Brown and McNeill's (1966) study, 21 versus 35% of TOTs, and did not vary for young and older adults, 23 versus 20%. An ANOVA on the mean number of "proper TOTs" (where the target was subsequently recognized or recalled) showed a pattern of significant effects identical to the ANOVA for all TOTs (see Table 12, bottom). Only the 361 proper TOTs were included in subsequent analyses.

Consistent with the age differences in Know and Don't know responses for certain word types, an analysis of the mean number of correctly recalled targets, independent of initial response, showed no main effect of age, but a significant word type effect, $F(4,160) = 15.47$, $MS_e = 5.55$, and an age by word type interaction $F(4,160) = 8.68$, $MS_e = 5.55$. Follow-up tests confirmed the pattern seen in Table 13, which resembled the pattern for Know responses, namely, higher correct recall by older adults for object names, adjectives and verbs, and place names.

Correct recognitions exhibited a similar pattern, shown in Table 13. Here percent correct is the unit of analysis because the number of recognition trials varied across subjects and word type. There was a significant effect of age, $F(1,40) = 8.31$, $MS_e = .06$ and an age by word type interaction, $F(4,160) = 2.87$. Follow-up tests indicated that older adults recognized more object names and place names than did young adults.

Relative number of TOTs. Comparing the absolute frequency of TOTs for young and older adults was problematic for object names, adjectives/verbs, and place names because older adults made more Know responses and fewer Don't know responses than young adults, and correctly recalled or recognized more targets for these three word types. These results suggest that older adults were simply more familiar with the words in these classes. Consistent with this hypothesis, older adults gave consistently higher familiarity and certainty-of-recall ratings than young adults for precisely these three word classes (see Table 14). A MANOVA showed no main effect of age, a significant word type effect $F(8,33) = 8.31$, univariate $F$'s $(4,37) = 15.63$ and 17.91 for certainty and familiarity, respectively, and an age by word type interaction, $F(8,33) = 4.73$, univariate $F$'s $(4,37) = 7.23$ and 9.52.

Because TOTs can only occur when a target is not immediately known, older

<p>| TABLE 13 |
| Mean Number of Target Words Recalled and Percent Recognized by Word Type |</p>
<table>
<thead>
<tr>
<th>Group</th>
<th>Non-object nouns</th>
<th>Object names</th>
<th>Adjectives, verbs</th>
<th>Place names</th>
<th>Famous people</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean number recalled</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>8.6</td>
<td>10.2</td>
<td>8.2</td>
<td>7.0</td>
<td>8.3</td>
</tr>
<tr>
<td>Old</td>
<td>8.0</td>
<td>12.8</td>
<td>11.2</td>
<td>10.7</td>
<td>7.5</td>
</tr>
<tr>
<td>Percent correct recognition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>56.9</td>
<td>60.1</td>
<td>66.5</td>
<td>53.7</td>
<td>56.6</td>
</tr>
<tr>
<td>Old</td>
<td>67.0</td>
<td>77.0</td>
<td>64.8</td>
<td>66.2</td>
<td>68.3</td>
</tr>
</tbody>
</table>

Note. A recognition test was presented only if the recall attempt was incorrect. Percent is based on actual number of recognition tests each subject received.
TABLE 14
MEAN CERTAINTY-OF-RECALL AND TOT TARGET FAMILIARITY RATINGS BY WORD TYPE

<table>
<thead>
<tr>
<th>Group</th>
<th>Non-object noun</th>
<th>Object name</th>
<th>Adjectives, verbs</th>
<th>Place names</th>
<th>Famous people</th>
</tr>
</thead>
<tbody>
<tr>
<td>Certainty-of-Recall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>4.61</td>
<td>4.75</td>
<td>4.88</td>
<td>4.03</td>
<td>4.18</td>
</tr>
<tr>
<td>Old</td>
<td>4.51</td>
<td>5.59</td>
<td>5.46</td>
<td>4.86</td>
<td>4.31</td>
</tr>
<tr>
<td>Familiarity of</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOT target</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>5.00</td>
<td>5.01</td>
<td>5.27</td>
<td>4.43</td>
<td>4.88</td>
</tr>
<tr>
<td>Old</td>
<td>4.63</td>
<td>5.65</td>
<td>5.62</td>
<td>5.02</td>
<td>4.45</td>
</tr>
</tbody>
</table>

adults' superior knowledge of these three word types reduces their opportunities for TOTs relative to young adults'. Following Brown's (1991) prescribed adjustment for age differences in item difficulty, we expressed TOTs as a proportion of unsuccessful retrievals. For each subject, we calculated TOTs as a proportion of trials on which a Know response was not made (see Table 15). There was a significant effect of age on these proportions, \( F(1,38) = 7.92, MSe = .12 \), and word type, \( F(4,152) = 7.67, MSe = .04 \), and a significant age by word type interaction, \( F(4,152) = 2.39, MSe = .04 \). Follow-up \( t \) tests confirmed that the mean proportion of TOTs was larger for older than young adults for object names, adjectives and verbs, and famous people.

**Partial Information about Targets**

The mean number of correctly reported characteristics (i.e., initial letter, final letter, number of syllables, and similar sounding word) per TOT did not differ for young and older adults, .73 and .72, respectively. However, Pearson correlations between the mean number of correctly reported characteristics and the percent of TOTs with alternates approached significance for young, \( r = .27 \), but not older subjects, \( r = .02 \). Note, however, that 11 older adults had no alternates and thus floor effects for this variable reduce any possible correlation.

**Persistent Alternates**

Young adults reported alternates for a larger percent of TOTs than did older adults, 40.9% and 9.9%, respectively, \( t(40) = 4.91 \). Eleven older adults (52.4%), but only two young adults (9.5%), reported no alternates at all. As in Study 1, the rate of alternates for famous names was comparable to the overall rate, namely, 38.1% and 10.4% for young and older adults, respectively.

The agreement of alternates and TOTs in syntactic class, initial phonomes, and number of syllables was evaluated using the same procedures as in Study 1. Most alternates shared syntactic class with their TOT target, 76.2% for young and 79.0% for older adults. The first phonomes of an alternate and its TOT target was identical in 17.5% of the cases for young adults and in 21.1% for

**TABLE 15**
PROPORTION OF TOTs ON TRIALS WITH UNSUCCESSFUL TARGET WORD RETRIEVAL BY WORD TYPE

<table>
<thead>
<tr>
<th>Group</th>
<th>Non-object noun</th>
<th>Object noun</th>
<th>Adjectives, verbs</th>
<th>Place names</th>
<th>Famous people</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>.17</td>
<td>.26</td>
<td>.15</td>
<td>.11</td>
<td>.16</td>
<td>.17</td>
</tr>
<tr>
<td>Old</td>
<td>.16</td>
<td>.47</td>
<td>.39</td>
<td>.21</td>
<td>.31</td>
<td>.31</td>
</tr>
</tbody>
</table>
older adults, exceeding the respective chance percentages of 5.7% and 5.5%. Finally, the number of syllables in alternates and targets was identical in 36.5% of the cases for young adults and in 36.8% for older adults, exceeding the respective chance probabilities of 26.8% and 26.3%. Correlations between the number of syllables in alternates and targets were significant, r’s = .27 and .46, for young and older adults, respectively.

Resolution

Correct recall of TOT targets indicates spontaneous resolution. Age comparisons, however, must consider occurrence of alternates because alternates reduced the rate of recall and occurred more frequently for young than older adults. For TOTs with alternates, 15.9% (M = .48) and 5.3% (M = .05) of targets were recalled by young and older adults, respectively. For TOTs without alternates the corresponding rates were 53.6% (M = 2.48) and 37.6% (M = 3.19). An ANOVA on the number of TOTs without alternates showed an age effect, F(1,40) = 8.61, and more importantly, an interaction with type of resolution (recall vs. recognition), F(1,40) = 4.47, because young adults recalled more targets than they recognized (2.48 vs. 2.14) and older adults recalled fewer TOTs than they recognized (3.19 vs. 5.48).³

Results Related to Methodological Issues

Item correlations for young and older adults. Using TOT-inducing questions as the unit of analysis, there were significant correlations between young and older adults in the number of correct recalls (r = .48), correct recognitions (r = .32), and incorrect responses (r = .46). However, number of TOTs per question was uncorrelated for young and older adults, r = .12. Indeed, the two age groups overlapped on only one of the 22 questions that induced five or more TOTs in an age group.

Correlation of TOTs with vocabulary and Study 1 TOTs. Number of TOTs in Study 1 and Study 2 were strongly correlated for young adults, r = .58, but not for older adults, r = -.23, p > .1.⁴ WAIS vocabulary scores were negatively correlated with the number of induced TOTs in Study 2 for older adults, r = -.63, but not young adults, r = -.07,⁵ and positively correlated with the total number of words correctly recalled or recognized regardless of initial response for older adults, r = .59, but not for young adults, r = .22.

Discussion

Results of Study 2 confirmed some of the age differences obtained in Study 1. Older adults reported more TOTs for people’s names than young adults. This age effect is consistent with Maylor’s (1990b) finding that 70-year-olds reported more TOTs than 50-year-olds when trying to name familiar famous faces. Indeed, older adults in Study 2, but not young adults, reported more TOTs for famous people’s names than for any other word type. An issue for further research is whether recency plays a role in this age-linked increase in proper name TOTs: Young adults may have become familiar with some names more recently than older adults, especially the names of people who achieved fame before the young adults were born, for example, Sirhan Sirhan, Nathan Hale, Cassius Clay, Louisa May Alcott.

We also obtained age-related increases in relative frequency of TOTs for object names, adjectives and verbs, as well as proper names when we analyzed TOTs as a proportion of trials where the subject did

³ Statistical analysis of resolution of TOTs with alternates was precluded by floor effects for older adults.

⁴ The slightly negative correlation for older adults was largely attributable to a single subject: eliminating this person from the sample produced r = -.08.

⁵ One young adult with extreme scores was eliminated; eliminating one or more extreme scores had no effect on older adults’ correlation.
not know the answer. This analysis compensated to some extent for the fact that older adults knew more of the target words than young adults.

As in Study 1, persistent alternates decreased in frequency with age. This decrease was not a consequence of older adults’ greater frequency of proper name TOTs because the rate of alternates for proper names was the same as the overall rate. The mean number of target word characteristics reported did not differ for young and older adults, a finding inconsistent with the results of Study 1. The reasons for this null result are unclear. In Study 2 we only analyzed partial information that was correct, as in Maylor’s (1990a) study of experimentally induced TOTs and Cohen and Faulkner’s (1986) study of naturally occurring TOTs, which both found age-linked declines in phonological characteristics. Thus, the age difference in partial information may be less reliable than the age difference in persistent alternates.

As in Study 1, targets and persistent alternates tended to share syntactic class, initial phoneme, and number of syllables. Both alternates and age reduced TOT target recall, possibly because they delayed resolution beyond the brief interval available on each trial for recall. We assume that some of the unrecollected TOTs would have been recalled spontaneously after this interval because in Study 1 only 20–40% of the resolved TOTs (depending on subject age) were resolved during the first 5 min; no subject took longer than 5 min to complete a trial in Study 2. Thus, both alternates and greater age were associated with longer TOT resolution time in Studies 1 and 2.

Finally, we turn to the methodological issue of whether Study 1 and Study 2 both measure the same basic susceptibility to TOTs. The answer appears to be yes for the young whose number of TOTs in the two studies were highly correlated, but no for the older adults who showed no such correlation. Age differences in correlations with WAIS vocabulary suggest one possible explanation. In Study 1, WAIS vocabulary was unrelated to number of TOTs for both age groups, and in Study 2 this pattern was repeated for young adults. WAIS vocabulary scores of older adults, however, were correlated negatively with number of induced TOTs and positively with targets recalled or recognized. Thus, laboratory TOTs, but not spontaneous TOTs, were sensitive to older adults’ knowledge of the language as measured by the vocabulary test. We suspect that vocabulary reflects general knowledge (e.g., of famous names, place names, rare objects) in older adults but not young adults. This issue, however, requires further study.

**GENERAL DISCUSSION**

**Effects of Frequency, Recency and Aging on TOTs**

The present results suggest that TOTs can be explained within a general theory of how language units are retrieved during both everyday speech production and experimental tasks. Within this interactive activation model of speech production, TOTs are caused by deficits in the transmission of priming that occur when the connections between lexical and phonological nodes become weakened due to infrequent use, nonrecent use, and aging. Consistent with predictions of this theory, TOT targets were infrequent words in the language and often had not been recently used, even though they were highly familiar to the subjects.

Also as predicted, older adults experienced more TOTs, but fewer persistent alternates and, in Study 1, less partial information. Taken together, the results of Studies 1 and 2 indicated that this basic age effect is attributable in part to an age-linked transmission deficit that may be related to the general slowing of mental operations.

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6 We computed correlation coefficients for vocabulary and Study 1 TOTs using only the 21 young and 21 older adults participating in Study 2. This sample showed the same result as the complete pool of Study 1 subjects, namely, no correlation.
that has been frequently observed in older adults (e.g., Salthouse, 1985). As manifest in everyday life, however, the effect of age on TOTs is also attributable in part to the fact that older adults, by virtue of their greater age, know and use more acquaintance names that are infrequent and nonrecently used, and are therefore more vulnerable to TOTs. We found no evidence that the TOTs of older adults reflect age-related declines in memory for new information. Rather, TOTs, like other speech errors, seem to reflect basic representational and processing characteristics of the language production system. This contrasts with other age-linked declines in language use, e.g., the comprehension of anaphor (Light & Capps, 1986; Light & Albertson, 1988) and complex syntax (Kemper, 1988), which seem to reflect age-linked changes in attention or episodic memory processes.

**Persistent Alternates**

Representational and processing characteristics of the NST also explain properties of persistent alternates. Our finding in Study 1 that subjects who report more alternates also report more partial information about the target is consistent with the NST because transmission of priming influences both of these variables. The overlap in target–alternate phonology reflects spread of priming to lexical nodes sharing phonology with the target word. The overlap in target–alternate syntactic class reflects activation by domain (syntactic class) so that repeated attempts to retrieve the TOT target can only yield alternates in that domain. These same mechanisms, interactive priming and activation by domain, are responsible for parallel effects in substitution speech errors where the intruded word resembles the intended word in syntactic class and phonology (Dell & Reich, 1981; Fay & Cutler, 1977).

Within the NST, alternates are a consequence, not a cause, of a transmission deficit producing a TOT state. Nonetheless, we predicted and found that alternates delayed resolution of TOT states. Within the model, once an alternate is activated its lexical node replaces the target's as most primed because activation causes a temporary increase in linkage strength.

Besides explaining many aspects of the present data, the NST suggests some interesting predictions for future test. An example concerns effects of persistent alternates on the resolution of experimentally induced TOTs. For subjects in the TOT state, presenting a word that is phonologically related and in a different domain (syntactic class) from the target will facilitate resolution under the NST, whereas a phonologically related word in the same domain as the target will delay resolution.

**The Effects of Proper Names on TOTs**

The prevalence of proper name TOTs for all age groups in Study 1 and the age-related increase in proper name TOTs in Studies 1 and 2 is consistent with the transmission deficit explanation of TOTs. To illustrate the basis for this claim, compare the semantic representation underlying a proper name, such as Baker, in Fig. 6a, with the semantic representation underlying the phonologically identical common noun for the occupation, baker, in Fig. 6b. The occupation noun is connected to a large number of nodes representing semantic information about bakers, such as "bake bread," "get up early," and "knead dough." The proper name Baker is connected to semantic information only via the lexical nodes for John Baker (and Mary Baker and other known individuals sharing the family name Baker). John Baker is connected to a large number of nodes representing information known about this particular person such as "good tennis player," "handsome," "sells computers." However, Baker (family proper name) is not likely to have a set of connections representing information about that name. For example, the only semantic proposition related to Baker (family proper name) that
any of the present authors were able to generate is "Baker is an old English name."

Note that Baker (proper noun) and baker (occupation noun) share the same phonological nodes for producing the two words, as illustrated by the identical syllable nodes in Figs. 6a and b. Also shown are nodes within the visual concept system for recognizing and imaging, in Fig. 6a, the person with the name John Baker and, in Fig. 6b, a particular person who is known to be a baker.

When an attempt is made to produce baker, for example, in meeting an acquaintance who is a baker and inquiring about his business, the large number of connections linking the visual concept node for the person directly and indirectly to the occupation noun (see Fig. 6b), provide summation of priming that will make activation of baker (occupation noun) and its connected phonological nodes likely. This summation of priming from semantic to lexical nodes makes common nouns such as baker (occupation noun) relatively invulnerable to transmission deficit and TOTs.

In contrast, when an attempt is made to greet an acquaintance named John Baker, no corresponding summation of priming occurs at the lexical node for Baker (family
proper name). A number of connections link the visual concept node for John Baker to the node for John Baker (proper noun phrase), but only a single (divergent) connection links the visual concept node to Baker (family proper name) via John Baker (see Fig. 6a). Because Baker and its connected phonological nodes receive no convergent connections, they remain highly vulnerable to transmission deficit and TOTs, even though the person is very familiar. Moreover, the difficulty in retrieving proper names will increase with age because transmission deficits increase with age.

Finally, the same summation of priming principle can explain why a new acquaintance’s name is more difficult to learn than their occupation (see McWeeny et al., 1987; Cohen & Paulkner, 1986). The occupation (e.g., baker) has a number of preexisting connections to semantic nodes that can also be connected with the visual concept nodes representing the appearance of the person. Thus, the occupation node and the visual concept node will be linked by a number of connections. However, it is unlikely that the proper name (e.g., Baker) will have preexisting semantic connections. Thus the appearance of the person results in less transmission of priming to Baker (proper name) than to baker (occupation noun).

The Semantic Priming Paradox

The transmission deficit account of age effects on TOTs is consistent with other age-related deficits in word production. For example, older adults are slower and less accurate than young adults in producing a familiar word corresponding to a definition (Bowles & Poon, 1985a) or a picture (Borod, Goodglass, & Kaplan, 1980; Mitchell, 1989; Nicholas, Obler, Albert, & Goodglass, 1985; Thomas, Fozard, & Waugh, 1977). Impaired access to phonological information contributes to these deficits because age differences are reduced in naming accuracy when phonological cues are provided (Nicholas et al., 1985), and in naming latency when an object’s name precedes its picture (Thomas et al., 1977).

Paradoxically, however, semantic priming as measured by facilitation of word recognition by a semantically related word or sentence seems to be spared in old age (Burke & Harrold, 1988; Howard, 1988). The NST explains this paradoxical age constancy for semantic priming tasks in terms of summation of priming. Doctor and nurse are connected through a large number of shared propositions or phrases such as “work in hospitals,” “wear white uniforms,” “give injections” (see also Jones, 1985) and activation of nurse facilitates activation of doctor because priming spreads and summates via these many shared connections. These convergent connections therefore provide the summation of priming that can mask or overcome an age-linked transmission deficit for older adults in semantic priming tasks. However, in production, priming cannot converge and summate onto phonological nodes: top-down priming always diverges from a single lexical node onto many phonological nodes (see, e.g., Fig. 1).

The Inhibition Hypothesis: Pro and Con

Evidence for the hypothesis that alternate words cause TOTs by blocking or inhibiting the target word is far from clear cut. In previous studies, a TOT-inducing question has been presented together with a prime word that is phonologically and/or semantically related to the target answer providing a source of inhibition for the target according to the Inhibition hypothesis. Although semantically related primes may increase the time required to produce the target word (e.g., Brown, 1979), this effect reflects task-specific strategies for using the prime word as a cue (Bowles & Poon, 1985b; Roediger, Neely, & Blaxton, 1983). Indeed, Bowles and Poon (1985b) found that orthographically similar primes improve both speed and accuracy of target retrieval, an effect that clearly reflects stra-
The strategic use of orthographic information as a clue to the target.

Bowles and Poon's (1985b) findings also suggest an alternative interpretation for Jones' result that phonologically similar primes increased the frequency of experimentally induced TOTs, a result initially viewed as support for the Inhibition hypothesis (Jones, 1989; Jones & Langford, 1987). Under the alternative interpretation, a phonologically similar prime provides partial access to the target word, resulting in "TOT" responses for questions that would normally receive a "Don't know" response. Data on "Don't know" responses required to test this interpretation have never been reported, but Maylor (1990a) replicated the increase in TOT responses with phonologically similar prime words and found no accompanying decrease in correctly answered questions. This result is puzzling if the prime blocks an otherwise available target, as postulated under the Inhibition hypothesis.

Aspects of the present results also challenge the Inhibition hypothesis. Most notably, alternates decreased with age in Studies 1 and 2, whereas TOT frequency increased or remained constant with age, depending on the type of target word. If alternates cause TOTs, then some additional mechanism must be postulated for explaining why TOTs do not also decrease with age. Further, this or another mechanism must explain why alternates decrease with age, an additional complication for the Inhibition hypothesis.

Alternates also do not accompany all TOTs. Perhaps the Inhibition hypothesis can explain the many alternate-free TOTs by postulating "unconscious alternates" with insufficient activation to be retrieved, but enough to inhibit the target. However, this unconscious alternate hypothesis fails to explain why TOTs increase with age whereas conscious alternates decrease with age. Thus, this pattern presents an intriguing challenge for models postulating lateral inhibition between words as the cause of TOTs. Only our finding that alternates increase resolution time fits the Inhibition hypothesis. As discussed above, this correlation also fits the NST, a model that does not postulate between-word inhibition.

APPENDIX: TOT-INDUCING QUESTIONS IN STUDY 2 WITH CORRECT ANSWER, FOILS FOR MULTIPLE CHOICE, AND NUMBER OF "TOT" RESPONSES GIVEN BY YOUNG AND OLDER ADULTS, RESPECTIVELY (IN PARENTHESES)

Non-object Noun Targets

1. What do you call a formal exercise by a team of marchers? Target: drill Foils: routine, revue, pattern (0.2)
2. What do you call a sharp and sudden pain in the side? Target: stitch Foils: cramp, twinge, pang (0.0)
3. What do you call a secret agreement or pact (as between lovers)? Target: tryst Foils: cartel, rendezvous, conspiracy (0.3)
4. What do you call a habitual spasmodic motion or twitching of particular muscles, especially in the face? Target: tic Foils: palsy, ague, tremor (1.2)
5. What do you call a moderately fast gait of a horse in which the legs move in diagonal pairs? Target: trot Foils: lope, gallop, pace (0.3)
6. What is the name of the unrhymed verse form of Japanese origin having three lines containing usually 5, 7, and 5 syllables? Target: haiku Foils: dactyl, tanka, villanelle (2.1)
7. What word means the form of something in the form of a spiral or coil? Target: helix Foils: cork, screw, cochlea, whorl (1.1)
8. What do you call a feeling of resentment, often at some fancied slight or insult? (usually follows the verb "take") Target: umbrage Foils: rancor, grudge, offense (2.3)
9. In which sport does a rider on horseback hit a ball with a mallet? Target: polo Foils: croquet, dressage, lacrosse (0.1)
10. What do you call stage entertainment consisting of various unrelated acts, such as magicians, acrobats, etc? Target: vaudeville Foils: revue, spectacle, cabaret (2.0)
11. What is the word meaning the promises from God to humans? Target: covenant Foils: oath, compact, concordia (3.1)
12. What is the proper name for a "tidal wave"? Target: tsunami Foils: cyclone, undulation, swell (0.3)
13. What do you call the three periods... used to indicate an omission or a pause? Target: ellipsis Foils: concision, elision, diacresis (1.1)
14. What do you call the purification or purgation of the emotions that is supposed to happen through art? Target: catharsis. Foils: hubris, climax, epuration (1.2)

15. What do you call a word or sentence that reads the same backward or forward, such as "Madam, I'm Adam"? Target: palindrome. Foils: inversion, retroversion, chiasmus (7.4)

16. What is the name of the process by which plants make their food? Target: photosynthesis. Foils: chloroplasts, phototaxis, mitochondria (3.4)

17. What do you call a solemn declaration made by a person who conscientiously declines taking an oath? Target: affirmation. Foils: testimony, assertion, affidavit (0.3)

18. What do you call a law that gives exclusive right of inheritance to the eldest son? Target: primogeniture. Foils: hegemony, patriarchy, propriety (5.1)

19. What is the name of the art of Japanese paper folding? Target: origami. Foils: tatami, paper, mat, chashitsu, kirigami (6.2)

20. What do you call a prolonged and usually abnormal inability to obtain adequate sleep? Target: insomnia. Foils: desuetoriness, hyperactivity, somnambulism (3.3)

Object Nouns

21. What do you call the leather band formerly used for sharpening an old-fashioned razor? Target: stop. Foils: buff, flannel, whetstone (1.0)

22. What is the name of the hardwood of an Asian Indian timber tree often used for furniture? Target: teak. Foils: maple, mahogany, bamboo (4.0)

23. What do you call a plant material such as straw used as a roofing material for a house? Target: thatch. Foils: gable, palm, cellulose (0.1)

24. What do you call a chain of rocks or coral at or near the surface of the water in an ocean? Target: reef. Foils: shelf, strand, archipelago (1.0)

25. What do you call the vessel, usually an ornamental vase on a pedestal, which is used to preserve the ashes of the dead? Target: urn. Foils: amphora, ewer, flagon (4.2)

26. What do you call the weapon used by the Indians and gauchos of South America to entangle the legs of cattle and other animals? Target: bola. Foils: grapple, lasso, sling (3.1)

27. What do you call the accumulation of earth and stones carried and finally deposited by a glacier? Target: moraine. Foils: aluvium, geest, steppe (3.2)

28. What is the navigation instrument used at sea to plot position by the stars? Target: sextant. Foils: pinnacle, compass, astrolabe (8.3)

29. What is the name of the nylon fabric which has two pieces which stick to each other and is used as a fastener? Target: velcro. Foils: cambria, latchet, tape (2.7)

30. What is the name of the migratory grasshopper that travels in vast swarms and strips areas passed of all vegetation? Target: locust. Foils: katydid, cicada, cricket (3.1)

31. What is the name for a mixture of dried spices and flowers used for perfuming a room? Target: potpourri. Foils: sachet, nosegay, pomander (3.5)

32. What is the name of the substance derived from a whale that is used to make perfume? Target: ambergris. Foils: bitumen, myrrh, blubber (1.4)

33. What do you call an instrument for performing calculations by sliding beads along rods or grooves? Target: abacus. Foils: quipu, slide rule, logometer (3.3)

34. What is the name of the Egyptian plant that is cut into strips and pressed into a material to write on? Target: papyrus. Foils: parchment, lotus, vellum (3.0)

35. What do you call a savory sauce in which meat, fish, or a vegetable is soaked before cooking to enhance the flavor? Target: marinade. Foils: baste, gravy, garnish (3.3)

36. What do you call a member of a volunteer group organized to suppress and punish crime (as when legal processes seem inadequate)? Target: vigilante. Foils: posse, lynch, extra-judiciary (2.3)

37. What are people who make maps called? Target: cartographers. Foils: drafters, ichonographers, limners (1.4)

38. What do you call a person who collects and studies stamps? Target: philatelist. Foils: paleontologist, bellotrist, numismatist (2.3)

39. What do you call a stone building (often found in a cemetery) with places for entombment of the dead above ground? Target: mausoleum. Foils: catacomb, mortuary, sepulcher (6.2)

40. What is the order of lower mammals including kangaroos and oppossums which carry their young in an abdominal pouch? Target: marsupials. Foils: rodents, marsupials, bandicoots (3.2)

Adjectives and Verbs

41. What word denotes the series of units of weight used to measure gold, in which a pound equals twelve ounces? Target: troy. Foils: depot, trent, imperial (9.3)

42. What word means to cut or chop (food) into very small pieces? Target: mince. Foils: grate, dice, grind (1.2)

43. What word means to raise into position by means of a pulley? Target: hoist. Foils: heighten, haul up, winch (0.0)

44. What word means to deposit (something valuable) as a security for money borrowed? Target: pawn. Foils: hock, pledge, lease (5.5)

45. What word means to shed hair, feathers, or an
outer layer periodically, as with the changing seasons? Target: molt Foils: doff, new, cast (1,3)
46. What word means to trade by exchanging goods for other goods rather than money? Target: barter Foils: swap, bargain, exchange (2,1)
47. What word means relating to or situated on the back, especially of an animal? Target: dorsal Foils: posterior, ventral, lumbar (2,1)
48. What is the name of the severe headache that returns periodically and often is accompanied by nausea? Target: migraine Foils: neuralgia, malaise, colic (2,1)
49. What word means to observe and offer unwanted advice or comment, especially at a card game? Target: kibitz Foils: heckle, pester, meddle (3,1)
50. What word means having a healthy reddish color? Target: rosy Foils: fair, flush, rosy (2,4)
51. What do you call the position of the arms when the hands are on the hips and the elbows are out? Target: akimbo Foils: Sifurcate, bent, splayed (0,9)
52. What is the word that means to cause to explode or to set off, for example: a bomb? Target: detonate Foils: ignite, blast, explode (2,3)
53. What word means to formally renounce a throne? Target: abdicate Foils: abrogate, resign, relinquish (3,3)
54. What word means to bleed heavily or uncontrollably? Target: hemorrhage Foils: effuse, gush, discharge (4,1)
55. What word means to voluntarily sacrifice (e.g., cargo) in order to lighten a ship or aircraft’s load in time of distress? Target: jettison Foils: discard, eject, expel (0,6)
56. What do you call a question that is asked for effect with no answer expected? Target: rhetorical Foils: oratorical, figurative, declamatory (2,0)
57. What is the musical term that means “without instrumental accompaniment”? Target: a cappella Foils: cantata, allegro, lyric (1,4)
58. What word means to divide an area into electoral districts in order to give special advantage to one political party? Target: gerrymander Foils: rack and ruin, wrangle, swindle (4,3)
59. What do you call a verb that does not take a direct object? Target: intransitive Foils: inflected, participial, declined (3,3)
60. What word means lasting only a very brief time? Target: ephemeral Foils: transient, ethereal, temporal (1,3)

Place Names

61. What is the national park in Utah, northeast of Zion, which is famous for the rock formations in its canyon? Target: Bryce Foils: Canyons, Arches, Chaco (6,3)
cities of birds and animals? Target: Galapagos
Foils: Colon, Canary, Madagascar (4,3)

Famous People

81. What is the last name of the current mayor of New York City? Target: Koch Foils: Moynihan, Bradley, Cuomo (2,1)
82. What is the last name of the author of Jonathon Livingston Seagull? Target: Bach Foils: De Vries, Richards, Imoja (2,3)
83. What is the last name of the man who said, "I only regret that I have but one life to lose for my country?" Target: Hail Foils: Henry, Paine, Jackson (2,7)
84. What is the original last name of the boxer who later became known as Mohammed Ali? Target: Clay Foils: Browning, Reid, Jeffers (0,5)
85. What is the last name of the actor who played Perry Mason on TV? Target: Burr Foils: Grant, Cooper, Hankins (2,5)
86. What is the last name of the actor who starred in both the Broadway production and the film, "A Streetcar Named Desire?" Target: Brando Foils: Garfield, Williams, Grant (1,2)
87. What was the last name of Lucille Ball’s first husband, who starred with her on "I Love Lucy"? Target: Arnaz Foils: Morton, Hunt, Anderson (1,1)
88. What is the last name of the actress who played Gloria on TV’s "All in the Family"? Target: Struthers Foils: Field, Stapleton, Sommers (4,5)
89. What is the last name of the actor who starred in "Hart to Hart" and "Switch" on TV, and also in many movies? Target: Wagner Foils: Moore, Chamberlain, Carson (6,1)
90. What is the last name of the movie critic who has co-hosted a number of film-review TV shows with Roger Ebert? Target: Siskel Foils: Rea soner, Stanley, Kremer (2,3)
91. What is the last name of the author of Little Women? Target: Alcott Foils: Sewell, Phillips, Brink (1,5)
92. Who is the man who assassinated Robert Kennedy? Target: Sirhan Foils: Os wald, Nagara, Cimino (3,10)
93. What is the last name of the woman who wrote Gone With the Wind? Target: Mitchell Foils: Meyers, Seaver, Gaskell (3,3)
94. What is the last name of the actor who played the scarecrow in the movie, "The Wizard of Oz?" Target: Bolge Foils: Baum, Chamey, Carpenter (3,4)
95. What is the last name of the Cuban leader that Castro overthrew? Target: Batista Foils: Franco, Sandino, M, inez (1,8)
96. What is the last name of the cosmonaut who was the first person to orbit the earth? Target: Gagarin Foils: Ivanov, Patrovski, Solokov (2,4)

97. What is the name of the man who removed the thorn from the lion’s paw in the story from Aesop’s fables? Target: Androcles Foils: Tele mchus, Aegiphys, Theseus (1,2)
98. What is the last name of the candidate who ran as an independent against Reagan and Carter in 1980? Target: Anderson Foils: Johnson, Greer, Fuller (2,5)
99. What is the last name of the Romanian gymnast who scored 7 perfect “10’s” and won 3 gold medals in the 1976 Olympics? Target: Comaneci Foils: Rigby, Karolyi, Korbut (1,6)
100. What is the last name of 1980 Olympic hopeful Randy Gardner’s ice skating partner? Target: Babilonia Foils: Hamill, Summers, Torvill (1,1)

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