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Contribution of the Prefrontal Cortex to Metamemory Experiences

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Abstract

We examined the contribution of the prefrontal cortex (PFC) to feeling-of-knowing (FOK) and tip-of-the-tongue (TOT) reports. We reasoned that FOKs are based on information that is retrieved as a result of strategic searches of memory and that the PFC is engaged when there are these types of memory searches. Consequently, we expected a contribution of the PFC to FOK reports. Further, if one assumes that TOTs are strong FOKs then one would expect the PFC to play a greater role for TOT reports relative to FOK reports. In Experiment 1 we found that level of PFC functioning affected the frequency of FOK reports, the number of objective FOK reports, and the accuracy of FOK reports but had no effect on participant-assigned FOK strength levels. In Experiment 2 we found that PFC functioning did not affect the frequency of TOT reports, the number of objective TOTs, the accuracy of TOT reports, nor the strength of TOT reports. Based on these data we proposed a two-stage model of TOT reports where the first stage contains little in way of strategic searches of memory and consequently, little use of the PFC and the second stage is comprised primarily of strategic searches of memory, engages working memory, and involves a substantial contribution by the PFC.

Our aim in the present study was to determine the extent to which the prefrontal cortex (PFC)[1] plays a role when there are strategic memory searches for sought-after information but the searches result in retrieval failures. Specifically, we were interested in the contribution of the PFC when information is available but temporarily inaccessible. The likelihood of successfully retrieving information is influenced by several factors with two important ones being how well the information was originally encoded and how effectively it can be retrieved. We add that the effectiveness with which information can be retrieved may be dependent, in large part, on whether there are strategic searches of memory and that such searches may be initiated by unintentional sources (e.g., a strong feeling that some sought-after information is available). We will discuss later what we mean by "unintentional influences on intentional[2] processes" (e.g., strategic searches for the solution to an unsolved problem).

Recent psychobiological models of memory incorporate two major brain structures to account for the retrieval of information: the hippocampus and the PFC. It has been suggested that the hippocampus (a region located within the medial-temporal lobe, along with the dentate gyrus, subiculum, and the entorhinal cortex) plays a major role in the encoding of information – particularly when that information is episodic in nature (see Gluck & Myers, 1997 for a review). To illustrate, recently acquired information will be relatively immune to interference (e.g., overwriting of old knowledge by new knowledge) once the memory trace has been consolidated (e.g., McClelland, McNaughton, & O'Reilly, 1994). However, for consolidation to occur the hippocampus must repeatedly transfer the information to the neocortex.

[1] The PFC is the anterior portion of the frontal lobe – the term, as used in the present paper, excludes the posterior frontal cortex which is thought to be specialized for motor functions.

[2] In the present study we equate intentionality with consciousness/awareness (see Searle, 1983 for a philosophical discussion)

On the other hand, the ability to successfully retrieve information is attributed, primarily, to the PFC. As noted by Parkin (1997), the PFC comprises approximately one-third of the cerebral cortex. Therefore, it is not surprising that several functions have been attributed to this brain structure (e.g., confabulation, source amnesia, deficiencies in temporal memory, increased false alarms on recognition tests, and defective recall; see Schacter, 1987; Shimamura, 1993; Shimamura, Janowsky, & Squire, 1991, and Squire, 1987 for reviews). Further, many PFC disorders are associated with impairments in working memory (e.g., Baddeley, 1986; Moscovitch, 1994) and, as identified by recent neuroimaging studies, specific PFC regions are associated with distinct behaviors (e.g., Buckner & Petersen, 1996). For example, the left portion is predominantly involved in the encoding of new information whereas the right portion is involved in the retrieval of stored information (e.g., Fletcher, Frith, Grasby, & Shallice, 1995; Shallice, Fletcher, Grasby, Frackowiak, & Dolan,1994; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994).

Our goal in the present study was to determine the contribution of the PFC to metamemory phenomena. Generally defined, metamemory is the knowledge that we have as to whether some unit of information is stored in memory (e.g., Janowsky, Shimamura, & Squire, 1989; Shimamura, 1994). For example, if asked "Who was the first ruler of the Holy Roman Empire?" (answer: Charlemagne), one might recall having had a history class in school and in that class there was a discussion about the history of Rome. Based on the retrieval of this information one might conclude that the answer to the posed question is known even though it cannot be retrieved immediately.

In cognitive psychology there is a growing interest in these sorts of phenomological issues (e.g., Schwartz, 1994; Shimamura, 1994; Wheeler, Stuss, & Tulving, 1997). What is particularly intriguing about metamemory experiences is that they frequently function as internal flags that signal to the rememberer that a specific memory(ies) is available (even though it may not be readily accessible; e.g., Hart, 1965; Schwartz, 1994). This distinction between available versus accessible information is not novel (e.g., Tulving & Pearlstone, 1966). What is novel, from a metamemory perspective, is that such experiences are personal in nature; they are experiences in which the rememberer feels that the sought-after information is available despite an inability to retrieve it immediately (e.g., Schwartz, 1994). Such experiences are intimately associated with how efficiently we function on a daily basis because frequently we act upon such feelings hoping that the sought-after information will eventually materialize. To illustrate, a student studying for an upcoming exam might "feel" that they are prepared after having engaged in several self-tests; tests in which feelings-of-knowing the queried material existed but in which the target information was not actually retrieved. With such feelings in hand, the student ascertains, prematurely, that he/she is prepared for an upcoming exam – resulting, unfortunately, in the all too frequent claim, "I knew the material. What happened?".

We limited our examination of metamemory phenomena to feeling-of-knowing (FOK) and tip-of-the-tongue (TOT) reports because they are frequently occurring experiences in our daily lives and because they have been the focus of much research. An FOK experience exists when an individual believes that the sought-after information is known (e.g., the answer to an experimenter-posed question) and, given that the information is not forthcoming, believes that he/she can identify it if it was shown at some later point in time (e.g., Hart, 1965). Another phenomenological experience that suggests information is available but temporarily inaccessible is the TOT experience. A TOT is frequently defined as a strong feeling that the sought-after information is known and that the information will "pop" into mind at any moment (e.g., Brown

& McNeill, 1966; Koriat & Lieblich, 1974). Thus, at first glance, what differentiates FOKs from TOTs is that for the latter experience there exists an intense feeling that the sought-after information is available in memory.

An additional reason for our focus on these two experiences is that there exists an intuitive relationship between the two: TOTs are strong FOKs. Not only is the relationship intuitive but it is a sentiment shared by several memory researchers. For example, the first sentence in the Shimamura and Squire (1986) paper states, "Often one experiences a sense of feeling of knowing some information without being able to recall it. In its most frustrating form the information seems to be on the "tip of the tongue."" (p. 452). Inherent in such assertions is a quantitative relationship. In the present study we provide data that weakens this view and we assert that TOTs and FOKs are different experiences; that there is a qualitative, not a quantitative, relationship. Support for a qualitative distinction would be obtained if an experimental variable has an effect on one experience (e.g., FOKs) and not on the other experience (e.g., TOTs).

We attempted to minimize the contribution of the hippocampus in the present study by focusing on information that is primarily semantic in nature (e.g., general-knowledge information). Having participants retrieve semantic information is quite different from having them retrieve episodic information (e.g., words on an experimental study list). Presumably, the hippocampus plays a somewhat greater role when episodic information must be retrieved relative to when semantic information must be retrieved. From our perspective, an important goal for neuropsychologists is the identification of brain structures that mediate some phenomenon that is under study. To accomplish such a goal it is imperative that the type of information (e.g., episodic / semantic) that is being encoded and/or retrieved is under experimental control so as to minimize confounding effects. To illustrate, in Janowsky et al. (Experiment 1; 1989) the stimuli on which FOK reports were based consisted of sentences acquired during the experimental session. That is, the material on which FOKs were based was primarily episodic in nature and consequently, there may have been a substantial contribution by the hippocampus. Thus, the interpretation of Janowsky et al.'s findings, with respect to the assignment of a role played by the PFC, becomes problematic because of possible contamination by the hippocampus. We return to this issue in the General Discussion.

The retrieval of either type of information (semantic or episodic) may engage conscious processes and, consequently, utilization of substantial amounts of cognitive resources. This is an important point - we stress that the retrieval of information from memory, on which FOKs (but not TOTs) are based, is an intentional process; a process that requires awareness and substantial amounts of cognitive resources. The intentional retrieval of information contrasts with the retrieval of information that is unintentional and does not tap substantially the cognitive resource pool.

Widner (1999) hypothesized that cognitive resources, and attention, are required when there are strategic searches of memory and that FOK reports are based, in large part, on information that is retrieved as a result of such memory searches. Retrieved information might include an assessment of one's familiarity with the cue (e.g., Metcalfe, Schwartz, & Joaquim, 1993), partial target information (e.g., Koriat, 1993), or the target itself (Schwartz & Smith, 1997). Widner examined this hypothesis by requiring one group of participants to answer general-knowledge questions under divided-attention conditions (monitoring single digits presented over a set of headphones for three consecutive odd numbers) and another group to answer questions under full-attention conditions (no secondary task). Widner reasoned that under divided-attention conditions individuals would likely retrieve less information from memory on which to base FOK reports, relative to individuals in the full-attention condition, and if less information was retrieved there would likely be fewer and less accurate FOK reports. That is what Widner found; participants under divided-attention conditions reported fewer and less accurate FOKs than individuals in the full-attention condition. Thus, the data supported the hypothesis that FOK reports are based, in large part, on information that is intentionally retrieved from memory. Further, given the logic of Nyberg, Winocur, and Moscovitch (1997), that dividing attention at study and/or test should have a negative impact on performance if the task (s) is dependent on frontal lobe involvement, one might conclude from Widner's findings that FOK reports engage the PFC; a conclusion based on the finding that dividing attention at test resulted in a reduction in the number and accuracy of reported FOKs.

Tasks that require substantial amounts of cognitive resources and awareness (e.g., selection of task-relevant information; inhibition of irrelevant information; encoding of information; retrieval of information during free-recall) have been linked to working memory; more specifically, to executive functions (e.g., Baddeley, 1986; Hasher & Zacks, 1988; Norman & Shallice, 1986; Zacks & Hasher, 1994). Further, findings from positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) studies have lead several researchers to argue for the existence of an association between the PFC and working memory (e.g., Braver, Cohen, Nystrom, Jonides, Smith, & Noll, 1997; Fiez, Raife, Balota, Schwarz, Raichle, & Peterson, 1996; Norman & Shallice ,1986; Shimamura (1994); Stuss, Eskes, & Foster (1994); Stuss & Benson, 1986; Swartz, Halgren, Fuster, Simpkins, Gee, & Mandelkern, 1995; Wheeler et al., 1997). This association has been emphasized recently by Baddeley (1986) when he refers to cognitive deficits that are associated with PFC dysfunctions as "dysexecutive".

In the present study we reasoned that if process A is associated with process B and process B is associated with process C then process A is likely associated with process C. Thus, if tasks that require cognitive resources (and awareness) involve working memory and working memory is associated with PFC functioning then it is reasonable to assert that tasks that require cognitive resources (and awareness) involve the PFC. Given that FOK reports are based on information that is retrieved as a result of strategic searches of memory (a cognitively demanding process that requires resources and awareness; e.g., Widner, 1999), that strategic searches of memory engage working memory (e.g., Zacks & Hasher, 1994), and that utilization of working memory resources engage the PFC, it is reasonable to assert that the reporting of FOK experiences engage the PFC.

To summarize, we asserted that: (1) the intentional retrieval of information requires cognitive resources and awareness (e.g., Schacter, 1987), (2) tasks that require cognitive resources and awareness engage working memory resources (e.g., Moscovitch, 1994), and (3) tasks that require working memory resources engage the PFC (e.g., Buckner & Petersen, 1996). Given that FOK reports are based on information that is intentionally retrieved from memory (e.g., Widner, 1999) we hypothesized that FOK reports would be affected by the level of PFC functioning. If we assume that TOTs are strong FOKs (i.e., TOTs lie further up on a strength continuum than FOKs) then we should expect a greater contribution of the PFC when reporting TOTs relative to when reporting FOKs. In the present study we examined these predictions with regards to FOK reports (Experiment 1) and TOT reports (Experiment 2).

EXPERIMENT 1

Given that individuals with deficient PFC functioning retrieve less information from memory, relative to individuals with intact PFCs, there would be less information available on which to base FOK reports. With less information available we predicted fewer, less accurate and weaker FOK reports by individuals with deficient PFCs relative to individuals with intact PFCs (who would, presumably, retrieve more information).

The Wisconsin Card Sort Test (WCST) is a standardized test used to assess PFC functioning (e.g., Fristoe, Salthouse, & Woodard, 1997; Janowsky et al. 1989; Milner, 1964). This test is designed to assess individuals' abilities to plan and switch from one categorization rule to another without reverting back to previous rules. The test consists of four stimulus cards and 128 response cards and the participant's task is to sort response cards based on one of three dimensions: color, form, or number. After each trial feedback is provided as to whether the response card was correctly placed into a category. After ten correct consecutive trials the scoring dimension changes without the participant's knowledge. Upon completion of the card sort task a report is generated that provides scores on various task components - of interest in the present study is the number of preserverative errors. Preserverative errors are indicative of the difficulty that individuals have in switching from one dimension to a new dimension and presumably, the greater the number of preserverative errors the less efficient is PFC functioning. We chose to use preserverative errors as our index of PFC functioning because of its reliability (e.g., Fristoe et al., 1997).

Baddeley and Wilson (1988) found that participants with frontal lobe lesions had difficulty learning the patterns of the WCST. Similarly, Shimamura (1994) found that participants who made more errors on the WCST, primarily older adults, had more difficulty in recall tasks. Spencer and Raz (1994) used the WCST to assess age-related differences in frontal lobe functioning. While participants with frontal lobe lesions, relative to individuals with intact PFC functioning, score within the normal range for intelligence tests, they often have difficulty with short-term memory, poorer recall performance, greater difficulty categorizing, and difficulty with problem solving tasks such as the WCST (Shimamura, 1994). Also, as noted by Shimamura (1994), individuals with frontal lobe lesions do not show an impairment in perception or memory but rather the deficit appears when there is an attempt to integrate the perceptions and memories. Thus, it is the effortful nature of integrating information that results in an observed impairment in PFC functioning. Further, as noted by others, many frontal lobe disorders appear to be related to impairments in working memory (e.g., Baddeley, 1986; Moscovitch, 1994; Shimamura, 1994).

We included older adults in the present experiment to increase the range of PFC functioning (as assessed by preserverative errors on the WCST). Our rationale for inclusion of older adults is that, as a group, they have deficient PFC functioning (e.g., Shimamura, 1994) and as noted by Spencer and Raz (1994), "it is highly plausible that age-related declines in executive functions are linked to deterioration of their material substrate". Additionally, Haug, Barmwater, Eggers, Fischer, Kuhl, and Sass (1983) asserted that there is substantial neuronal loss associated with normal aging and that the majority of this loss occurs in the PFC.

Method

Participants. 24 individuals participated in the present experiment. If we define an older adult as being 53 years of age or older then there were 10 older adults (M age = 64.70; SD = 10.69) and 14 young adults (M age = 21.43; SD = 3.65). Older participants were selected from a database established by the first author that included individuals who indicated an interest in participating in psychology experiments conducted in the psychology department at the University of Colorado. All older adults were residents in the Colorado Springs community (independent life styles) and were compensated for their participation with a University of

Colorado Memory and Aging Laboratory logo coffee cup. Young adults were undergraduate students enrolled in psychology classes at the University of Colorado at Colorado Springs and received extra credit for their participation.

Participants self-rated their health on a scale that ranged from 1 = "poor health" to 5 = "excellent health" with a mean rating for older adults of 4.10 (SD = .88) and for young adults 4.11 (SD = .79), $t(22) = .02$, $SE = .34$, $p < .98$. Three of the older adults reported no medical problems or use of prescribed mediations whereas the remaining older adults reported some form of cardiovascular disease with the majority of these being high blood pressure. None of the young adults reported medical problems or use of prescribed medications. Finally, none of the participants, old or young, reported having had head injuries. The amount of education acquired by older adults did not differ from the amount acquired by young adults [Ms = 14.80 (SD = 2.57) and 13.93 (SD = 1.07), respectively], $t(22) = -1.14$, $SE = .76$, $p < .27$.

Materials. Thirty general-knowledge questions were selected from the Nelson and Narens (1980) norms with presentation times controlled using SuperLab experimental software. To increase the likelihood that there would be strategic searches of memory for answers to posed questions we selected questions to be of moderate difficulty [p (correct recall) = .50; range .407-.58] . The question with the lowest probability of correct recall [p (recall) = .407] was: "What is the last name of Batman's secret identity in the Batman comics? (Wayne)" and the question with the highest probability of recall [p (recall) = .58] was: "What is the name of deer meat? (Venison)". A self-paced, pencil-and-paper, forced-choice recognition test was administered with questions on the recognition test being the same questions that were presented during the first portion of the experiment. Each question on the recognition test was presented with four alternative answers (one of which was correct). Distractor items for each question were selected from the same topic domain as the target (e.g., for the target DALI, the distractors were DA VINCI, RUBENS, and REMBRANDT). In the present study we used a computerized version of the WCST (Heaton, 1993) to assess PFC functioning.

Procedure. The experimental session lasted approximately one hour with participation being on an individual basis. Each individual was presented with a practice session that consisted of five questions selected from the Nelson and Narens norms (1980). The practice session was followed with presentation of the 30 general-knowledge questions, one question at a time, on a 15" monitor with each question remaining on the monitor for 20 seconds. Fifteen seconds into the 20 second session an instruction slide appeared, "Please Respond", to remind participants to provide a response to the experimenter if that had not already done so. This was done to reduce the likelihood that individuals might use some portion of the time that was allocated to the next question.

During the time that the general-knowledge question was on the monitor participants were to provide one of three possible responses: Report the answer if they knew it; report "don't know" if they didn't know the answer; or to report that they were experiencing a FOK. The FOK definition provided to participants was: "When you feel you know the answer to a presented question but you can't remember it at the moment and you feel that you could identify the answer if it was mixed in with similar words as the answer at some later point in time then you are in a feeling-of-knowing state. If this occurs, please report to the experimenter that you are in a FOK state". Upon reporting an FOK participants were asked to rate how strongly they felt that they could detect the correct answer if it was shown to them at some later point in the experiment [i.e., "1" (not sure) to "20" (sure)].

Upon completion of the 30 questions participants were administered a self-paced, four alternative forced-choice recognition test that consisted of the general-knowledge questions that were presented in the first part of the experiment (different order). Participants were instructed to circle answers they thought were correct and to guess if they didn't know the answer. Following the recognition test all participants were administered the WCST and a health questionnaire, were debriefed, and thanked for their participation.

Results

For all statistical analyses the significance level was set at .05 unless noted otherwise and all tests were planned and two-tailed.

Wisconsin Card Sort Test Scores. We used the number of preserverative errors on the WCST as an index of PFC functioning and in the present experiment errors ranged from 4 to 37. Because our interest was in the contribution of the PFC when reporting FOKs we divided participants into two post-hoc groups (High- and Low-Error), based on the number of preserverative errors, using a median split. The range of preserverative errors exhibited by individuals in the High-Error group ($n = 12$) was 9 to 37 with an average of 16.00 ($SD = 8.16$) and for individuals in the Low-Error group ($n = 12$) the range was from 4 to 9 with an average of 6.08 ($SD = 1.73$), $t(22) = -4.12$, $SE = 2.41$, $p < .0001$.

The age of individuals within each group differed such that individuals in the High-Error group were older ($M = 49.17$; $SD = 22.47$) than individuals in the Low-Error group ($M = 29.75$; $SD = 19.48$), $t(22) = -2.25$, $SE = 8.64$, $p < .035$. The finding of an age-related difference in the number of preserverative errors on the WCST is common (e.g., Axelrod & Henry, 1992). Mean educational levels were 14.25 ($SD = 1.71$) and 14.33 ($SD = 2.06$) for individuals in the High- and Low-Error groups, respectively, $t(22) = .11$, $SE = .77$, $p < .92$. Mean health ratings ("1" = poor to "5" = excellent) for individuals in the High-Error group was 4.13 (SD = .86) and for individuals in the Low-Error group 4.08 (SD = .79), $t(22) = -.12$, $SE = .34$, $p < .90$. In conclusion, we found that individuals in the two groups differed on age and number of preserverative errors.

We found a Pearson correlation coefficient of .44 ($p < .05$) between age and PFC functioning (as indexed by number of preserverative errors on the WCST). A correlation of this magnitude permits one to assume, at least in the present study, that there are older adults with relatively intact PFC functioning and younger adults with relatively deficient PFC functioning. Given this, it seemed reasonable to be cautious about including age as a variable when trying to determine the contribution of the PFC to FOK and TOT reports. Inclusion of age can result in misleading conclusions with regards the contribution of the PFC to whatever phenomenon that is under study.

Thus, for several reasons we included analyses-of-covariances (ANCOVAs) using age as the covariate. First, we observed a difference in the mean ages of individuals in the High- and Low-Error groups. Second, the correlation between age and preserverative errors was far from perfect. Finally, our interest was not in the effects of age on FOK and TOT reports but on the role played by the PFC in these reports (see Widner & Otani, 1999 for a discussion of the relationship between age and FOK/TOT reports). We used ANCOVAs as a means of statistically controlling for the effects of age on FOK and TOT reports.

Recall and Recognition. There was no difference in the number of correctly recalled answers to the general-knowledge questions by individuals in the High- ($M = 14.42$; $SD = 7.38$) and Low-Error groups ($M = 11.50$; $SD = 5.49$), $t(22) = -1.10$, $SE = 2.65$, $p < .28$. This failure to observe a difference in recall performance persisted when age was used as a covariate in an

ANCOVA; correctly recalled answers by individuals in the Low- (M = 12.20; SE = 1.97) and High-Error (M = 13.71; SE = 1.97) conditions, F (1, 21) = 0.27, MS_e = 41.82, $p < .61$.

Correct recognition, which was well above chance, did not differ between individuals in the High- and Low-Error groups (Ms = 24.42 and 22.83, respectively), t (22) = .98, SE = 1.61, $p < .34$. As with recall performance, this relationship held when age was used as a covariate, F (1, 21) = 0.40, MS_e = 14.40 [Ms = 23.80 (SE = 1.16) and 23.45 (SE = 1.16), for the High- and Low-Error groups, respectively], $p < .84$.

Feeling-of-Knowing Reports. There were a total of 161 FOK reports: 58 by individuals in the High-Error group (M = 4.83; SD = 2.37) and 103 by individuals in the Low-Error group (M = 8.58; SD = 3.42), t(22) = 3.12, SE = 1.20, $p < .005$. A one-way ANCOVA indicated that individuals in the High-Error group reported fewer FOKs (M = 5.31; SE = .86) than individuals in the Low-Error group (M = 8.11; SE = .86), F (1, 21) = 4.81, MS_e = 7.95, $p < .04$.

One might reasonably argue that a FOK in which an individual correctly identifies the answer on a subsequent recognition test differs from FOKs in which the answer is not correctly identified. To address this issue we categorized reports into objective (FOKs in which the answer was correctly recognized on the recognition test) and subjective (FOKs in which the answer was not correctly identified) FOKs. We found that 71% of the FOKs reported by individuals in the High-Error group were objective and 72% of the FOKs reported by individuals in the Low-Error group were objective. We also found that individuals in the High-Error group reported a total of 58 FOKs whereas individuals in the Low-Error group reported a total of 103 FOKs. An analysis comparing the mean number of objective FOKs (Ms = 3.42 and 6.17, respectively) revealed a difference, t (22) = -3.28, $p < .003$, SE = .84. Thus, it appears that how well the PFC functions affects the number of FOKs reported and whether those FOKs are objective or subjective.

FOK Confidence Ratings. To determine whether there are differences in participant-assigned FOK strength ratings we calculated a mean strength rating for each participant (included the strength rating assigned to each reported FOK by a particular participant)and then performed an analysis on the obtained means. The analysis revealed no difference in the FOK strength ratings by individuals in the High- and Low-Error groups ($\underline{M}$s = 13.51 and 13.18, respectively), $\underline{t}(22) = .23$, $\underline{SE} = 1.44$, $\underline{p} < .82$. An ANCOVA, using age as a covariate, revealed no difference in FOK strength ratings by individuals in the High- ($\underline{M} = 13.09$; $\underline{SE} = 1.07$) and Low-Error groups ($\underline{M} = 13.59$; $\underline{SE} = 1.07$), $\underline{F}\,(1, 21) = .10$, $\underline{MS_e} = 12.23$, $\underline{p} < .77$.

Next, we converted the confidence ratings into probability estimations by dividing the mean confidence rating for each participant by 20 (range of confidence levels) to yield a score that could range from 0 to 1. Then, for each participant we correlated the mean expectation score with the Goodman-Kruskal Gamma correlation ($\underline{G}$; Goodman & Kruskal, 1954). $\underline{G}$ can range from –1 to 1, with zero indicating no relationship between FOK reports and recognition performance. For individuals in the Low-Error group we found a Pearson correlation coefficient of .45, $\underline{p} < .14$ and for individuals in the High-Error group a correlation of .11, $\underline{p} < .73$. These correlations are indicators as to whether there is a relationship between participants' perceptions of how they would perform (as indexed by participant assigned strength ratings) and actual accuracy of their FOK report (see Metcalfe, 1986 for a similar procedure). Though we found a numerically larger correlation coefficient for individuals with intact PFC functioning, relative to the coefficient observed for individuals with deficient PFC functioning, this difference wasn't statistically significant, $\underline{z} = .79$, $\underline{p} < .21$ (z-test for two correlation coefficients; Kanji, 1998).

FOK Accuracy. Finally, we addressed the issue as to whether the accuracy of FOK reports differed between individuals with intact versus deficient PFC functioning. Assessing the accuracy of FOK reports entails not only whether a reported FOK resulted in accurate recognition but includes to what extent "don't know" reports result in correct recognition. To determine this we calculated a G value for each participant. We found that individuals with deficient PFC functioning reported FOKs that were less accurate than individuals with intact PFC functioning (mean Gs = .01 and .51, respectively), $t(22) = -2.23$, $SE = .23$, $p < .03$. Similar results were obtained with an ANCOVA using age as a covariate; individuals in the Low-Error group (mean $G = 0.56$; $SE = 0.17$) had more accurate FOKs than individuals in the High-Error group (mean $G = -0.06$; $SE = 0.17$), $F(1, 21) = 6.12$, $MS_e = 0.32$, $p < .02$.

To summarize, we found that individuals with intact PFC functioning (Low-Error group) reported more FOK experiences, more objective FOKs, and more accurate FOKs than did individuals with deficient PFC functioning (High-Error group). Additionally, there appears to be little effect of PFC functioning on participant-assigned FOK strength ratings; individuals in the High- and Low-Error groups produced mean ratings that were equivalent. We did find a substantially larger correlation between assigned strength ratings and accuracy of reported FOKs for individuals in the Low-Error group relative to the outcome for individuals in the High-Error group but the difference between correlations was not significant. Finally, we found no difference in the number of questions that were correctly answered (recall) or in the number of answers that were correctly identified at test (recognition) by individuals in the High- and Low-Error groups.

EXPERIMENT 2

In this experiment we examined the contribution of the PFC to TOT reports. If we assume that TOTs are strong FOKs and that the two experiences lie along the same dimension (e.g., strength) then one would expect a greater contribution of the PFC to TOT reports given that we already observed a contribution of the PFC to FOK reports (Experiment 1). Thus, we expected that the frequency, accuracy, and strength of reported TOTs would be greater for individuals with intact PFC functioning relative to individuals with deficient PFC functioning.

Method

Participants. Thirty individuals participated in the present experiment. As in Experiment 1, we included older adults to increase the range of PFC functioning. If we define an older adult as being 53 years of age or older (as in Experiment 1) then there were 10 older adults (M = 63.60; SD = 7.98) and 20 young adults (M = 21.90; SD = 4.98) who participated in the present experiment. Older participants were selected from a database established by the first author that included individuals who indicated an interest in participating in psychology experiments conducted in the psychology department at the University of Colorado. All older adults were residents in the Colorado Springs community (independent life styles) and were compensated for their participation with a University of Colorado Memory and Aging Laboratory logo coffee cup. Young adults were undergraduate students enrolled in psychology classes at the University of Colorado at Colorado Springs and received extra credit for their participation.

Older adults self-rated their health ("1" = poor to "5" = excellent) as being 4.00 (SD = .94) and young adults as being 4.10 (SD = .72), t (28) = .32, p < .75. Six of the older adults did not report the existence of a medical condition nor of taking prescribed medications. The remaining older adults reported some form of cardiovascular disease with the majority being high blood pressure. One young adult reported hypertension with the remaining young adults reporting no medical disease or use of prescribed medications. Older adults had slightly more education ($M = 16.10$; $SD = 2.81$) than did young adults ($M = 14.60$; $SD = 1.50$), $t(28) = -1.92$, $p < .06$.

Materials and Procedure. The materials were the same as those used in Experiment 1. The procedure was the same as that used in Experiment 1 with the following exception: Participants were asked to provide TOT, rather than FOK, reports. Each participant was provided with the following TOT definition: "When you feel you know the answer to a presented question but you can't remember it at the moment and you feel the answer is about to pop into mind at any second then you are in a tip-of-the-tongue state. If this occurs, please report to the experimenter that you are in a TOT state".

Results and Discussion

As in Experiment 1, we set the significance level at .05 and all tests were planned and two-tailed unless noted otherwise.

Wisconsin Card Sort Test Scores. As in Experiment 1 we used the number of preserverative errors on the WCST as an index of PFC functioning which ranged from 3 to 27. Because our interest was in the contribution of the PFC, rather than age, to TOT reporting, we divided participants into two post-hoc groups, based on the number of preserverative errors, using a median split: High- and Low-Error error groups. The range of preserverative errors exhibited by individuals in the High-Error group ($n = 15$) was 8 to 27 with an average of 14.07 ($SD = 6.19$) and the range of errors exhibited by individuals in the Low-Error group ($n = 15$) was 3 to 7 with an average of 5.00 ($SD = 1.31$), $t(28) = 5.55$, $SE = 1.63$, $p < .0001$.

The average age of participants in the High-Error group was 46.80 (SD = 23.50) and for individuals in the Low-Error group 24.80 (SD = 9.53), $t(28) = 3.36$, SE = 6.55, $p < .002$. Mean educational levels were 15.27 (SD = 2.58) and 14.93 (SD = 1.58) for individuals in the High- and Low-Error groups, respectively, $t(28) = .43$, SE = .78, $p < .67$. Mean self-ratings of health ("1" = poor to "5" = excellent) were 4.00 (SD = .85) and 4.13 (SD = .74) for individuals in the High- and Low-Error groups, respectively, $t(28) = -.46$, SE = .29, $p < 65$.

We found a Pearson correlation coefficient of .70, $p < .01$, between age and the number of reported preserverative errors on the WCST. This correlation was higher than that observed in Experiment 1 but it is still far from perfect. Thus, for the same reasons as outlined in Experiment 1, in addition to the regular analyses, we included ANCOVAs using age as a covariate.

Recall and Recognition. As in Experiment 1, the number of correctly recalled answers to the general-knowledge questions by individuals in the two groups did not differ with mean recall being 12.60 (SD = 7.14) and 11.13 (SD = 6.22) for individuals in the High- and Low-Error groups, respectively, $t(28) = .60$, SE = 2.45, $p < .55$. An ANCOVA, using age as a covariate, revealed a marginal effect of PFC functioning on recall performance with individuals in the High-Error group (M = 9.77; SE = 1.40) correctly recalling fewer answers than individuals in the Low-Error group (M = 13.96; SE = 1.40), $F(1, 27) = 3.83$, $MS_e = 24.45$, $p <.06$

Further, we found that the number of correctly recognized answers to the general-knowledge questions by individuals in the two groups did not differ with average recognition being 24.73 (SD = 3.43) and 22.87 (SD = 4.67) for individuals in the High- and Low-Error groups, respectively, $t(28) = 1 .25$, SE = 1.50, $p < .22$. An ANCOVA, using age as a covariate, revealed that the failure to observe a difference in recognition levels by individuals in the Low-

(M = 24.03; SE = 1.05) and High-Error groups (M = 23.57; SE = 1.05) persisted, $F(1, 27) = 0.80$, $MS_e = 13.69$, $p < .77$.

Tip-of-the-Tongue Reports. There were a total of 165 TOT reports with 83 reported by individuals in the High Error group (M = 5.53; SD = 2.80) and 82 reported by individuals in the Low Error group (M = 5.64; SD = 3.39), $t(28) = -.10$, SE = 1.15, $p < .93$. Unlike the results of Experiment 1, where FOKs were examined, we found no difference in the number of TOT reports by individuals who had deficient versus intact PFC functioning. A one-way ANCOVA, using age as a covariate, revealed no difference in the frequency of TOT reports by individuals in the Low- (M = 4.76; SE = 0.82) and High-error groups (M = 6.24; SE = 0.82), $F(1, 27) = 1.39$, $MS_e = 8.45$, $p < .25$.

One might reasonably argue that TOTs in which an individual correctly identifies the answer on the recognition test differs from TOTs in which the answer is not correctly identified. To address this issue we categorized reports into objective (TOTs in which the answer was correctly recognized) and subjective (TOTs in which an answer was not correctly identified) TOTs. We found that 81.93% of the TOTs reported by individuals in the High-Error group were objective whereas 68.29% of the TOTs reported by individuals in the Low-Error group were objective. An analysis comparing the mean number of objective TOTs (Ms = 4.53 and 3.73, respectively) revealed no difference, $t(28) = .87$, $p < .39$, SE = .92. Thus, it appears that how well the PFC functions has little effect on the number of objective TOT reports.

TOT Confidence Ratings. As with the FOK ratings of Experiment 1, we found no difference in TOT confidence ratings by individuals with deficient PFC functioning (High-Error group: M = 13.67, SD = 3.95) versus individuals with intact PFC functioning (Low-Error group: M = 12.17, SD = 3.81), $t(28) = 1.06$, SE = 1.42, $p < .30$. An ANCOVA in which age was used as a covariate revealed no difference in TOT strength ratings by individuals in the Low- (M = 13.12; SE = 1.03) and High-Error (M = 12.72; SE = 1.03) groups, F (1, 27) = 0.07, MS_e = 13.13, $p < .80$.

Next, we converted the confidence ratings into probability estimations by dividing the mean confidence rating for each participant by 20 (range of confidence levels) to yield a score that could range from 0 to 1. Then, for each participant we correlated the mean expectation score with G, as we did for the FOK reports in Experiment 1. For individuals in the Low-Error group we found a Pearson correlation coefficient of -.18, $p < .53$ and for individuals in the High-Error group a correlation of .62, $p < .01$. These correlations are suggestive as to whether there is a relationship between participants' perceptions of how well they would perform (as indexed by assigned strength ratings) and actual accuracy of TOT reports (see Metcalfe, 1986 for a similar procedure). Though the correlation for individuals with deficient PFC functioning was numerically greater than for individuals with intact PFC functioning this difference was not statistically significant, z = 1.27, $p < .10$ (z test for two correlation coefficients; Kanji, 1998).

TOT Accuracy. Finally, we addressed the issue as to whether the accuracy of TOT reports by individuals with intact PFC functioning differed from individuals with deficient PFC functioning. As in Experiment 1, we determined this by calculating a G for each participant. We found a marginal effect such that individuals in the Low-Error group (mean G = .005) reported less accurate TOTs than individuals in the High-Error group (mean G = .47), $t(28)$ = -1.99, SE = .23, $p < .06$. An ANCOVA, using age as a covariate, revealed no difference in the accuracy levels of TOTs reported by individuals in the High- (M = 0.37; SE = 0.18) and Low-Error groups (M = 0.10; SE = 0.18), F (1, 27) = 1.00, MS_e = 0.39, $p < .33$. Apparently, there is a substantial influence of age on the accuracy of reported TOTs; an assertion based on the observed reversal of significance by individuals in the two groups when age was used as a covariate (see Widner & Otani, 1999 for a discussion of the effects of age on FOK and TOT reports).

To summarize, we found that the frequency, the number of objective TOTs, accuracy, and strength of TOT reports did not vary as a function of PFC functioning when age was used as a covariat in ANCOVAs. When age was included in the analysis we found a marginal effect of TOT accuracy such that individuals with deficient PFC functioning reported more accurate TOTs than individuals with intact PFC functioning. Further, when age was included we found that a relationship between participant-assigned TOT strength ratings and TOT accuracy levels for indinviduals with deficient PFC functioning. This pattern did not hold for individuals withintact PFC fucntioning. Given this reversal in the findings as a function of including age it appears that age plays an important role in the reporting of TOTs (see Widner & Otani, 1999).

GENERAL DISCUSSION

In the present study our interest was in the contribution of the PFC when there are attempts to retrieve information from memory but the attempts fail. More specifically, we focused on a category of retrieval failures that shared a common characteristic: there exists a signal to the rememberer that the sought-after information may be available but temporarily inaccessible. We focused on feeling-of-knowing (FOK) and tip-of-the-tongue (TOT) reports because these are common everyday experiences and there exists an intuitive relationship between the two: that TOTs are strong FOKs.

In the Introduction we cited several studies that supported the following assertions: (1) the intentional retrieval of information requires cognitive resources (and awareness), (2) tasks that require cognitive resources engage working memory resources, and (3) tasks that require working memory resources engage the PFC. Given that FOK reports are based on information that is intentionally retrieved from memory (e.g., Widner, 1999) we predicted that the reporting of FOKs would be affected by level of PFC functioning such that individuals with intact PFC functioning would report more frequent, accurate, and stronger FOKs relative to individuals with deficient PFC functioning.

Our predictions were partially supported by the data obtained in Experiment 1. We found that individuals with deficient PFC functioning (as assessed by the number of preserverative errors reported on the WCST) reported fewer FOKs, fewer objective FOKs, and less accurate FOKs than individuals with intact PFC functioning. We failed to find the same pattern for participant-assigned FOK strength levels. It is unclear as to why the strength ratings did not vary as a function of PFC functioning. One possibility is that individuals with deficient PFC functioning may have been overconfident in the accuracy of their FOK reports. We know that individuals with deficient PFC functioning are inclined to confabulate (i.e., produce false memories; e.g., Moscovitch,1989) and are relatively poor at estimations (e.g., when estimating the prices of everyday items; Smith & Milner, 1984). It is possible that in the present study that the frequency and strength of FOK reports by individuals with deficient PFCs may have been affected by this inclination to confabulate.

Widner, Smith, and Graziano (1996) addressed the effect of demand characteristics on FOK and TOT reports (an opportunity for confabulation). The assumption made by Widner and associates was that participants would not wish to appear "ignorant" by not knowing answers to experimenter-provided general-knowledge questions (particularly when misinformed that the questions were easy to answer). Under such conditions individuals might be inclined to report FOK and TOT experiences rather than having to admit to the experimenter that they don't know the answer. Widner et al. found that participants who were incorrectly informed that the questions were easy to answer reported more TOTs than individuals who were informed that the questions were difficult to answer whereas with FOKs there was a failure to observe an effect of demand characteristics. Given this failure to observe an effect of demand characteristics on FOK reports it is reasonable to assume that the need to confabulate (if it existed) would have little impact on the frequency and/or strength ratings of FOKs reported in the present study.

The present findings extend what we know about the contribution of the PFC to FOK reports in that when age was used as a covariate we observed a difference in the accuracy of reported FOKs that varied as a function of PFC functioning. Individuals with less-than-optimal PFCs reported less accurate FOKs than individuals with relatively intact PFCs. Additionally, we observed that individuals with deficient PFC functioning reported fewer FOKs relative to individuals with intact PFCs. Finally, we observed that there were a greater number of objective FOK reports by individuals with intact PFCs relative to the reports by individuals with deficient PFCs.

It is interesting to note that individuals with deficient PFC functioning reported approximately the same number of FOK experiences ($\underline{M} = 4.83$) as TOT experiences ($\underline{M} = 5.53$) whereas individuals with intact PFC functioning reported a substantially greater number of FOKs ($\underline{M} = 8.58$) than TOTs ($\underline{M} = 5.64$). Nelson and Narens (1990) have suggested that an individual's willingness to report metamemory states can be altered by changing the response threshold. Thus, it is possible that in the present study individuals with deficient PFCs adopted a response criterion that was impervious to the type of metamemory report that they were required to make. A strategy that may have been adopted is the use of a more stringent response "threshold" for reporting FOKs by individuals with deficient PFC functioning relative to individuals with intact PFC functioning – such a strategy would increase the likelihood that an

FOK was actually being experienced before reporting it to the experimenter. If this is the case then one might expect the participant-assigned strength levels would be greater for individuals who adopted a stringent criterion (e.g., individuals with deficient PFC levels) versus those who adopted a less stringent criterion (e.g., individuals with intact PFC levels). However, this possibility is weakened by the finding that 63.79 % of reported FOKs by individuals with deficient PFC levels had a strength rating above 10 (excluding 10) and individuals with intact PFC levels had 61.17 % above a strength level of 10.

That deficiencies in PFC functioning can affect the qualitative dimensions of a phenomenon that is under study (e.g., affecting response threshold placement) is not a new finding. For example, Braver et al. noted that in neuroimaging studies of working memory there is an increase in the demands on processing resources in the activation condition, relative to the control condition, which may cause participants to adopt new strategies and therefore, may change the nature of the task (e.g., the processes / mechanisms) such that the engaged processes are no longer related to working memory.

If we accept the assumption that TOTs are merely strong FOKs then we would expect the PFC to play a greater role when individuals report TOTs relative to when they report FOKs. We examined this possibility in Experiment 2 and found this expectation to be unsupported; the frequency of TOTs, the number of objective TOTs, the accuracy of TOT reports, and the participant-assigned TOT strength ratings were invariant to level of PFC functioning. One might argue that because different individuals participated in Experiments 1 and 2 that these individuals differed in terms of level of PFC functioning and it is this difference that resulted in the differential effects of PFC functioning on FOK and TOT reports. We examined this by statistically comparing the number of preservative errors exhibited by individuals in

Experiment 1 with the number of errors exhibited by individuals in Experiment 2 and found no difference, $t(52) = .79$, $p < .43$, $SE = 1.91$. Thus, level of PFC functioning was the same for individuals who participated in Experiment 1 as it was for individuals in Experiment 2.

Based on the present findings we can, with some confidence, conclude that FOKs and TOTs are qualitatively different metamemory phenomena; TOTs and FOKs do not lie along a single continuum of strength (a quantitative relationship). For several reasons the finding of a qualitative difference between these two metamemory phenomena was not surprising. First, the TOT definition commonly provided participants is comprised of two components: a feeling that the answer is known and a feeling that the answer will "pop" into mind at any moment (e.g., Brown & McNeill, 1966; Koriat & Lieblich, 1974). According to Widner et al. (1996), what differentiates FOKs from TOTs is that for the latter experience there exists a feeling of "imminence" (i.e., that the sought-after information will materialize at any moment). A second reason for expecting a qualitative difference between these two experiences is the finding reported by Widner et al. (1996) where it was found that demand characteristics of the experimental setting affected the frequency of TOT reports but had no effect on the frequency of FOK reports.

It is intriguing that given there was a substantial difference in the number of preserverative errors on the WCST by individuals in the High- and Low-Error groups that there was no difference in recall levels (the one exception was in Experiment 2 when age was used as a covariate). When information is retrieved from memory, as under free-recall conditions, there is utilization of working memory. Shimamura (1994) has shown that individuals with frontal lobe dysfunctions perform poorly when they must retrieve information from memory such as under free-recall conditions (i.e., retrieval of information without contextual support), though these same individuals show intact recognition performance (where contextual support is high). Even when one matches the difficulty level of the recall and recognition test (e.g., Hanley & Davies, 1997) there still remains a distinct disadvantage in recall for individuals with frontal lobe dysfunctions. It appears that in the present study there were questions to which answers came to mind without a substantial amount of cognitive resources and therefore were unaffected by level of PFC functioning. Several participants, particularly older adults, commented on how answers came to mind without much effort on their part; they were "surprised" how many answers they knew. As noted by Janowsky et al. (1989), some general-knowledge questions may tap information that is well integrated into an individual's knowledge structure and therefore readily available and consequently, unaffected by level of PFC functioning

Another explanation for the present findings is suggested by a conclusion drawn by Winocur, Moscovitch, and Stuss (1996). They proposed that the PFC plays a role in those instances in which the retrieval cues are not effective. Thus, it is possible in that in Experiment 1 recall levels did not differ because for those questions that were correctly answered there may have been effective retrieval cues present whereas for those questions in which the answer was not produced retrieval cues may have been less effective.

It is intriguing that in the present study we failed to find an effect of PFC functioning on TOT reports. An area of major interest in cognitive psychology is the possibility that unconscious (i.e., unintentional) mental processes can affect conscious (i.e., intentional) perceptions and memories. In the present study we observed a cognitive process, the reporting of TOT experiences, that is affected by an unintentional process (e.g., an intense feeling that some sought-after information is available in memory). We propose that the intense feeling that exists when one is having a TOT experience is independent of an individual's intention to retrieve information from memory. Further, we suggest that this intense feeling initiates strategic searches of memory for the sought-after information and it is this latter stage that is dependent on intentional cognitive processes.

This notion that individuals with deficient PFCs have access to non-intentionally retrieved information is not novel. A similar claim was made by Kimberg, D'Esposito, and Farah (1998) where they asserted that a salient characteristic of PFC dysfunctions is that the system operates autonomously without much influence from top-level control mechanisms. Similarly, Coslett and Saffran (1989) have shown that patients with "pure alexia" are unable to identify briefly presented words but perform at above chance levels on lexical decision and forced-choice categorization tasks. Finally, Shimamura (1986, 1993) has shown that individuals with PFC dysfunctions exhibit priming effects that are similar to those exhibited by individuals with intact PFC functioning.

Given that we found no difference in the frequency, accuracy, or strength of TOT reports by individuals with intact versus deficient levels of PFC functioning it is possible to generate a post-hoc explanation. We suggest that there are two stages involved when reporting TOTs. The first stage is comprised of a spontaneous, effortless, feeling that the sought-after information is available in memory; a feeling not based on the intentional retrieval of information. Thus, at this first stage we would not expect a contribution of the PFC. We propose that the second stage is substantially more effortful, and frustrating, than the first stage and it is at the second stage where there exist intense and systematic searches of memory for the sought-after information. It is at this second stage that we would expect a substantial contribution by the PFC such that individuals with deficient PFC functioning would retrieve less information from memory than individuals with intact PFCs. Such a model as proposed here raises several intriguing issues.

For example, how intense does a feeling that some sought-after information is available have to be before there is initiation of a strategic search process of memory. We are currently examining this possibility along with other possibilities.

There is a precedent for the proposal of a two-stage model that incorporates an unintentional as well as an intentional component. For example, it has been suggested that the initial encoding of temporal information is automatic but that a later stage may involve more effortful processes (e.g., Jackson, 1990; Naveh-Benjamin, 1990; Zacks, Hasher, Alba, Sanft, & Rose, 1984). Support for our hypothesized first stage can be obtained from Mandler's (1994) assertion that there exist several cognitive phenomena (e.g., hypermnesia, TOTs, and solving crossword puzzles) in which the deliberate retrieval of sough-after information actually impedes a successful outcome whereas non-intentional approaches would likely result in the successful retrieval of the information. With respect to TOT experiences, many of us in our daily lives have adopted a non-intentional strategy to retrieve the elusive information. For example, we might change the topic of discussion (i.e., refrain from thinking about the sought-after information) hoping that the information we were so intent on finding will materialize.

Given this logic (i.e., information can come to mind without the rememberer's intent) it is reasonable to expect that individuals with deficient PFC functioning will have little difficulty in retrieving information that is non-intentional in nature (e.g., such as a strong feeling that the sought-after information is available). Thus, one might expect, based on this reasoning, that individuals with deficient PFC functioning would experience TOTs that are similar in all aspects (e.g., frequency, accuracy, and strength) to TOTs experienced by individuals with intact PFC functioning. This is the pattern of results that we observed in the present study.

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