The Effect of Inhibition on the Tip-of-the-Tongue Phenomenon in Older Adults: Postprint

Authors: Peng Huamao, Mao Xiaofei

Date: 2018-09-07T00:00:00+00:00

Abstract

The inhibition deficit theory posits that older adults have insufficient inhibitory ability, rendering them susceptible to interfering information that hinders retrieval of target words and leads to more frequent tip-of-the-tongue (TOT) phenomena than younger adults. Experiment 1 manipulated the inhibitory access sub-function to investigate its role in TOT phenomena among older adults, employing a 2 (interference condition: present, absent) × 2 (age group: older, younger) mixed design. Compared to the no-interference condition, the age difference in TOT phenomena was exacerbated under interference conditions, indicating that TOT phenomena in older adults are related to access function. Experiment 2 manipulated the inhibitory deletion sub-function, employing a 2 (whether interference is activated: yes, no) × 2 (age group: older, younger) mixed design. The age difference in TOT phenomena was not significant when interference was not activated, but became significant when interference was activated; the age-related increase in TOT phenomena is associated with insufficient deletion function. Insufficient access and deletion functions are important contributors to the increase in TOT phenomena among older adults.

Full Text

The Influence of Inhibition on Tip-of-the-Tongue Phenomenon in Older Adults

PENG Huamao[1]**; MAO Xiaofei**[2]**,**[1] [1] Institute of Developmental Psychology, Beijing Normal University, Beijing 100875, China
[2] Department of Psychology, The Second Military Medical University, Shanghai 200433, China

Abstract

The inhibition deficit theory posits that older adults' insufficient inhibitory capacity makes them more susceptible to interference, which hinders target word retrieval and results in more frequent tip-of-the-tongue (TOT) experiences compared to younger adults. Experiment 1 examined the role of the access subfunction of inhibition in older adults' TOT phenomenon using a 2 (interference condition: present vs. absent) × 2 (age group: older vs. younger) mixed design. The age difference in TOT rates became significantly larger under interference compared to the no-interference condition, indicating that TOT in older adults is related to access function. Experiment 2 manipulated the deletion sub-function of inhibition using a 2 (interference activation: yes vs. no) × 2 (age group: older vs. younger) mixed design. No significant age difference in TOT emerged when interference was not activated, whereas a significant age difference appeared when interference was activated, suggesting that age-related increases in TOT are associated with deletion function deficits. Deficits in both access and deletion functions constitute important factors underlying the increased prevalence of TOT among older adults.

Keywords: tip-of-the-tongue; older adults; inhibition; access; deletion
Classification Code: B844

The tip-of-the-tongue (TOT) phenomenon represents the most salient form of word retrieval difficulty, referring to a state where a speaker temporarily cannot retrieve a specific word yet feels certain they know its meaning, creating a sensation of the word being on the verge of articulation (Brown & McNeill, 1966). Both naturalistic observations and laboratory studies have demonstrated that TOT episodes increase with age (Burke, MacKay, Wothley, & Wade, 1991; Rastle & Burke, 1996). Moreover, TOT is not only an unavoidable and embarrassing speech production impediment (Gollan & Brown, 2006) but also the most frequently reported memory difficulty among the 28 memory problems identified by older adults (Sunderland, Watts, Baddeley, & Harris, 1986). TOT experiences cause greater difficulties in verbal expression for older adults and increase their sense of frustration in social interactions. Therefore, investigating the aging mechanisms underlying TOT is of great significance for improving communication quality among older adults.

Brown and McNeill (1966) pioneered experimental research on TOT by employing a low-frequency word method, presenting participants with word definitions and requiring them to retrieve the corresponding target words. For example, participants would see "An ornamental stoppered glass vessel used for serving wine" with the target word being "Decanter." TOT was identified when participants could not produce the answer but were certain they knew the target word.

The inhibition deficit theory proposes that when individuals activate target words through semantic cues, related interference words disrupt retrieval and extraction processes, activating incorrect lexical information associated with the

target word. Under conditions of insufficient inhibitory function, this can cause retrieval pathways to deviate, ultimately leading to more TOT episodes (Woodworth, 1938). This theory has received support from numerous researchers (Anderson & Bjork, 1994; Brown, 1991; Reason & Lucas, 1984; Schacter, 1999). Jones et al. (1987, 1989) found that interference words first activate information related to target words and further activate recently processed interference words, disrupting target word retrieval and causing more TOT episodes. If participants could suppress these interference effects, TOT might not increase. Choi and Smith (2005) argued that if TOT results from blocking effects—that is, interference words obstructing retrieval of correct answers—then delaying the TOT question should allow participants to overcome interference and resolve the retrieval failure. Their results showed that delayed retesting yielded twice the resolution rate of immediate retesting. Reason and Lucas (1984) used diary methods to study TOT and found that 59% of TOT episodes were accompanied by at least one interference word. In daily life, particularly with proper names (e.g., people' s names, place names), interference words can involuntarily and repeatedly become active in the mind, hindering target word retrieval (Burke et al., 1991; Cohen & Faulkner, 1986).

Hasher and Zacks (1988) and Zacks and Hasher (1994, 1997) proposed that inhibitory function declines with age in older adults, who activate more irrelevant information than younger adults and have difficulty suppressing its influence on current tasks. Inhibition comprises three sub-functions: limiting access to irrelevant information (access), deleting information no longer relevant from the focus of attention (deletion), and restraining the production of dominant responses (restrain) (Lustig, Hasher, & Zacks, 2007). During target word retrieval, failure to effectively prevent irrelevant information from entering the focus of attention, delete stimuli no longer relevant to the current task, or restrain strong dominant responses can lead to interference activation and maintenance, thereby blocking target word retrieval and producing TOT episodes.

Both cross-sectional and laboratory studies have demonstrated close relationships between inhibition and language aging. Borella, Ghisletta, and De Ribaupierre (2011) used structural equation modeling to confirm that inhibitory ability influences age differences in text processing performance through working memory capacity. Additionally, Arbuckle and Gold (1993) found that older adults'performance on tasks reflecting deletion function (verbal fluency test, Wisconsin Card Sorting Task) and restraint function (Trailmaking Test) correlated significantly with off-topic verbosity levels. Pushkar et al. (2000) obtained similar results, finding that test performance reflecting access (verbal fluency test) and restraint functions (Stroop test) were closely related to off-topic verbosity. Laboratory studies have further confirmed these conclusions. Chen, Zhang, and Zhu (2015) found that in Chinese sentence construction tasks, older adults performed significantly worse than younger adults when required to inhibit role information, suggesting that insufficient inhibitory function constitutes an important cause of deteriorating language task performance in older adults. Yin and Peng (2016) explored the role of inhibitory sub-functions in age-related

off-topic verbosity and found that off-topic verbosity in aging was closely related to age-related declines in deletion and restraint functions. Ayasse and Wingfield (2017) found that more competing information led to poorer sentence comprehension task performance. Cohen and Gordon-Salant (2017) found that greater irrelevant audiovisual interference resulted in poorer speech recognition performance in older adults. These findings indicate that aging in language production and comprehension abilities (text comprehension, sentence understanding, speech recognition, off-topic verbosity, sentence construction tasks) is closely related to inhibitory function.

Brain function research also suggests a relationship between inhibition and TOT aging. Shafto and Tyler (2014) noted that TOT aging is associated with brain function decline. When naming pictures of faces, older adults showed activation in brain regions such as the inferior frontal gyrus and right middle frontal gyrus during TOT episodes compared to successful naming (Shafto, Stamatakis, Tam, & Tyler, 2010). Inhibitory function is believed to be closely related to the right frontal cortex (Aron, Robbins, & Poldrack, 2004), and when inhibitory function is insufficient, activation in frontal cortex regions increases (Dempster, 1992; Hartley, 1993; Arbuckle & Gold, 1993). This suggests that increased TOT episodes in older adults are related to insufficient inhibitory function.

Cross and Burke (2004) noted that the effect of insufficient inhibition is more pronounced in older adults' TOT experiences, with inhibition potentially operating through two processes: first, the widespread "spreading" of interference words in the semantic system, activating interference words related to target words; and second, older adults' difficulty in effectively controlling activated interference information from entering conscious awareness, causing interference information to repeatedly appear in the mind. This suggests that inhibition may function during the semantic system activation stage, and if participants can suppress interference word effects during semantic activation, TOT episodes may decrease.

Analysis of existing research reveals that most studies on inhibition and language aging have focused on analyzing correlations between inhibitory test performance and older adults' language performance, preventing causal inferences and failing to clarify inhibition' s specific role in language aging. Laboratory studies have rarely manipulated inhibitory sub-functions, leaving their respective influences on language aging unknown. TOT represents the most frequently occurring language expression difficulty among older adults (Ryan, Meneer, & Trovato, 1994) and has very detrimental effects on their daily verbal communication. However, current TOT research has not manipulated inhibitory sub-functions, making causal inference difficult. Therefore, the specific mechanisms through which inhibitory function operates in older adults' TOT require urgent clarification.

This study investigates the specific role of inhibitory sub-functions in older adults'TOT through experimental manipulation, which will not only help clarify the causal relationship between inhibition and TOT aging and understand the

psychological mechanisms underlying TOT aging but also provide a basis for improving TOT experiences and quality of life among older adults. Furthermore, confirming the specific roles of inhibitory sub-functions in older adults' TOT is important for clarifying the mechanisms of language function aging. Since the restraint sub-function refers to suppressing strong dominant responses from within the individual and is difficult to manipulate experimentally, this study only examines the influence of access and deletion sub-functions on older adults' TOT. This research uses laboratory methods to test two hypotheses:

If older adults experience more TOT episodes due to access sub-function deficits, then older adults should show more TOT than younger adults under conditions requiring high access function. If older adults experience more TOT episodes due to deletion sub-function deficits, then older adults should show more TOT than younger adults under conditions requiring high deletion function.

Experiment 1: The Role of Access Function in Older Adults' TOT

Participants

Thirty younger adults aged 18–33 years (10 males) were recruited in Beijing, with a mean age of 22.73 $\pm$ 2.89 years, mean education of 16.27 $\pm$ 1.74 years, and vocabulary test scores of 18.17 $\pm$ 2.07. Thirty older adults aged 60–79 years (9 males) were recruited from Beijing communities, with a mean age of 68.17 $\pm$ 5.63 years, mean education of 14.63 $\pm$ 2.16 years, and vocabulary test scores of 17.43 $\pm$ 2.01. All participants were native Chinese speakers with normal (corrected) vision and no history of brain disease or cognitive impairment. Younger adults had significantly higher education levels than older adults, $t(58) = 3.23$, $p < 0.01$, but vocabulary test scores showed no significant age difference, $t(58) = 1.39$, $p > 0.05$.

Experimental Design

Following Brown and McNeill' s (1966) TOT experimental task, we employed a 2 (interference condition: present vs. absent) $\times$ 2 (age group: older vs. younger) mixed design, with interference condition as a within-subjects variable and age group as a between-subjects variable. The dependent variable was TOT rate, calculated as the number of TOT episodes divided by the total number of questions. In the interference condition, participants were presented with a TOT-inducing question simultaneously with an interference stimulus [Figure 1: see original paper] and were instructed to ignore the interference stimulus as much as possible. This required participants to prevent the interference stimulus from entering the focus of attention, reflecting access function. The no-interference condition presented only the TOT-inducing question. If older adults' TOT is related to access function deficits, older adults should be more susceptible to interference stimuli and exhibit more TOT episodes, with the age difference in

TOT rates being significantly larger in the interference condition than in the no-interference condition.

Materials and Measures

TOT Task. TOT-inducing questions were presented via computer. After reading each question, participants who knew the answer spoke it aloud (target word); those who did not know the answer reported "don' t know" ; those experiencing TOT reported "TOT." Participants proceeded to the next question after completing each item. There was no time limit for each question, and participants controlled their own response pace. They were instructed to respond truthfully without guessing or repeated deliberation. TOT was operationally defined as temporarily being unable to produce the answer while feeling certain that one knew it, with the sensation that the answer was on the tip of the tongue. TOT rate was calculated as the number of TOT episodes divided by the total number of questions.

Task Materials. Since previous research primarily used Western participants, the questions were too unfamiliar for Chinese participants and difficult to use to induce TOT. Therefore, it was necessary to develop experimental materials suitable for Chinese participants.

We recruited 26 younger and 18 older adults for a pilot study. Referencing general knowledge questions used by Nelson and Narens (1980), Schwartz (2010), and Zhang (2013), we developed 300 questions, such as "Who was the founding emperor of the Song Dynasty? (Zhao Kuangyin)," covering categories including history, geography, and general life knowledge.

Questions were presented in questionnaire format, and participants rated their knowledge of each answer: 1 = knew the answer and could state it accurately, 2 = did not know the answer, 3 = currently experiencing TOT. Based on responses, we eliminated questions that completely failed to induce TOT (i.e., questions where participants either always knew the answer or always did not know it), leaving 170 questions with a TOT induction rate of 0.1697 ± 0.094. These 170 questions were randomly divided into two sets for the interference and no-interference conditions, with TOT induction rates of 0.1698 ± 0.094 and 0.1695 ± 0.093, respectively, showing no significant difference, $t(84) = 0.02$, $p > 0.05$.

Interference Stimuli. Older adults may have difficulty inhibiting interference from semantically related stimuli, contributing to TOT aging. Therefore, we obtained interference stimuli with semantic similarity to target words through pilot testing. Semantic relatedness refers to the degree of shared semantic features between two concepts (Fang & Zhang, 2013). The more shared semantic features, the higher the relatedness. For example, "cat" and "dog" share higher semantic relatedness than "cat" and "ant," though all three belong to the "animal" category. Three graduate students in psychology collaboratively designed three sets of incorrect interference stimuli with semantic relatedness. Each TOT-

inducing question had three incorrect semantically related interference stimuli (e.g., for "Which Chinese city is famous for hot dry noodles? Answer: Wuhan," interference stimuli were Changsha, Nanchang, and Macau). Fifteen younger adults rated the semantic relatedness between each of the three interference stimuli and the correct answer on a 1–7 scale (1 = low relatedness, 7 = high relatedness). Ratings ranged from 1.13 to 6.40, with a mean of 3.57 ± 1.27. Fang and Zhang (2013) found that interference words with high semantic relatedness facilitated target word retrieval, but interference words with too low relatedness had no interfering effect. Therefore, we selected interference stimuli with moderate semantic relatedness (mean rating = 3.85). Additionally, a t-test on word frequency between answers (0.008 ± 0.014) and interference words (0.023 ± 0.074) showed no significant difference, t(85) = -1.79, p = 0.075 > 0.05, indicating equivalent familiarity between answers and interference words.

Education level and vocabulary comprehension ability are considered possible factors influencing age differences in TOT (Dahlgren, 1998; Cross & Burke, 2004). Therefore, subsequent data analyses should control for education level and vocabulary comprehension ability as covariates.

Vocabulary Test. We used the vocabulary subtest from the Chinese version of the Wechsler Adult Intelligence Scale (Gong, 1992) to assess vocabulary comprehension ability. Ten words were randomly selected from the vocabulary subtest, and participants were asked to explain the meaning of each word. Each word received a score of 0–2, with total scores ranging from 0–20, where higher scores indicated better vocabulary comprehension ability.

Procedure

Participants first completed a demographic form (name, age, gender, education level, etc.) and then took the vocabulary comprehension test before proceeding to the experimental task.

The order of interference and no-interference conditions was counterbalanced across participants. The experimental task was presented on a computer (screen resolution: 1024$×$768) in 60-point Song font. In the interference condition, an italicized interference word appeared randomly above or below the TOT-inducing question (Samanez-Larkin et al., 2009; Gao, 2013). Each condition began with two practice questions to ensure participants understood the rules.

Instructions for the no-interference condition were: "Please read each question carefully and answer (do not guess). If you definitely know the answer, please say it aloud. If you feel you know the answer but cannot say it or can only say part of it, please report 'TOT.' If you completely do not know the answer, please report 'don' t know.' " The interference condition added: "When the question is presented, an italicized word will appear on the screen. The less you pay attention to it, the better your performance."

Results

Background Variables Analysis Correlation analysis revealed that only education level correlated significantly with TOT rates in both experimental conditions (r_{interference} = -0.262, $p < 0.05$; r_{no}-interference = -0.291, $p < 0.05$). Therefore, only education level was included as a covariate in subsequent analyses.

Manipulation Check If interference words produced interfering effects, questions that participants originally knew should show higher error rates, with a higher proportion of incorrect answers reported in the interference condition than in the no-interference condition. A t-test on the proportion of incorrect answers reported for known items revealed that the error rate in the interference condition (0.27 ± 0.16) was significantly higher than in the no-interference condition (0.19 ± 0.10), $t(59) = 6.37$, $p < 0.001$, indicating that interference stimuli produced interfering effects.

The Role of Access Function in Older Adults' TOT TOT rates for different age groups are presented in Table 1 and Figure 2 [Figure 2: see original paper]. A 2×2 repeated-measures ANOVA was conducted with education level as a covariate, age and interference condition as independent variables, and TOT rate as the dependent variable. Results showed that the covariate effect was not significant, $F(1,57) = 0.08$, $p > 0.05$; the main effect of interference condition was not significant, $F(1,57) = 0.06$, $p > 0.05$; the main effect of age was significant, $F(1,57) = 11.90$, $p = 0.001$, $p^2 = 0.173$; and the interaction was significant, $F(1,57) = 5.91$, $p < 0.05$, $p^2 = 0.094$.

Simple effects analysis revealed significant age differences in both the interference condition ($F(1,57) = 16.29$, $p < 0.001$, $p^2 = 0.222$) and the no-interference condition ($F(1,57) = 5.12$, $p < 0.05$, $p^2 = 0.082$), with older adults showing higher TOT rates than younger adults in both conditions, and the age difference being larger in the interference condition. Furthermore, older adults showed significantly higher TOT rates in the interference condition than in the no-interference condition, $F(1,58) = 23.49$, $p < 0.001$, $p^2 = 0.288$, whereas younger adults showed no significant difference, $F(1,58) = 1.56$, $p > 0.05$. Comparing the differences in TOT rates between the two conditions for both groups (interference condition: 0.090 ± 0.097; no-interference condition: 0.053 ± 0.098), a t-test revealed that the age difference in TOT rates was significantly larger in the interference condition than in the no-interference condition, $t(58) = 2.40$, $p < 0.05$.

Experiment 2: The Role of Deletion Function in Older Adults' TOT

Participants

Thirty younger adults aged 19–27 years (11 males) were recruited in Beijing, with a mean age of 22.47 ± 1.94 years, mean education of 16.07 ± 1.29 years, and vocabulary test scores of 18.67 ± 1.69. Thirty older adults aged 61–78 years (9 males) were recruited from Beijing communities, with a mean age of 68.93 ± 5.42 years, mean education of 14.20 ± 2.40 years, and vocabulary test scores of 15.70 ± 3.50. Experiment 2 used newly recruited participants, all native Chinese speakers with normal (corrected) vision and no history of brain disease or cognitive impairment. Both education level ($t(58) = 3.76$, $p < 0.001$) and vocabulary test scores ($t(58) = 4.19$, $p < 0.001$) showed significant age differences between the two groups.

Experimental Design

A 2 (interference activation: yes vs. no) × 2 (age group: older vs. younger) mixed design was employed, with interference activation as a within-subjects variable and age group as a between-subjects variable, and TOT rate as the dependent variable.

Because deletion function was being investigated, participants needed to first activate interference information in their minds. In the interference activation condition, participants studied interference information before performing the TOT task, using the interference materials from Experiment 1 as interference information. In the no-activation condition, participants proceeded directly to the TOT task.

In the interference activation condition, participants needed to delete activated interference information from the focus of attention to perform the TOT task well, requiring good deletion function. If older adults experience TOT due to deletion function deficits, then the age difference in TOT rates should be significantly larger in the interference activation condition than in the no-activation condition.

Procedure

Participants completed a demographic form (name, age, gender, education level, etc.) and then took the vocabulary comprehension test before proceeding to the experimental task.

The order of experimental conditions was counterbalanced across participants. The no-activation condition followed the same procedure as the no-interference condition in Experiment 1. In the interference activation condition, participants first studied 85 interference words before the TOT task. To ensure participants processed the interference stimuli carefully, the experimenter informed them in

advance that a recognition test would follow the study phase. Each condition began with two practice questions to ensure participants understood the rules.

During the interference information learning task, interference words were presented on a computer for 2 seconds each. After studying, participants completed a 30-item number comparison task. For the recognition test, 30 words were randomly selected from the 85 interference words, and participants made recognition judgments about whether they had studied each word. If recognition performance was significantly above chance level, it indicated that participants had studied the interference words. Recognition rate was calculated as the number of correct judgments divided by the total number (Huang et al., 2014).

Results

Background Variables Analysis Correlation analysis revealed that neither education level nor vocabulary test scores correlated significantly with TOT rates, so no covariates were included in subsequent analyses.

Manipulation Check A t-test on participants' recognition rates showed that the younger group had a recognition rate of 0.79 ± 0.14, significantly above chance, $t(29) = 11.54$, $p < 0.001$, while the older group had a recognition rate of 0.64 ± 0.19, also significantly above chance, $t(29) = 4.02$, $p < 0.001$. The younger group' s recognition rate was significantly higher than the older group' s, $t(58) = 3.63$, $p < 0.01$, indicating that both groups studied the interference stimuli carefully. A t-test on the proportion of incorrect answers reported for "known" items across the two conditions revealed that the error rate in the interference activation condition (0.30 ± 0.15) was significantly higher than in the no-activation condition (0.23 ± 0.15), $t(59) = 5.98$, $p < 0.001$, indicating that the experimental manipulation effectively activated more interference information.

The Role of Deletion Function in Older Adults' TOT TOT rates for older and younger adults are presented in Table 1 and Figure 2. A 2×2 repeated-measures ANOVA was conducted with TOT rate as the dependent variable and age and interference activation as independent variables. Results showed that the main effect of interference activation was significant, $F(1,58) = 4.41$, $p < 0.05$, $p^2 = 0.071$; the main effect of age was significant, $F(1,58) = 4.43$, $p < 0.05$, $p^2 = 0.071$; and the interaction was significant, $F(1,58) = 5.32$, $p < 0.05$, $p^2 = 0.084$.

Simple effects analysis revealed a significant age difference in the interference activation condition, $F(1,58) = 6.70$, $p < 0.05$, $p^2 = 0.104$, with older adults showing higher TOT rates than younger adults. No significant age difference emerged in the no-activation condition, $F(1,58) = 1.33$, $p > 0.05$. This confirmed our hypothesis that activating interference increased the age difference in TOT rates, making it significantly larger than in the no-activation condition.

Additionally, older adults showed significantly higher TOT rates in the interference activation condition than in the no-activation condition, $F(1,58) = 9.71$, $p < 0.01$, $p^2 = 0.143$, whereas younger adults showed no significant difference, $F(1,58) = 0.02$, $p > 0.05$.

General Discussion

This study used two experiments to investigate the roles of inhibitory subfunctions (access and deletion) in older adults' TOT, supporting the inhibition deficit theory and further expanding its content. The inhibition deficit theory proposes that when individuals activate target words through semantic cues, related interference words disrupt retrieval, causing retrieval pathway deviations that ultimately lead to more TOT episodes. However, it does not elaborate on the possible sources of interference words or how they cause retrieval pathway deviations. Our study demonstrates that interference words originate from both internal and external sources. Older adults with poor inhibitory function may have their focus of attention occupied by external interference information, preventing target word extraction (i.e., weak access function), or they may be unable to shift attention away from previously activated information, leading to target word retrieval failure (i.e., weak deletion function).

In Experiment 1, under natural no-interference conditions, younger and older adults' TOT rates were 7.9% and 13.3%, respectively, consistent with previous reports. For example, Choi and Smith (2005) and James and Burke (2000) found TOT rates of 8% and 7.9% in younger adults using general knowledge questions, while Cross and Burke (2004) found an 8.1% TOT rate in younger adults using picture naming. James and Burke (2000) found a 13.8% TOT rate in older adults. These findings indicate that our TOT task materials were appropriately selected.

Experiment 1 investigated the role of access function in older adults' TOT. In the interference condition, participants needed to prevent interference words from entering the focus of attention. Older adults' access function deficits made it difficult to inhibit interference effects, resulting in more TOT episodes.

Experiment 1 results showed significant age differences in TOT rates under both experimental conditions, with older adults showing significantly higher TOT rates in the interference condition than in the no-interference condition, whereas younger adults showed no significant difference. Moreover, older adults had higher TOT rates than younger adults in both conditions. Comparing the differences in TOT rates between the two conditions for both groups revealed that the change in the older group was significantly larger than in the younger group, indicating that interference had a greater impact on older adults' TOT. These results collectively demonstrate that interference caused older adults to experience more TOT episodes, while younger adults' TOT was unaffected by the experimental manipulation, supporting our hypothesis and suggesting that access function deficits constitute an important factor in age-related TOT in-

creases. Research indicates that TOT episodes are caused by blocking from the first related word information that comes to mind (Jones, 1989; Jones & Langford, 1987; Reason & Lucas, 1984; Roediger, 1974; Brown, 1991). Meyer and Bock (1992) presented semantically related words while participants answered questions and found that semantically related words caused more TOT episodes than other words, suggesting that semantically related words may be important factors interfering with target word access. In Experiment 1's interference condition, participants needed to prevent italicized interference words from entering the focus of attention. Younger adults, with intact access function, could effectively prevent interference words from entering the focus of attention, whereas older adults, due to access function deficits, had difficulty inhibiting interference effects, resulting in higher TOT rates.

Yin and Peng (2016) found that access function was unrelated to increased off-topic verbosity in older adults, which is inconsistent with our results. This discrepancy may be related to differences between TOT and off-topic verbosity. Off-topic verbosity may be influenced by activated interference information, with individuals producing excessive speech, difficulty focusing on the current topic, and lack of logical coherence—functions regulated by restraint and deletion functions. Additionally, Yin et al. may have used tasks with relatively low difficulty that did not place high demands on older adults' access abilities, resulting in no effect of access function on off-topic verbosity. In contrast, TOT involves insufficient language expression ability and may be simultaneously influenced by access and inhibition functions. Our manipulation check in Experiment 1 showed that interference stimuli produced interfering effects, and the task placed high demands on access function, yielding different results from Yin et al.

In summary, older adults' access function deficits lead to more TOT episodes, supporting the inhibition deficit theory of TOT.

Experiment 2 examined the role of deletion function in older adults' TOT. In the interference activation condition, participants needed to delete previously activated information from the focus of attention to perform the TOT task well. Researchers have suggested that older adults' deletion function deficits make it difficult to delete irrelevant information activated during retrieval, easily causing current retrieval tasks to deviate from the correct direction and producing more TOT episodes (Abrams, Trunk, & Merrill, 2007). Analysis of participants' performance revealed significant age differences in the interference activation condition, with older adults showing higher TOT rates than younger adults, whereas no significant age difference emerged in the no-activation condition. Furthermore, older adults showed significantly higher TOT rates in the interference activation condition than in the no-activation condition, while younger adults showed no significant difference, indicating that activating interference caused older adults to experience more TOT episodes, while younger adults' TOT was unaffected by the experimental manipulation. This confirmed our hypothesis that activating interference increased the age difference in TOT rates, making

it significantly larger than in the no-activation condition.

The manipulation check revealed that the younger group' s recognition rate was significantly higher than the older group' s, which could be interpreted as differences in learning depth or memory effectiveness. This may be related to the older group's poorer memory function. The depth of learning interference words directly relates to the degree of activation of interference information in the mind—the deeper the learning, the greater the interfering effect of interference words during the TOT task. The older group' s poorer learning of interference words should have resulted in less activated interference information than the younger group. If older adults' deletion function were as good as younger adults' , older adults should have shown fewer TOT episodes. However, results showed that younger adults had significantly lower TOT rates than older adults in the interference activation condition. The fact that older adults still experienced more TOT episodes despite poorer learning of interference words suggests that older adults' deletion function is indeed worse than younger adults' , providing indirect evidence that deletion function deficits constitute an important factor in age-related TOT increases.

Why did TOT not show age differences in the no-activation condition? We compared TOT rates from Experiment 2 (no-activation condition) and Experiment 1 (no-interference condition) and found no significant difference in older adults' TOT rates between the two studies ($t(58) = 0.38$, $p > 0.05$, 0.140 vs. 0.133), whereas younger adults' TOT rates differed significantly ($t(58) = 2.62$, $p < 0.05$, 0.120 vs. 0.079). Therefore, the lack of significant age differences in TOT in the no-activation condition may be attributable to younger participants. T-tests on background information for younger participants across the two experiments revealed no significant differences in education level ($t(58) = -0.51$, $p > 0.05$, 16.07 vs. 16.27) or vocabulary test scores ($t(58) = 1.03$, $p > 0.05$, 18.67 vs. 18.17). Could this be related to differences in knowledge breadth between the two younger participant groups? T-tests on younger participants' know and don' t-know rates across the two experiments revealed no significant differences (know rate: $t(58) = 0.20$, $p > 0.05$, 0.615 vs. 0.607; don' t-know rate: $t(58) = -0.54$, $p > 0.05$, 0.261 vs. 0.283), indicating that knowledge breadth was not responsible. The reason for the lack of significant age differences in TOT in the no-activation condition requires further investigation.

In conclusion, older adults' inability to effectively delete previously activated interference information leads to more TOT episodes, confirming the inhibition deficit theory and suggesting that TOT aging may be related to age-related declines in the ability to delete irrelevant interference information.

In both experiments, the proportion of incorrect answers reported for "known" items in the experimental conditions was significantly higher than in control conditions, indicating that interference stimuli indeed activated more incorrect interference information and that the experimental tasks placed high demands on inhibitory function. Due to deficits in access and deletion functions, older adults showed reduced ability to prevent irrelevant information from entering

the focus of attention and to delete information irrelevant to the current task, resulting in more TOT episodes.

This study used laboratory methods to manipulate inhibitory access and deletion functions, providing causal-level explanations for the relationship between inhibition and older adults' TOT. It also expands and supplements the inhibition deficit theory, offering a clearer perspective on explaining older adults' TOT —namely, that decreased ability to prevent irrelevant information and delete semantically related interference stimuli constitutes an important reason for increased TOT among older adults. Practically, this study provides important evidence and insights for improving older adults' TOT: (1) For cognitive intervention, training programs specifically targeting inhibitory sub-functions could be designed to improve older adults' access and deletion functions; (2) In daily life situations, efforts could be made to reduce interference information in older adults' verbal communication environments, with greater emphasis on the current topic when conversations involve topic shifts.

This study confirmed the influence of inhibitory access and deletion functions on older adults' TOT, partially filling a gap in this research area. However, because current research on the relationship between inhibition and older adults' TOT is limited, our findings require further verification. Additionally, although we confirmed the important roles of access and deletion functions in older adults' TOT, we have not yet determined which plays a greater role, requiring further research. Furthermore, we did not manipulate the restraint function to examine its role in older adults' TOT, which future studies could explore. Finally, this study used laboratory methods, and the experimental materials cannot fully encompass the speech problems that trigger TOT in daily life. Moreover, the questions used to induce TOT in this study involved historical and literary knowledge, requiring participants to have certain education levels. Therefore, caution is needed when generalizing our findings.

References

Abrams, L., Trunk, D. L., & Merrill, L. A. (2007). Why a superman cannot help a tsunami: Activation of grammatical class influences resolution of young and older adults' tip-of-the-tongue states. *Psychology and Aging, 22*(4), 835–845.

Anderson, M. C., & Bjork, R. A. (1994). Mechanisms of inhibition in long-term memory: A new taxonomy. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory and language* (pp. 265–325). San Diego, CA: Academic Press.

Arbuckle, T. Y., & Gold, D. P. (1993). Aging, inhibition and verbosity. *Journal of Gerontology: Psychological Sciences, 48*(5), 225–232.

Aron, A. R., Robbins, T. W., & Poldrack, R. A. (2004). Inhibition and the right inferior frontal cortex. *Trends in Cognitive Sciences, 8*(4), 170–177.

Ayasse, N., & Wingfield, A. (2017). The impact of context and competition on speech comprehension in younger and older adults revealed using eye-tracking and pupillometry. *The Journal of the Acoustical Society of America, 141*(5), 3747-3747.

Borella, E., Ghisletta, P., & De Ribaupierre, A. (2011). Age differences in text processing: The role of working memory, inhibition, and processing speed. *Journals of Gerontology Series B Psychological Sciences and Social Sciences, 66*(3), 311-320.

Brown, A. S. (1991). A review of the tip-of-the-tongue experience. *Psychological Bulletin, 109*(2), 204-223.

Brown, R., & McNeill, D. (1966). The "tip of the tongue" phenomenon. *Journal of Verbal Learning and Verbal Behavior, 5*(4), 325-337.

Burke, D. M., MacKay, D. G., Worthley, J. S., & Wade, E. (1991). On the tip of the tongue: What causes word finding failures in young and older adults? *Journal of Memory and Language, 30*(5), 542-579.

Chen, X. Q., Zhang, J. J., & Zhu, Y. X. (2015). The research of inhibition deficit hypothesis in the aging of speech production: Evidence from different speech level. *Acta Psychologica Sinica, 47*(3), 329-343.

Choi, H., & Smith, S. M. (2005). Incubation and the resolution of tip-of-the-tongue states. *The Journal of General Psychology, 132*(4), 365-376.

Cohen, G., & Faulkner, D. (1986). Memory for proper names: Age differences in retrieval. *British Journal of Developmental Psychology, 4*(2), 187-197.

Cohen, J. I., & Gordon-Salant, S. (2017). The effect of visual distraction on auditory-visual speech perception by younger and older listeners. *The Journal of the Acoustical Society of America, 141*(5), 470-476.

Cross, E. S., & Burke, D. M. (2004). Do alternative names block young and older adults' retrieval of proper names? *Brain and Language, 89*(1), 174-181.

Dahlgren, D. J. (1998). Impact of knowledge and age on tip-of-the-tongue rates. *Experimental Aging Research, 24*(2), 139-153.

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review, 12*(1), 45-75.

Fang, Y. H., & Zhang, J. J. (2013). Roles of semantic similarity and category size on semantic effect in picture-word interference paradigm. *Acta Psychologica Sinica, 45*(5), 523-537.

Gao, Y. (2013). *The role of visual perceptual stress in inhibition aging* (Unpublished master' s thesis). Beijing Normal University.

Gollan, T. H., & Brown, A. S. (2006). From tip-of-the-tongue (TOT) data to theoretical implications in two steps: When more TOTs means better retrieval.

Journal of Experimental Psychology: General, 135(3), 462-483.

Gong, Y. X. (1992). *Manual of Wechsler adult intelligence scale—Chinese version.* Hunan: Hunan Map Press.

Hartley, A. A. (1993). Evidence for the selective preservation of spatial selective attention in old age. *Psychology and Aging, 8*(3), 371-379.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The Psychology of Learning and Motivation: Advances in research and theory* (Vol. 22, pp. 193-225). San Diego, CA: Academic Press.

Huang, Y. F., Wang, D. H., Xiao, H. X., & Jiang, W. (2014). Effects of aging on false memory within DRM paradigm: A study based on fuzzy-trace theory. *Psychological Development and Education, 30*(1), 24-30.

James, L. E., & Burke, D. M. (2000). Phonological priming effects on word retrieval and tip-of-the-tongue experiences in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(6), 1378-1391.

Jones, G. V. (1989). Back to Woodworth: Role of interlopers in the tip-of-the-tongue phenomenon. *Memory and Cognition, 17*(1), 69-76.

Jones, G. V., & Langford, S. (1987). Phonological blocking in the tip of the tongue state. *Cognition, 26*(2), 115-122.

Lustig, C., Hasher, L., & Zacks, R. (2007). Inhibitory deficit theory: Recent developments in a "new view." *Inhibition in Cognition, 17*, 145-162.

Meyer, A. S., & Bock, K. (1992). The tip-of-the-tongue phenomenon: Blocking or partial activation? *Memory and Cognition, 20*(6), 715-726.

Nelson, T. O., & Narens, L. (1980). Norms of 300 general-information questions: Accuracy of recall, latency of recall, and feeling-of-knowing ratings. *Journal of Verbal Learning and Verbal Behavior, 19*(3), 338-368.

Pushkar, D., Basevitz, P., Arbuckle, T., Nohara-LeClair, M., Lapidus, S., & Peled, M. (2000). Social behavior and off-target verbosity in elderly people. *Psychology and Aging, 15*(2), 361-374.

Rastle, K. G., & Burke, D. M. (1996). Priming the tip of the tongue: Effects of prior processing on word retrieval in young and older adults. *Journal of Memory and Language, 35*(4), 586-605.

Reason, J. T., & Lucas, D. (1984). Using cognitive diaries to investigate naturally occurring memory blocks. *Everyday Memory, Actions, and Absent Mindedness*, 53-70.

Roediger, H. L. (1974). Inhibiting effects of recall. *Memory and Cognition, 2*(2), 261-269.

Ryan, E. B., Meneer, W. B., & Trovato, D. (1994). Age-based perceptions of conversational skills among younger and older adults. *Sage Focus Editions, 173*, 15-15.

Samanez-Larkin, G. R., Robertson, E. R., Mikels, J. A., Carstensen, L. L., & Gotlib, I. H. (2009). Selective attention to emotion in the aging brain. *Psychology and Aging, 24*(3), 519-529.

Schacter, D. L. (1999). The seven sins of memory: Insights from psychology and cognitive neuroscience. *American Psychologist, 54*(3), 182-203.

Schwartz, B. L. (2010). The effects of emotion on tip-of-the-tongue states. *Psychonomic Bulletin and Review, 17*(1), 82-87.

Shafto, M. A., & Tyler, L. K. (2014). Language in the aging brain: The network dynamics of cognitive decline and preservation. *Science, 346*(6209), 583-587.

Shafto, M. A., Stamatakis, E. A., Tam, P. P., & Tyler, L. K. (2010). Word retrieval failures in old age: The relationship between structure and function. *Journal of Cognitive Neuroscience, 22*(7), 1530-1540.

Sunderland, A., Watts, K., Baddeley, A. D., & Harris, J. E. (1986). Subjective memory assessment and test performance in the elderly. *Journal of Gerontology, 41*(3), 376-384.

Woodworth, R. S. (1938). *Experimental psychology.* New York: Holt.

Yin, S. F., & Peng, H. M. (2016). The role of inhibition in age-related off-topic verbosity: Not access but deletion and restraint functions. *Frontiers in Psychology, 7*(65), 1-11.

Zacks, R. T., & Hasher, L. (1994). Directed ignoring: Inhibitory regulation of working memory. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 241-264). San Diego, CA: Academic Press.

Zacks, R., & Hasher, L. (1997). Cognitive gerontology and attentional inhibition: A reply to Burke and McDowd. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 52*(6), 274-283.

Zhang, H. Y. (2013). *The condition of questions that used in TOT research and the effect of emotion on TOT* (Unpublished master' s thesis). Henan University.

Note: Figure translations are in progress. See original paper for figures.