Contributions of the Frontal and Medial Temporal Lobes to Recognition Memory Performance in Young Adults

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Previous research with older adults suggests that the frontal lobes and the medial temporal lobes play an important role in recognition memory. The goal of this study was to investigate the impact of high/low frontal lobe and medial temporal lobe status in younger adults' recognition memory performance. Twenty-four college-aged women completed a neuropsychological battery and a recognition memory task. Behavioral and event related potential (ERP) data were collected during the recognition memory task. The results indicated that, in young adults, the medial temporal lobe showed the greatest contribution in both the old/new effect and in subsequent recollection and familiarity responses, with frontal lobe contributing minimally to either the old/new judgment or the recollection and familiarity judgment. In summary, though the frontal lobe plays a great role in the differentiation of recollect/familiar responses in older adults, we do not see this pattern in young adults. This suggests a developmental change occurring in the frontal lobe in older adulthood, where the frontal lobe assumes a bigger role in judgments succeeding the old/new judgment, either due to compensatory mechanisms or dedifferentiation.

"I enter a friend's room and see on the wall a painting. At first I have the strange, wondering consciousness, 'surely I have seen that before,' but when or how does not become clear. There only clings to picture a sort of penumbra of familiarity, - when suddenly I exclaim: "I have it, it is a copy of one of the Fra Angelicos in the Florentine Academy – I recollected it there!"

–from the *Principles of Psychology* (p. 658) by William James.

Recognition memory has long been recognized as an essential human cognitive ability that allows one to identify stimuli, such as people, places, and items, as having been previously experienced (Onyper, Zhang, & Howard, 2010). As James indicated in his passage in the Principles of Psychology, there are hypothesized to be two processes at work within recognition memory: recollection and familiarity. Recollection is the process posited to occur when a previously seen item is successfully recognized as 'old' and that this item is recognized in the presence of contextual, or source, information. We refer to this as "details" in this study. We see this recollection occurring later in James' statement, where he implicates the source of his recognition of the painting as being from the Florentine Academy. Familiarity, on the other hand, is the successful recognition of an 'old' item without attached context or source information. This, in James' statement, is the foremost notion that he has 'experienced' the painting before, but is unsure of the specifics of this experience.

These two processes have culminated, in cognitive psychology and neuroscience literature, into a dual-process explanation of recognition memory. This dual-process account assumes that recollection and familiarity are neurologically and neuropsychologically distinct mechanisms. Investigations into the distinctness of recollection and familiarity within recognition memory include neuropsychological studies as well as scalp electroencephalography and functional magnetic resonance imaging (Onyper, Zhang, & Howard, 2010). Literature has focused on illustrating that recollection and familiarity-based responses are associated with qualitatively different patterns of neural activity, leading to the inference that these brain regions are indeed contributing qualitatively different types of information to the ultimate recognition decision (Malmberg, 2008).

The goal of the current study is to utilize neuropsychological and EEG methodology to reproduce the finding that young adults can be differentiated into two functional groups—low and high frontal lobe and low and high medial temporal lobe functioning—in order to explore differences in old/new and recollection/familiarity behavioral judgments and neurological patterns associated with these judgments.

Application of Event Related Potentials to Recognition Memory

Event-related potential (ERPs) studies are a valuable method of investigation into the neural correlates underlying this dual process account. The ERP method extracts time-locked potentials from scalp-recorded electroencephalography records by averaging across defined conditions, and consists of a sequence of positive and negative voltage fluctuations of labeled components (Paller, Voss, & Boehm, 2007; Friedman & Johnson, 2000), which allows for indirect investigation of neural activity and, further, active brain regions, at both encoding and retrieval of information (Friedman & Johnson, 2000). Specifically, the distinct components of ERP can give us valuable information regarding the covert data: component amplitude provides an index of the extent of neural activation, such as how the component responds functionally to experimental variables; component latency, or the point in time at which the peak occurs, discloses the timing of this activation; finally, the scalp distribution component, or the pattern of voltage gradient over the scalp at any point in time, delivers information on the overall pattern of activated brain areas (Friedman & Johnson, 2000).

ERPs have a temporal resolution in the millisecond range, which allows for precise quantification of the temporal characteristics of neural activity, which is particularly important in memory research (Friedman & Johnson, 2000), though they lack the spatial resolution required to address questions regarding neural substrates, or brain regions, of specific and different processes (Rugg & Yonelinas, 2003). However, ERPs are incredibly valuable in terms of qualitative distinctions (as indicated by time epoch, scalp distribution/topography and magnitude of signals), which can still imply distinct neural substrates (Rugg & Yonelinas, 2003). The recent advent of functional imaging has allowed for the complementation of ERP data with fMRI data, especially event-related fMRIs, coupling the spatial resolution of hemodynamic data with the temporal resolution of scalp EEG, allowing for a more complete interpretation of the processes and brain areas recruited during formation and retrieval of explicit memories (Friedman & Johnson, 2000).

Recognition memory paradigms make direct reference to previous learning, usually a series of items or words which, after a designated delay period, are tested with lists that include both these ‘old’ stimuli and stimuli not previously seen (new) (Friedman & Johnson, 2000). ERPs recorded about 300 to 800ms after the onset of a recognition memory test stimulus show reliable differences between these old (studied) and new (not studied) conditions (Curran, 2004), where old words elicit a larger late positive component over parietal scalp in the interval between 400-800ms than do new words (Friedman & Johnson, 2000). This effect has been referred to as the parietal old/new effect (Friedman & Johnson, 2000).

Dissociating the processes of Recollection and Familiarity: ERP, and how it is complemented by Neuroimaging Data

ERP Data. Support for the distinction of familiarity and recollection as involving different neural patterns and, perhaps, brain regions, has come from ERP investigations. In many of these studies, the Remember/Know paradigm is utilized. First introduced by Tulving in 1985, this paradigm attempts to investigate the conscious experience accompanying explicit memory retrieval, whereas participants indicate a Remember judgment only if the recognized stimuli evokes recollection of a specific source in which the stimuli was previously experienced (Tulving, 1985). On the other hand, participants would indicate a Know judgment if the recognized stimuli were thought to have been previously experienced, but that this judgment did not contain context or source information about the previous experience (Henson, Rugg, Shallice, Josephs, & Dolan, 1999). Remember judgments are thought to reflect recollective processes, and Know judgments are thought to reflect familiarity-based processes.

Encoding. It is reasoned that, if recollection and familiarity are distinct processes at retrieval, these differences might have their locus at encoding. In a study by Friedman and Trott, the ERPs associated with study items that were subsequently associated with Remember judgments (that is, a response indicating that an item has been retrieved along with its context), elicited a greater amplitude from roughly 400 to 1,100ms than those items that were subsequently unrecognized, or missed. In contrast, patterns observed to study items subsequently associated with Know judgments (thought to reflect familiarity-based retrieval) did not differ reliably from patterns elicited by items subsequently unrecognized, or missed (Friedman & Trott, 2000; Friedman & Johnson, 2000). These findings suggested that processes prompting a Remember or Know judgment might have their locus during encoding.

In an article utilizing recognition memory for pictures (where participants studied pictures of objects in two types of study blocks and subsequently made Remember-Know and source memory judgments at retrieval), investigators indicated that, when processes at encoding were investigated in reference to pictures that were successfully recognized as ‘old,’ a right anterior positivity at 300-450ms was observed for pictures subsequently indicated as ‘remembered’ and a left anterior positivity at 300-450ms was observed for pictures subsequently indicated as ‘known,’ which investigators believed to imply the familiarity-component__(Duarte, Ranganath, Winward, Hayward, & Knight, 2004). While the onset times of these ERP patterns were similar, the topography and time course was distinguishable, which implied that recollection and familiarity could potentially present as different neural processes at encoding.

An intriguing hypothesis drawn from these data implicates various parts of the medial temporal lobe, suggesting that the perirhinal cortex subserves familiarity (sufficient for Know judgments), whereas the hippocampus proper subserves recollection (Remember judgments) (Aggleton & Brown, 1999). This hypothesis is supported by the limited investigations of the processes of Remember and Know judgments at encoding; specifically, Mangels et al. (2000) indicated that an early negativity (N340) did not differentiate ERPs elicited by items that would subsequently elicit Remember judgments from those that would elicit Know judgments, but that this data was recorded outside the hippocampus proper (Fernandez, Effern, Grunwald, Pezer, Lehnertz, & al, 1999; Friedman & Johnson, 2000). Likewise, the hypothesis was supported in two studies indicating that slow positivity during encoding was sensitive to recollective processes in which recordings were taken from within the hippocampus proper (Fernandez, Effern, Grunwald, Pezer, Lehnertz, & al, 1999; Friedman & Johnson, 2000; Friedman & Trott, 2000).

The small amount of data revolving around the differentiation of recollective- and familiarity-based processes at encoding does not allow one to reach a definitive conclusion about potential neural implications or associated brain regions.

Retrieval

Familiarity. The research revolving around familiarity-based processes at retrieval is mixed, with some research implicating an early (300-500ms), mid-frontal, negative ERP effect, usually known as the FN400 old/new effect, in familiarity (Curran, 1999; Curran, 2000; Curran, Tanaka & Weiskopf, 2002; Curran & Cleary, 2003; Curran, 2004; Curran & Dien, 2003)

The FN400 is thought to relate to familiarity for several reasons. In one of the prime arguments for its relationship to the familiarity process, the FN400 responds similarly to studied items and similar lures, such as studied words and plurality-reversed lures (Curran, 2000), studied pictures and orientation-reversed lures (Curran & Cleary, 2003), studied geometric figures and visually similar lures (Curran, Tanaka, & Weiskopf, 2002) and studied words and semantically similar lures (Nessler, Mecklinger, & Penney, 2001; Curran, 2004). During these phenomena, the FN400 component does not change, while the component hypothesized to be related to recollection, the parietal old/new component, is affected. Finally, this FN400 begins roughly 100ms earlier than the proposed parietal old/new effect implicated in recollection, which correlates with speeded responding experiments implicating familiarity-based processes as present earlier than recollective processes (Yonelinas & Jacoby, 1995; Friedman & Johnson, 2000). Thus, the FN400 is thought to reflect familiarity (Paller, Voss, & Boehm, 2007).

However, the FN400 has been questioned in its validity for assessing familiarity, whereas some authors have not replicated the finding in amnesic patients (Curran, 2004; Olichney, Petten, Paller, Salmon, Iragui, & Kutas, 2000), suggesting that the FN400 may be more related to a novelty-detection process downstream of familiarity judgment (Tsivilis, Otten, & Rugg, 2001), or that the FN400 could measure an unknown combination of familiarity and other co-occurring memory phenomena, like conceptual priming (Paller, Voss, & Boehm, 2007).

Recollection. A later (400-800ms), parietal, positive ERP effect is thought to be related to recollection, and is often called the parietal old/new effect (Curran, 2004). This parietal old/new effect is maximal over left parietal electrode sites, and is topographically and functionally distinct from the mid-frontal/FN400 old/new effect (Diana, Van den Boom, Yonelinas, & Ranganath, 2011; Allan, Wilding, & Rugg, 1998; Curran, 2000; Curran & Cleary, 2003; Curran & Dien, 2003; Curran, Tanaka, & Weiskopf, 2002)

As stated earlier, recollection is characterized by the retrieval of qualitatively specific source information regarding the recognized items, and therefore the observation that this proposed parietal old/new effect is affected in experiments involving studied and similar lures (see aforementioned examples) provides consistent support for a relationship to the process of recollection (Curran, 2004). This parietal old/new effect is larger when the subsequent recognition of an item is based upon “remembering” rather than “knowing,” in the Remember/Know paradigm discussed earlier (Duzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Rugg, Schloerschedit, & Mark, 1998; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999). The parietal old/new effect has been found to be sensitive to other variables affecting recollection, like word frequency (Rugg M. D., 1990; Rugg, Cox, Doyle, & Wells, 1995), level-of-processing (Rugg, Allan, & Birch, 2000; Paller & Kutas, 1992), and words versus pseudowords (Curran, 1999; Curran, 2004). Decisions thought not to involve recollection (incorrectly categorizing old words as new, incorrectly categorizing new words as old and correctly rejecting new words) all reflect parietal effects that are dissimilar to the proposed parietal old/new effect in recollection (Johnson, Kreiter, Russo, & Zhu, 1998a; Smith & Guster, 1993; Wilding, Doyle, & Rugg, 1995; Friedman & Johnson, 2000).

In summary, a plethora of ERP studies have hypothesized regarding the neural patterns underlying familiarity and recollection. The FN400 and parietal old/new effects have been dissociated in research as encompassing different time epochs and scalp topographies, and having differential effects in experimental manipulations (Curran, 2004). The general opinion of investigators supports the implication of a parietal old/new component at retrieval for recollection, though opinions are divided on the implication of an FN400 component as representing familiarity at retrieval. Moreover, the evidence is more conclusive of this difference at retrieval than at encoding, though the cumulative evidence does inspire the view that these differences are present in both instances and reflect different brain processes possibly underlying recollection and familiarity. Taken along with recent functional neuroimaging studies and neuropsychological results, these data imply that recollection and familiarity are supported via functionally distinct neural representations_(Duarte, Ranganath, Winward, Hayward, & Knight, 2004).

Support from neuroimaging and neuropsychological data

The finding that recollection and familiarity result in distinct ERP components is complemented by neuropsychological and neuroimaging data. Patients with medial temporal lobe lesions support Aggleton and Brown’s (1999) hypothesis (suggesting that the perirhinal cortex subserves familiarity, whereas the hippocampus proper subserves recollection), implicating the hippocampus proper in recollection and the surrounding regions, like the rhinal cortex, in familiarity. Recent fMRI studies have supported this distinction. An overview of fMRI studies at retrieval has implicated that different patterns of brain activity in frontal, parietal, and medial temporal cortices make-up recollection and familiarity, and suggest that recruitment of additional brain regions in frontal and medial temporal cortices occurs during recollection (Skinner & Fernandes, 2007).

Familiarity. The ERP component, FN400, as discussed earlier, has been shown via intracranial recordings and magnetoencephalography (MEG) to possibly originate from anterior, inferior temporal regions like the perirhinal cortex (Duzel, et al., 2003; Curran, 2004). Further, recent fMRI research has implicated an old/new difference in the perirhinal cortex thought to be related to familiarity, such that these differences were not sensitive to processes thought to involve recollection, such as intentional/incidental task differences and amount of contextual information received (Curran, 2004).

The role of level of confidence was found to be important in implicating brain regions associated with familiarity judgments. In a large meta-analysis of fMRI data at retrieval, studies found that frontal BA areas 45 (pars triangular of the inferior frontal gyrus) and 6 (premotor cortex and supplementary motor area) of the left hemisphere showed high agreement in increasing activation with increasing confidence, as did left BA 39 (angular gyrus) in the inferior parietal lobe. In all of the studies, medial temporal lobe activation increased with decreasing confidence, specifically in the hippocampus (Yonelinas, Otten, Shaw, & Rugg, 2005), perirhinal cortex (Montaldi, Spencer, Roberts, & Mayes, 2006) and rhinal cortex (Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006; Skinner & Fernandes, 2007).

Recollection. The ERP left parietal old/new effect is corroborated by much neuropsychological and neuroimaging evidence. An amnesic patient with seemingly isolated bilateral hippocampal damage sustained in childhood demonstrated the FN400 old/new effect, but not the parietal old/new effect, suggesting that hippocampal activity is central to the process of recollection (Rugg & Yonelinas, 2003). The debate still continues as to whether or not the hippocampal region also contributes to familiarity, as briefly indicated in the above section; however, functional imaging studies have shown that hippocampal activity is more associated with "remember" rather than "know" judgments (Eldrige, Knowlton, Frumanski, Bookheimer, & Engel, 2000), and in source recollection (Dobbins, Rice, Wagner, & Schacter, 2003; Curran, 2004). Performance on source recollection tasks is commonly used to elucidate the processes of recollection, as the foundation of recollection relies on the ability to recall source information along with successful recognition (Friedman & Johnson, 2000). In a meta-analysis of fMRI studies at retrieval, high levels of agreement were found for activation in BA 40 in the parietal lobe, with higher concordance in the left hemisphere, and high agreement was found across the 11 studies examining activity within the medial temporal lobe (Skinner & Fernandes, 2007).

Brain regions and patterns implicated in recollection and familiarity. Thus, ERP data and complementary neuroimaging and neuropsychological evidence have contributed to the understanding of brain regions and patterns of activity associated with the processes of familiarity and recollection.

The prefrontal cortex has come under close scrutiny, as it has been realized that this area plays a critical role in both recollection- and familiarity-based processes, but that recollection probably involves additional prefrontal activity (Skinner & Fernandes, 2007). This conclusion makes considerable sense, as many studies have implicated the anterior prefrontal cortex in the retrieval of source information (Cansino, Maquet, Dolan, & Rugg, 2002; Kahn, Davachi, & Wagner, 2004; Rugg, Fletcher, Firth, Frackoqiak, & Dolan, 1996; Skinner & Fernandes, 2007). rTMS (repetitive transcranial magnetic stimulation) over dorsolateral prefrontal cortices (DLPFC) at encoding was found to significantly affect both recollection and familiarity, which is likewise corroborated by the neuroanatomy of this system, such that the DLPFC receives direct projections from the entorinal/perirhinal cortex and hippocampus (Turriziani, Smirni, Oliveri, Semenza, & Cipolotti, 2010). Aforementioned evidence suggests that familiarity and recollection, respectively, involve these brain areas, therefore upholding the finding that rTMS at encoding affects both processes. Neuropsychological analyses, such as the remember/know, receiver operation characteristic and source recognition paradigms, have also indicated that prefrontal cortex damage can impair both recollection and familiarity (Duarte, Ranganath, & Knight, 2005; Farovik, Dupont, Arce, & Eichenbaum, 2008; MacPherson, Bozzali, Cipolotti, Dolan, Rees, & Shallice, 2008; Yonelinas, Aly, Wang, & Koen, 2010). However, the precise contribution of the frontal cortex, specifically prefrontal cortex, to the processes of recollection and familiarity remains unclear.

The parietal cortex has also been implicated in the differentiation of recollection and familiarity, especially due to the ERP finding of the maximal left parietal old/new effect in recollection. In general, multiple studies have found that the parietal lobe shows greater activation for hit than correct rejection responses (Kahn, Davachi, & Wagner, 2004; Konishi, Wheeler, Donaldson, & Buckner, 2000; Wheeler & Buckner, 2004; Skinner & Fernandes, 2007). More specifically, we learn, from the same fMRI meta-analysis mentioned earlier, that both recollection and familiarity activate precuneus regions of the parietal lobe (BA 7), but recollection also activates the inferior parietal lobe (BAs 40 and 39) (Skinner & Fernandes, 2007). This finding was subsequently corroborated by another meta-analysis, mentioning that the left inferior lateral parietal cortex (BA 39/40) has been consistently linked to recollection (Vilberg & Rugg, 2007).

The medial temporal lobe has been discussed extensively throughout this section, as research is drawn as to whether or not the medial temporal lobe supports only recollection, or both recollection and familiarity. Some research has indicated that the level of confidence of a judgment reflects uniquely within the medial temporal lobe, such that familiarity-based responding is associated with a decrease in activity in some parts of the medial temporal lobe, such as the hippocampus (Yonelinas, Otten, Shaw, & Rugg, 2005), perirhinal cortex (Montaldi, Spencer, Roberts, & Mayes, 2006) and rhinal cortex (Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006; Skinner & Fernandes, 2007). In other studies, familiarity is generally associated with the surrounding entorhinal and perirhinal volume of the medial temporal lobe (Yonelinas, Aly, Wang, & Koen, 2010). Recollection is thought to be related to the hippocampus proper (Aggleton & Brown, 1999); this is corroborated using different paradigms, such as the Remember/Know, source memory and ROC paradigms, whereas 16 of 19 studies showed that the hippocampus was involved in recollection (Yonelinas, Aly, Wang, & Koen, 2010).

Contributions of the Frontal Lobe and Medial Temporal Lobe and the Frontal Lobe Hypothesis of Cognitive Aging

We have discussed data from ERP and neuroimaging studies implicating specific brain regions and patterns of activation in the processes of recollection and familiarity. The ability to tap into these areas via neuropsychological investigation opens the doors to utilizing ERP to investigate the varied functional contribution of areas such as the frontal lobe and medial temporal lobes to judgments of recollection and familiarity, and to possibly obtain a double dissociation between brain areas utilized during tasks tapping into these processes.

Glisky et al. administered several neuropsychological tests to an elderly population in an attempt to create two independent factors measuring frontal lobe and medial temporal lobe function (Glisky, Polster, & Routhieaux, 1995). The highest loading tests on the frontal lobe factor were the Mental Arithmetic Test (consisting of 14 time-limited questions requiring mental arithmetic) and the Mental Control Test (consisting of several prompts ranging from easy to difficult, reaching from naming the months of the year to alternating counting by sixes whilst reciting the days of the week), both from the Weschler Memory Scale-Revised. The highest loading tests on the medial temporal lobe factor were the Logical Memory Test (involving the recitation of two stories, with the second story being presented twice, and requiring the verbatim response of each story from the participant), Verbal Paired Associates (involving a list of word pairs and a subsequent prompt to elicit the correct word to complete the pair) and Visual Paired Associates (involving a shape/image paired with a color and a subsequent prompt to match the shape/image with the correct color), all subtests of the Weschler Memory Scale. A long-delay cued recall subtest from the California Verbal Learning Test was also included (Glisky, Polster, & Routhieaux, 1995). The test performances of 48 older adults, between the ages of 65 and 87, allowed for subsequent classification of each individual into high or low frontal lobe functioning and high or low medial temporal lobe functioning groups.

Much research suggests that frontal lobe functioning in older adults has been shown to mediate age-related deficits in item and source memory (Glisky, Polster, & Routhieaux, 1995), in that a decreased involvement of the frontal lobe in aging populations causes poorer recollection though intact familiarity. This theory of cognitive aging is broadly known as the frontal lobe hypothesis of aging. The frontal lobe hypothesis predicts that functions principally dependent on frontal regions would decline in cognitive aging (for example, recollection), while functions fundamentally independent of frontal lobes would continue comparatively spared. The hypothesis further predicts that age-related brain change would selectively impact frontal regions. However, evidence suggesting otherwise is illustrated well by Glisky and Kong, who found that neither college freshmen nor a group of more educated young adults differed significantly from older adults on the cumulative frontal lobe factor, either in mean level of performance or in variability (Glisky & Kong, 2008). This result leads one to question the validity of the frontal lobe hypothesis of aging's main point, which presumes that the frontal lobe is as heavily implicated in recollection in young adults as it is in older adults.

There is mounting evidence to support the view that not all cognitive functions diminish at the same rate, and that there are marked individual differences playing a part in the decline rate (Glisky, Polster, & Routhieaux, 1995). Research investigating the frontal lobe hypothesis of cognitive aging has largely assumed that all younger adults are high in frontal lobe functioning and that differentiation in level of functioning only occurs with aging. Thus, if younger adults show differentiation in level of frontal lobe functioning, it is likely that this level will be associated with variance in performance on measures of memory, in that younger adults lower in frontal lobe functioning may perform significantly worse on cognitive tasks compared to high functioning younger adults, and that this poor performance due to individual difference may show exacerbated differences with age. This finding is highly probable, as Glisky and Kong indicated that, among normal young people, the variability between the two neurocognitive domains (frontal lobe and medial temporal lobe) was sufficient for differentiation into two distinct (low versus high functioning) categories (Glisky & Kong, 2008). There is also the possibility that young adults may show completely different functional usage of the frontal lobe in recognition memory, where the frontal lobe may not play as big of a role in recollection young adults as it does in older adults.

Present Study

All evidence taken together, it may well be the case that frontal lobe function is a product contingent on individual and cognitive age differences. The present study aims reproduce the finding that a group of young adults can be differentiated into two functional groups—low and high frontal lobe and low and high medial temporal lobe functioning—as first demonstrated by the neuropsychological assessment of Glisky and Kong, in order to be the first study to test the hypothesis that differences (behavioral and neurological) in old/new and recollection/familiarity success in recognition memory tasks exist in populations other than those who are experiencing cognitive aging, and to explore if young adults show the same functional patterns (that is, determining if the judgments of old/new and recollection/familiarity implicate similar brain regions and time epochs) as we see in older adults.

Behavioral Hypotheses H_1: Young adults will be reliably differentiated into high and low functioning groups based on their performance on the frontal lobe and the medial temporal lobe measures in the Glisky battery.

H_2: High and low frontal lobe and high and low medial temporal lobe young adult groups will differ in terms of overall memory performance.

H_3: High and low frontal lobe and high and low medial temporal lobe groups will differ in terms of their recognition memory judgments both in terms of the number of recollection and familiar responses and their newness judgments.

Neurological (ERP) Hypotheses H_1: The old/new effect will be replicated in this population of young adults, resembling the old/new effect seen maximally over parietal electrodes in the epoch 300-800ms.

H_2: Following illustration of an old/new effect, it is hypothesized that the ERP patterns of words judged as "old" (hits) will be different in the high and low frontal lobe and high and low medial temporal lobe group.

H_3: ERP pattern differences will differ for recollected versus familiar judgments; it is predicted that the high medial temporal lobe group will show a more positive recollective ERP component than the low medial temporal lobe group and frontal lobe groups during recollection, if indeed the frontal lobe does not play as significant of a role in recollection young adults as it does in older adults.

METHOD

Participants. Participants were recruited via email from the population of Bryn Mawr College, an all-women's liberal arts college near Philadelphia, PA. Participants (n=24) were all female, between the ages of 18-22 and currently enrolled in the college. Of the 24 participants, 17 spoke English as their first language, with the remaining speaking English for a mean of 14.71 years. Participants were compensated $30 for the experiment. Of the 24 participants that were originally recruited, 2 were removed due to problems with EEG data collection or incompletion of the neuropsychological portion of the study.

Materials.

Neuropsychological evaluation. The neuropsychological evaluation consisted of six tasks pulled from the Glisky battery (Glisky, Polster, & Routhieaux, 1995), of which three tapped frontal lobe function (Mental Arithmetic, Mental Control and Letter Fluency) and three tapped medial temporal lobe function (Logical Memory, Verbal Paired Associates and Visual Paired Associates). These tasks were chosen because they had the highest loading on the frontal lobe and medial temporal lobe factors.

Mental Arithmetic consisted of fourteen time-limited questions that require mental arithmetic to answer. Scores were based on accuracy and response time. The Mental Control task required participants to recite as quickly and accurately as possible the days of the week, the months of the year, and the numbers 1-20 forwards and backwards as well as alternating counting by sixes and reciting the days of the week. Scores were based on accuracy and response time. In the Letter Fluency task, participants are given one minute to generate words beginning with a given letter (e.g., F, A, S). In the Logical Memory task, participants heard two short stories: the first story was presented once and the second story was presented twice. After the presentation of each story, participants were asked to verbally recall as much of the story as possible. Scores were based on a standardized assessment of how accurately the participant recalls the story. On Verbal Paired Associates, participants were read a list of word pairs. Participants were then prompted with the first word of each pair and asked complete the pair with the correct recalled word. The list was read four times and recall was assessed after each presentation. Scores were based on the number of correctly completed pairs over the four trials. Finally, on Visual Paired Associates, participants are shown a series of colors and designs and must recall which design was associated with which specific color. The list is shown six times and recall is assessed after each presentation. Scores were based on the number of correctly completed pairs over the six trials.

Administration of the tests within this battery were arranged randomly for each participant, with the exception of the Visual Paired Associates II, which, by necessity, had to be either the second-to-last or last test administered due to its delayed nature. This battery took approximately half an hour to complete, and was either done directly after the memory experiment or within a week of completion of the memory experiment.

Recognition Memory Stimuli. The recognition memory task involved a study and test phase. The task utilized a 17” computer screen monitor. In the study phase, a fixation cross appeared for 1000ms, followed by a study word that also remained for 1000ms. At test, the participant was prompted for two decisions. The first decision was an old/new decision and revolved around whether or not the word presented was or was not seen on the previous study list. After making their old/new judgment, participants were further prompted to subjectively qualify their answer. If the participant indicated that the word was “new” and therefore not seen on the study list, they were then prompted to rank this answer on a continuum as “very sure new,” “sure new” or “somewhat sure new.” If the participant indicated that the word at test was “old” and therefore seen on the study list, they were then prompted to rank this answer on a recollection/familiarity continuum, from “weak feeling of familiarity,” “strong feeling of familiarity,” “few details,” or “lots of details.” The meaning of familiarity versus recollection was explained to the participant before any portion of this task was completed.

All indications of subjective ranking were done using assigned computer keys. The assignment of the possible responses to keys appeared on the screen with every test item, so that subjects did not have to memorize key assignments (for example, M=old, Z=new). There was also a time limit associated with each response: subjects only had 3000 ms to make each evaluation, at which point a message reading “too slow or wrong key” would appear, and transition into the next fixation and test word would occur.

Before the EEG cap was fitted, participants completed a shortened, practice version of the task to establish that the participant understood the meaning of familiar versus recollected words. In this shortened, practice version of the task, 20 words were presented at study and 40 words at test.

When the EEG cap was successfully fitted, subjects completed the full version of this recognition memory task, which involved three blocks of study/test. At study, 150 words were presented, with 300 words presented at test. There were two version of this paradigm, which were counterbalanced between participants.

Each block took roughly 16 minutes to complete. After each block, subjects were given a break that ranged anywhere from 2 to 5 minutes in length.

Electroencephalography. The memory ERP component utilized a NeuroScan Quik-Cap 32-port electrode cap, attached to NeuroAmp and recorded via Scan 4.5 software. The EEG machinery employed six facial electrodes to control for artifacts, which were placed as such: one on each mastoid, one on each temple, and one above and below the participant's left eye. These sites were prepped with an alcohol wipe and an exfoliating scrub. The facial electrodes were first filled with a water-based gel, adhered to the skin via easily removable adhesive collars, and subsequently "twirled" with a blunt-tipped needle to loosen the skin and insert a fresh column of gel. Before the cap was fitted, the electrodes were filled with QuikCells, a technology created by NuAmp, utilizing a compressed, desiccated cell placed in the electrode reservoir. When fitted on the head, these QuikCells were filled with an electrolyte, thus allowing the electrolyte to expand the cell, much like a sponge, to target the precise scalp area with little chance of bridging. The ground electrode, placed 10cm above the nasium, was the only electrode site filled with the water-based gel. Medical mesh was placed over the cap if the cap did not fit snuggly in certain places, as was often the case near the occipital electrode sites. The cap was then plugged into the NuAmp amplifier.

Data was collected on the Scan 4.5 program. Experimenters aimed for impedances in the 5.0-25.0 kOhms range. A screenshot of the impedances was taken before and after the recognition memory task completion. The ERP data was recorded continuously throughout the memory task.

Design and Procedure Participants were each designated a 2.5 hour time slot. As the participant entered the lab, they first received their monetary compensation, filled out the informed consent form, a demographics form, and were then explained the details of the recognition memory task as described in the design. When the experimenter was sure that the participant understood the recognition memory task subjective judgment portion, the participant engaged in the shortened practice version of the task, which did not involve wearing the EEG cap. After successful completion of the practice task, experimenters asked the participants if they "felt that they used all of the keys (a range of subjective judgments) at test" to evaluate that the participant understood the task.

The participants were then fitted in the EEG cap, and connected to the amplifier. Impedances were checked and fixed (sometimes requiring extra twirling of the QuikCells or additional electrolyte solution), and the data began recording before the participant began the recognition memory task. The data was collected continuously throughout the task, even throughout the break periods, as not to miss any events. After completion of the three blocks of the task, the cap was removed and participants were allowed to clean up in the nearby restroom.

Many participants opted to stay after completion of the EEG component to do the neuropsychological evaluation component. If the participant opted to finish the neuropsychological evaluation component at a later date, they were encouraged to come back to the lab within one week of the date. The neuropsychological component was completed in a separate, smaller room from the one where the participant completed the memory and EEG portion. The experimenter sat caddy-corner from the participant.

Data Analysis

Neuropsychological. The neuropsychological tests were double scored, the first scorer usually being the administrator of the examination. Each participant's raw score on the six measures was converted to a z-score. Next, a frontal lobe score was computed for each participant by averaging the participant's z-scores on Mental Arithmetic, Mental Control, and Letter Fluency. Similarly, a medial temporal lobe score was computed for each participant by averaging the participant's z-scores on Logical Memory, Verbal Paired Associates and Visual Paired Associates. Lastly, younger adults were classified as low or high functioning based on their z-score for each of the two factors. Specifically, individuals who had an average z-score below 0 in either category were designated as 'low functioning' and individuals with an average z-score above 0 were designated as 'high functioning' in that category.

EEG Data. The EEG was digitally filtered and cleaned. First, an infinite impulse response (IIR) filter was utilized to bandpass the data, providing a cut-off of a high of 20 Hz and a low of 1 Hz within the data in order to eliminate aberrant electrical artifacts. Eye blinks were corrected using the ocular artifact correction via a designated EOG channel and regression. In this system, well-defined blinks were identified as ‘prototypes,’ and designated as an artifact at the peak or trough of the signal. For each file, at least 40 of these blink-representative artifacts were identified, in order to provide sufficient power for the regression coefficient to be applied. This regression coefficient was then generalized to the entire time series by utilizing the examples of the selected prototypes. Further, a specialized filter was employed that utilized manually separated segments of ‘bad’ data (that is, horizontal data often accompanying blinks due to the necessity to look across and down the computer screen and response keys) and clean, artifact-free data. At least 30 horizontal segments were identified in each file, and at least 15 clean segments were identified to provide a slate with which to filter the horizontal data. EMSE’s comparison of horizontal segments and clean data provided a logarithmic ratio with which to estimate how many components to remove according to the linear pattern of data. Components removed tended to be one in most cases, though there were several time series that required two components to be removed.

In few cases, channels of interest presented with higher frequency than desired, even after the above procedures had been completed. In this case, a spatial interpolation filter was applied, utilizing a probe to extrapolate data from nearby electrodes in order to estimate the frequency and amplitude of the ‘bad’ channel. This was done in only a few cases in channels under review.

After having completed the aforementioned steps to ‘clean’ the ERP data, each time series was divided into major events in order to more closely assess the data pattern of the specific channels. Events were segmented via the event review; each epoch was designated as -0.2 seconds to 1.0 seconds, in the interest of looking for the prime ERP components FN400 and the parietal old/new effect. Events were rejected on the basis of conservative estimates, whereas only events presenting with especially high frequency in one or more of the channels were rejected. In most cases, this did not consume more than one-quarter of the file. Event intervals of interest, namely Old, New, Recollected, Familiar and New Subjective Judgments, were averaged across all channels of interest for each participant after rejections had been completed. These averages were compared to the E-prime behavioral and accuracy judgments. Again, the epoch of interest in event averaging ranged from -0.2 to 1.0 seconds, and all separated events were reviewed at 100 uV/cm.

RESULTS

Behavioral Results

Hypothesis 1 (H_1). The first analysis examined variability in younger adults’ performance on the frontal and medial temporal lobe measures. That is, we aimed to illustrate if our cohort of young adults could be differentiated into two different functional groups based on low versus high function in the frontal and medial temporal lobes. The results revealed that young adult participants could be reliably differentiated by their frontal lobe and medial temporal lobe functioning. Specifically, the high frontal lobe group had a significantly higher z-score (*M*= .58, *SD*= .45) than the low frontal lobe group (*M*= -.53, *SD*= .49), *t* (21) = 5.68, *p* < .001, *d* = 2.38. A similar pattern was observed with the medial temporal group (high MTL = .53 *SD*= .35, low MTL = -.49, *SD*= .34), *t* (21) = 7.15, *p* < .001, *d* = 2.97.

Hypothesis 2 (H_2). Next, we examined whether the high/low frontal lobe and high/low medial temporal lobe groups differed in their overall recognition memory performance. An independent t-test was utilized, using correct rejections and hits from the memory paradigm as the test variables, and the group type (frontal or medial temporal lobe) as the grouping variable. For correct rejections, the low frontal lobe group (*M*=.77, *SD*=.12) was not significantly different than the high frontal lobe group (*M*=.74, *SD*=.09), *t* (21) = .71, p=.49, *d*=.30. For the medial temporal lobe group, the high group (*M*=.80, *SD*=.11) showed a trend toward significance for more correct rejections than the low group (*M*=.72, *SD*=.09), *t* (21) = -1.82, *p* = 0.08, *d* = 0.76. We next looked at hits. The high (*M*=.78, *SD*=.14) and low (*M*=.73, *SD*=.13) frontal lobe groups did not significantly differ, *t* (21) = 0.71, *p* = .35, *d* = 0.40. We saw a similar pattern for the high (*M*=.79, *SD*=.14) and low (*M*=.73, *SD*=.12) medial temporal lobe groups, whereas there was not a significant difference in terms of hits, *t* (21) = -1.05, *p* = .31, *d* = 0.44.

We noted that the low versus high distinction in the medial temporal lobe group showed a trend toward significance for correct rejections. The medial temporal lobe high individuals were always better than the low individuals at correct rejections, which lead us to turn to signal detection theory to further clarify potential differences within this group.

Signal detection theory provides a way to quantify recognition memory performance that takes both memory sensitivity (d') and response bias (C) into account. The results of the independent t-tests revealed that the high medial temporal lobe group (*M* = 1.8, *SD*= .53) outperformed the low medial temporal lobe group (*M* = 1.27, *SD*= .55) on memory sensitivity (d'), *t* (21) = 2.35, *p* = .03, *d* = .98, but that the two groups (High *M*= .01, *SD* = .49; Low *M*= -.02, *SD* = .21) did not differ with respect to response bias (C), *t* (21) = .23, *p* = .82, *d* = .10.

Within the frontal lobe group, there was not a significant difference in d' (sensitivity) between the high (*M*=1.55, *SD*=.73) and low (*M*=1.50*, SD*=.47) groups, *t* (21) = -.20*, p* = .84, *d* = 0.09. Likewise, there was not a significant difference in C (bias) between the high (*M*=-.10, *SD*=.19) and low (*M*=.08, *SD*=.38) frontal lobe groups, *t* (21) = 1.44, *p* = .16, *d* = 0.65, although this *p* value did trend toward significance. This indicated that the high frontal lobe group tended to make more conservative judgments (less likely to say 'old' to an item that is new) while the low frontal lobe group tended to make more liberal judgments (more likely to say 'old' to an item that is new) (see Table 1). The results implicating the medial temporal lobe groups as having high sensitivity for old/new judgments is what we would expect from literature, which indicates that it is the medial temporal lobe that contributes to this first old/new judgment, rather than the frontal lobe.

Hypothesis 3 (H_3). In light of the significant difference in memory performance between the high and low medial temporal lobe groups, we examined potential differences in the subjective judgments underlying memory performance. Specifically, we examined whether high medial temporal lobe individuals were more inclined to 'recollect' a response rather than call it 'familiar,' and further, if high medial temporal lobe individuals showed higher recollection than low individuals while also showing fewer instances of familiarity, as is suggested in the literature of non-pathological aging adults.

First, it was noted that, overall, all individuals tended to make more 'recollect' than 'familiar' responses. We wanted to break this down into objective versus relative markers. To analyze this judgment dichotomy objectively, we utilized individual's 'recollect' scores (that is, of the words that they correctly designated as old, the words that they then designated as having 'remembered with detail') and divided this by the total possible number of hits, 150. Separate 2 (group: high vs. low) x 2 (judgment: recollection vs. familiarity) mixed-factorial ANOVAs were conducted to examine the effect of frontal lobe and medial temporal lobe functioning on recollection and familiarity (see Tables 2 and 3). An alpha level of $p < .05$ was used for all analyses conducted.

A significant main effect of judgment was found, such that more 'recollect' (*M*=.52, *SD*=.04) than 'familiar' (*M*=.22, *SD*=.02) judgment responses were made by all individuals, *F* (1, 21) = 30.03, $p < .001$, $n_p^2 = .59$, as was expected from a glance over the data. There was not a main effect of group, showing that the high medial temporal lobe group (*M*=.39, *SD*=0.02) was not significantly different than the low medial temporal lobe group in the type of judgments made (*M*=.36, SD=.02), *F* (1, 21) = 1.09, *p* = .31, $n_p^2 = .05$, though an interactive trend was noticed, where high medial temporal lobe individuals made more 'recollect' responses than low individuals, and high individuals made fewer familiarity judgments than low medial temporal lobe individuals (see Figure 1). Though the interaction of judgment by medial temporal lobe group was not significant, *F* (1, 21) = 2.58, *p* = .12, $n_p^2 = .11$, the effect size was large and, with more participants, the expectation is that the power would increase, and an interaction of judgment by medial temporal lobe group would trend toward significance, indicating that higher medial temporal lobe individuals 'recollect' significantly more than lower medial temporal lobe individuals. This is what we would expect from previous literature, and what was shown by our behavioral results.

For the frontal lobe group, the ANOVA illustrated a significant main effect of judgment, where 'recollect' responses (*M*=.52, *SD*=.04)

TABLE 1. Signal detection analyses of the differences between frontal and medial temporal lobe groups.

Group	**d’**	**d’ Sig. (*p*)**	**Effect**	**C**	**C Sig. (*p*)**	**Effect**
MTL-High	1.80	**0.03**	**0.98**	0.01	0.82	0.10
MTL-Low	1.27			-0.02		
FL-High	1.55	0.84	0.09	-0.10	0.16	0.65
Fl-Low	1.50			0.08		

TABLE 2. Descriptive statistics of relative and objective judgments of recollection and familiarity in medial temporal lobe group.

	MTL	**Mean**	**SD**
Recollect	Low	0.47	0.17
	High	0.58	0.19
Familiar	Low	0.25	0.09
	High	0.19	0.11

TABLE 3. Relative and objective judgments of recollection and familiarity in medial temporal lobe group.

Repeated Measure Anova – Medial Temporal			
	p	Partial eta squared	Observed Power
Judgment x MTL	**0.12**	**0.11**	**0.34**
MTL	0.31	0.05	0.17
Judgment	**0.00**	**0.59**	**0.99**

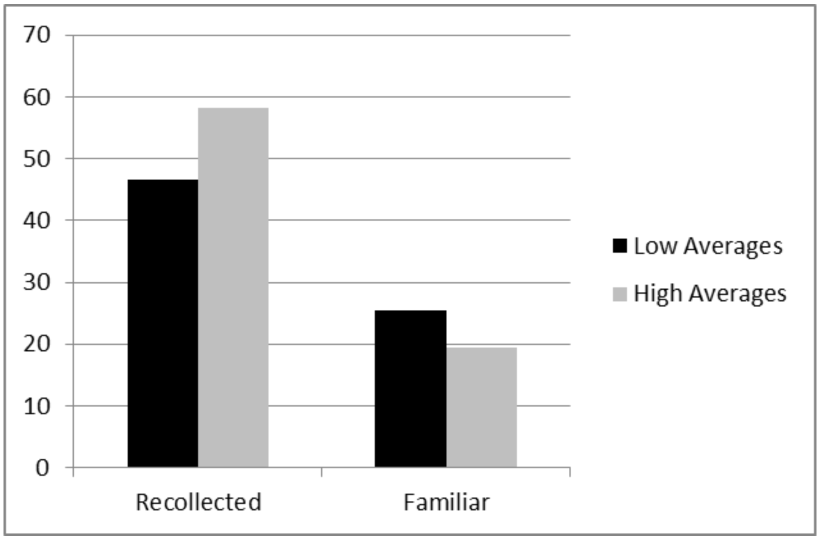

FIGURE 1. Objective recollect and familiar responses grouped by medial temporal lobe**.** On the y-axis, the average percent correct out of 150 hits (objective marker); on the x-axis, type of objective judgment. Note the distinguishable interaction between familiarity and recollected responses in the high medial temporal lobe group.

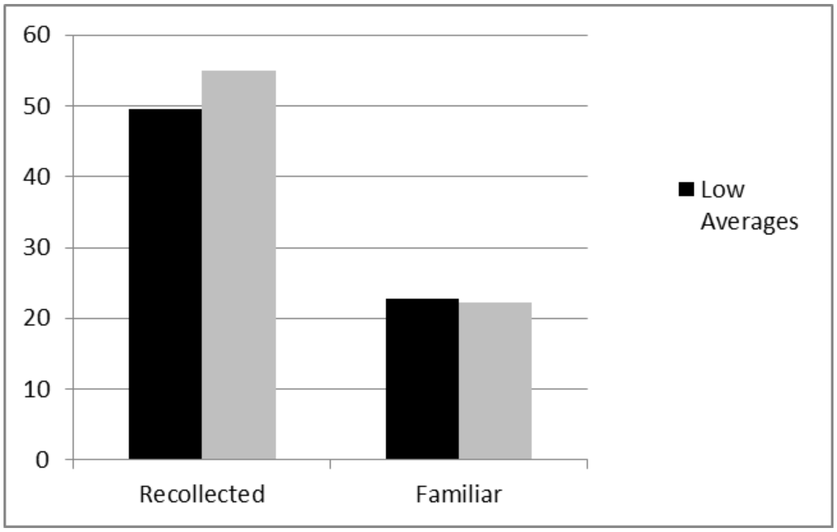

FIGURE 2. Objective recollect and familiar responses grouped by frontal lobe. On the y-axis, the average percent correct out of 150 hits (objective marker); on the x-axis, type of objective judgment. Note that there is not a distinguishable interaction across either low or high functioning groups, unlike in the medial temporal lobe groups.

were indicated significantly more than 'familiar' responses (*M*=.23, *SD*=.02), F (1, 21) = 26.64, p < .001, n_p^2 = .56. However, a main effect of group was not found, so that the high frontal lobe group (*M*=.39, *SD*=.02) was not significantly different in type of judgment than the low frontal lobe group (*M*=.36, *SD*=.02), F (1, 21) = 0.83, p = .37, n_p^2 = .04. Likewise, the interaction of judgment and frontal lobe was not significant, indicating no specific pattern in frontal lobe group response, F (1, 21) = 0.28, p = .60, n_p^2 = .01 (see Tables 4 and 5).

It occurred to us that being high in medial temporal lobe function would objectively contribute to the individual making more 'recollect' than 'familiar' responses, but we were

TABLE 4. Descriptive statistics of relative and objective judgments of recollection and familiarity in frontal lobe group.

	FL	**Mean**	**SD**
Recollect	Low	0.49	0.16
	High	0.55	0.21
Familiar	Low	0.23	0.16
	High	0.22	0.10

TABLE 5. Relative and objective judgments of recollection and familiarity in frontal lobe group.

Repeated Measure Anova – Frontal			
	p	Partial eta squared	Observed Power
Judgment x FL	0.60	0.01	0.08
FL	0.37	0.04	0.14
Judgment	**0.00**	**0.56**	**0.99**

TABLE 6. Descriptive statistics of relative and objective judgments of newness in the medial temporal lobe group.

	MTL	**Mean**	**SD**
Very Sure	Low	0.28	0.25
	High	0.27	0.16
Sure	Low	0.19	0.13
	High	0.27	0.11
Somewhat Sure	Low	0.23	0.14
	High	0.25	0.16

TABLE 7. Relative and objective judgments of newness in the medial temporal lobe group.

Repeated Measure Anova – Medial Temporal			
	p	Partial eta squared	Observed Power
Judgment x MTL	0.83	0.02	0.05
MTL	**0.07**	**0.15**	**0.45**
Judgment	0.57	0.02	0.09

TABLE 8. Descriptive statistics of relative and objective judgments of newness in the frontal lobe group.

	FL	**Mean**	**SD**
Very Sure	Low	0.31	0.20
	High	0.24	0.21
Sure	Low	0.25	0.13
	High	0.21	0.12
Somewhat Sure	Low	0.22	0.13
	High	0.26	0.16

TABLE 9. Relative and objective judgments of newness in the frontal lobe group

Repeated Measure ANOVA – Frontal			
	p	Partial eta squared	Observed Power
Judgment x FL	0.44	0.03	0.12
FL	0.36	0.04	0.15
Judgment	0.58	0.02	0.08

also interested in the relative judgment of the individual in reference to her own understanding of 'recollect' and 'familiar' responses. Instead of using the total number of hits possible, 150, we divided each individual's number of recollected and familiar responses by their own total hit rate, thus allowing their hit rate to function as 100% correct. In so doing, we could regard the relative judgments of the high versus low individuals in both groups.

Separate 2 (group: high vs. low) x 2 (judgment: recollection vs. familiarity) mixed-factorial ANOVAs were conducted to examine the effect of frontal lobe and medial temporal lobe functioning on this 'relative' recollection and familiarity (see Tables 4 and 5). An alpha level of $p < .05$ was used for all analyses conducted.

For the medial temporal lobe group, a main effect of judgment was seen, mirroring the objective data just described, where more 'recollect' (*M*=.68, *SD*=.03) than 'familiar' (*M*=.32, *SD*=.03) responses were indicated, F (1, 21) = 30.05, $p < .001$, $n_p^2 = .59$. Notably (again), the judgment by group interaction approached significance, indicating that high medial temporal lobe individuals had a tendency to make more 'recollect' judgments than low individuals, and fewer 'familiar' judgments than low individuals, F (1, 21) = 2.37, $p = .14$, $n_p^2 = .10$. The relative judgments in the frontal lobe group also mirrored the objective judgments of this group; results illustrated a significant main effect of judgment, where 'recollect' responses (*M*=.68, *SD*=.04) were indicated significantly more than 'familiar' responses (*M*=.32, *SD*=.04), F (1, 21) = 26.54, $p < .001$, $n_p^2 = .56$. Like in the objective results, the interaction of judgment and frontal lobe was not significant, indicating no specific pattern in frontal lobe group response, F (1, 21) = 0.06, $p = .80$, $n_p^2 = .003$.

Objective and subjective judgments of newness were also of interest to us. In the study, participants could indicate three levels of newness, ranging from 'very sure' to 'sure' and finally to 'somewhat sure.' Separate 2 (group: high vs. low) x (judgment: very sure new vs. sure new vs. somewhat sure new) mixed-factorial ANOVAs were conducted to examine the effect of frontal lobe and medial temporal lobe functioning on this newness judgment (see Tables 6-9). An alpha level of $p < .05$ was used for all analyses conducted.

For those in the medial temporal lobe group, there was not a main effect of judgment, indicating that for items indicated as 'very sure new' (*M*=.28, *SD*=.04), 'sure new' (*M*=.23, *SD*=.03) or 'somewhat sure new' (*M*=.24, *SD*=.03), there was no distinct difference in the objective choice of items correctly rejected as new, F (2, 20) = 0.38, $p = .67$, $n_p^2 = .02$. The main effect of the medial temporal lobe group approached significance, indicating that high individuals within the medial temporal lobe group (*M*=.27, *SD*=.01) were better, overall, at correct rejections than low individuals (*M*=.23, *SD*=.01), F (1, 21) = 3.71, $p = .07$, $n_p^2 = .15$ (see Tables 6 and 7). There was also no interaction between judgment and medial temporal lobe, indicating no pattern between type of judgment, F (2, 20) = 0.05, $p = .83$, $n_p^2 = .02$.

Looking objectively at the frontal lobe revealed no significant main effect of judgment, where judgments of new words as 'very sure new' (*M*=.28, *SD*=.04), 'sure new' (*M*=.23, *SD*=.03) and 'somewhat sure new' (*M*=.24, *SD*=.03) were not significantly different. There was also no main effect of frontal lobe group in judgments of newness, indicating that the high group (*M*=.24, *SD*=.01) and low group (*M*=.26, *SD*=.01) did not make significantly different types of judgments, F (1, 21) = 0.88, $p = .36$, $n_p^2 = .04$. Finally, there was no interaction of judgment with frontal lobe, F (1, 21) = 0.63, $p = .44$, $n_p^2 = .03$ (see Tables 8 and 9). This result echoes the literature, which does not implicate the frontal lobe in the judgment of old/new.

Finally, we wanted to look at the relative judgments of newness in both groups (thus utilizing their hit rate as 100%). In the frontal lobe, the relative judgments mirrored the objective judgments, in that no main effect of judgment was seen between 'very sure new' (*M*=.36, *SD*=.05), 'sure new' (*M*=.31, *SD*=.03) and 'somewhat sure new' (*M*=.33, *SD*=.04), F (1, 21) = 0.08, $p = .77$, $n_p^2 = .004$. Likewise, there not a significant interaction between judgment and frontal lobe group, F (2, 42) = 0.47, $p = .63$, $n_p^2 = .02$. For the medial temporal lobe group, there was not a significant main effect of judgment for the response choices: 'very sure new' (*M*=.36, *SD*=.05), 'sure new' (*M*=.31, *SD*=.03) or 'somewhat sure new' (*M*=.33, *SD*=.05). There was also not a significant interaction between judgment and medial temporal lobe group, F (2, 42) = 0.32, $p = .73$, $n_p^2 = .02$ (see Figures 3 and 4). These relative judgments mirrored the objective judgments.

ERP Results

Hypothesis 1 (H_1). The goal of hypothesis 1 was to replicate the old/new effect—greater

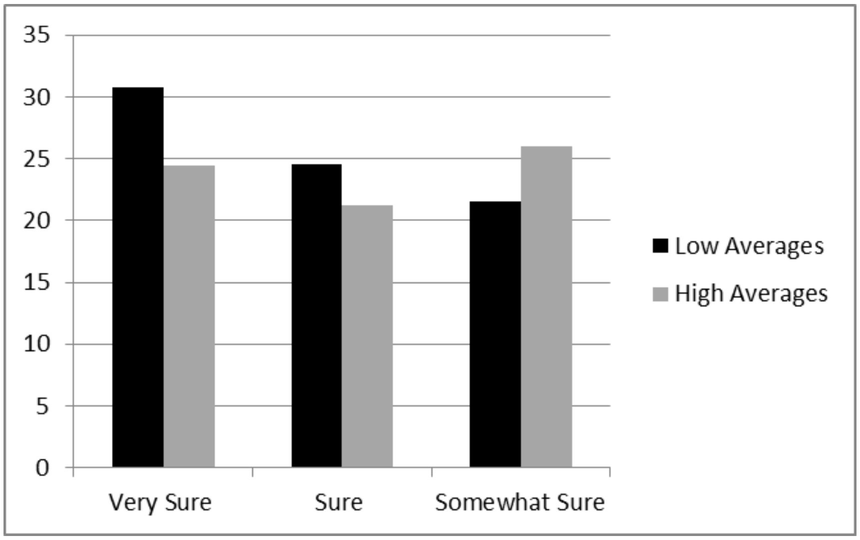

FIGURE 3. Objective newness responses grouped by frontal lobe. On the y-axis, average percent correct out of 150 hits (objective marker); on the x-axis, individual participants. Note that there is not a distinguishable interaction in either grouping condition.

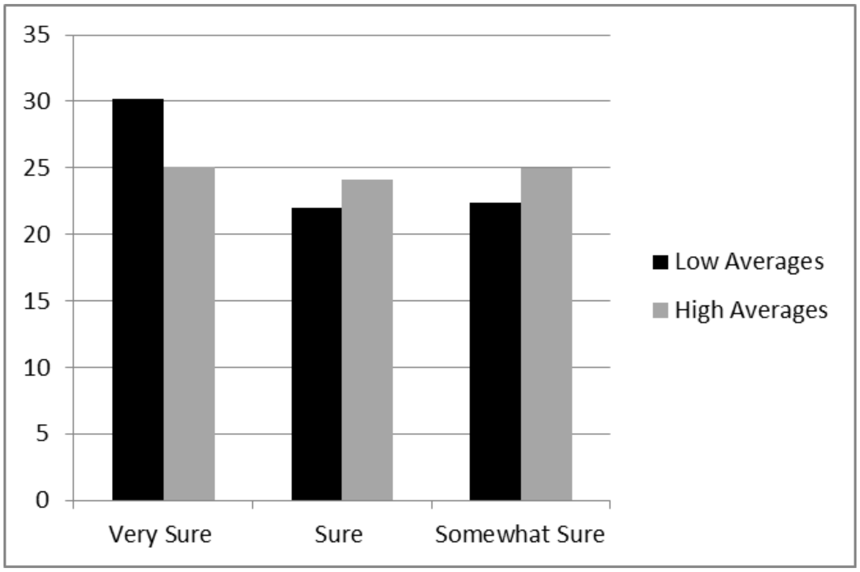

FIGURE 4. Objective newness responses grouped by medial temporal lobe. On the y-axis, average percent correct out of 150 hits (objective marker); on the x-axis, individual participants. Note that there is not a distinguishable interaction in either grouping condition.

activation for hit than correct rejection responses (Kahn, Davachi, & Wagner, 2004; Konishi, Wheeler, Donaldson, & Buckner, 2000; Wheeler & Buckner, 2004; Skinner & Fernandes, 2007)—in this population of young adults. This old/new effect has been cited as occurring maximally over left parietal electrodes in the cumulative time epoch of 300-800ms. In this study, we focused on electrodes P3 and FT7, and found them to elicit the old/new effect, though this effect varied by functional group.

Separate 2 (group: high vs. low) x (electrode: hits and correct rejections) mixed-factorial ANOVAs were conducted to examine the effect of frontal lobe and medial temporal lobe functioning on this newness judgment. An alpha level of $p < .05$ was used for all analyses conducted. For the medial temporal lobe groups, the main effect of old/new judgment was not significant, illustrating that the component wave of hits (*M*=.57, *SD*=.15) and of correct rejections (*M*=.62, *SD*=.19) judgments was not significantly different, *F* (1, 18) = 0.17, *p* = .69, n_p^2 = .01. The main interaction of medial temporal lobe group was also not significant, indicating that high temporal lobe individuals (*M*=.64, *SD*=.21) did not show greater positivity for hits or correct rejections as compared to low temporal lobe individuals (*M*=.62, *SD*=.19), *F* (1, 18) = 0.08, *p* = .78, n_p^2 = .08. However, the interaction of old/new judgments and medial temporal lobe groups for ERP did approach significance, indicating that the low medial temporal lobe group showed the more replicated finding of more positive ERP components for hits than correct rejections, while the high medial temporal lobe group showed more positive ERP components for correct rejections over hits, *F* (1, 18) = 3.46, *p* = .08, n_p^2 = .16 (see Figure 5).

Hypothesis 2 (H_2). Following illustration of an old/new effect, it was hypothesized that the ERP patterns of words judged as "old" (hits) would be different in the high and low frontal lobe and high and low medial temporal lobe group. This hypothesis investigated the notion that all correctly identified "hits" would look different across the differing functional groups; by looking for these differences, we could subsequently study the recollection and familiarity responses for each functional group.

Independent t-tests were run for all electrode channels of interest (F3, F4, FT7, FT8, T3, T4, P3 and P4) within the time epoch of 300-800 ms for events containing "hits." For the medial temporal lobe group, several electrode channels showed greater activation (significant or approaching significance) for the low group than the high group for "hits:" **FT7** (High *M*=.05, *SD*=.47; Low *M*=.54, *SD*=.50), *t* (17) = 2.16, *p* = .05, *d* = 1.01; **FT8** (High *M*=.11, *SD*=.38; Low *M*=.52, *SD*=.50), *t* (17) = 1.98, *p* = .06, *d* = .93; **T3** (High *M*=.13, *SD*=.47; Low *M*=.46, *SD*=.30), *t* (17) = 1.87, *p* = .08, *d* = .86; **P3** (High *M*=.31, *SD*=.78; Low *M*=.86, *SD*=.56), *t* (17) = 1.83, *p* = .09, *d* = .82; and **P4** (High *M*=.39, *SD*=.58; Low *M*=.97, *SD*=.72), *t* (17) = 1.90, *p* = .08, *d* = .89 (see Table 10 and Figure 5).

Between the high and low frontal lobe groups, there was no significant difference in activation for hits across any electrodes, all *p*s greater than 0.42 and all *d*s smaller than 0.40 (see Table 11).

Hypothesis 3 (H_3). Having found a significant difference in the pattern of hits, in that there was a group difference revolving around activation levels of "hit" components at differing time epochs, the third hypothesis of this study (concerning recollection and familiarity components) could be addressed. It was predicted that the high medial temporal lobe group would show greater activation for the 'recollective' ERP component than the low medial temporal lobe group and frontal lobe groups during recollection, if indeed the frontal lobe does not play as significant of a role in recollection young adults as it does in older adults.

Familiarity. All "hit" events marked as "familiar" (in the memory paradigm, test words either marked as remembered with 'weak feeling of familiarity' or 'strong feeling of familiarity') were considered in the early epoch of interest (300-500ms). An independent t-test was performed comparing all electrodes at this early epoch of interest, grouping them by frontal and medial temporal lobe status. Aging literature has suggested that the familiarity component is usually illustrated in this early epoch. Medial temporal lobe status was significant for all electrodes in this early epoch, illustrating that the low status group showed greater activation associated with old words subsequently designated as "familiar" than the high group: **F3** (High *M*=-.91, *SD*=1.60; Low *M*=1.31, *SD*=1.93), *t* (19) = 2.79, *p* = .01, *d* = 1.25; **F4** (High *M*=-.94, *SD*=1.50; Low *M*=.79, *SD*=1.31), *t* (19) = 2.82, *p* = .01, *d* = 1.23; **FT7** (High *M*=-.83, *SD*=1.55; Low *M*=1.13, *SD*=1.80), *t* (19) = 2.62, *p* = .02, *d* = 1.17; **FT8** (High *M*=-.78, *SD*=1.37; Low *M*=.49, *SD*=1.30), *t* (19) = 2.17, *p* = .04, *d* = 0.95; **T3** (High *M*=-.56, *SD*=1.30; Low *M*=1.06, *SD*=1.79), *t* (19) = 2.29, *p* = .03, *d* = 1.04; **T4** (High *M*=-.52, *SD*=1.40; Low *M*=.97, *SD*=1.26), *t* (19) = 2.55, *p* = .02, *d* = 1.12; **P3** (High *M*=-.35, *SD*=1.62; Low *M*=2.04, *SD*=1.61), *t* (19) = 3.36, *p* < .001, *d* = 1.48; and **P4** (High *M*=-.35, *SD*=1.45; Low *M*=2.20, *SD*=1.71), *t* (19) = 3.59, *p* < .001, *d* = 1.61 (see Table 14). This mirrors the behavioral response described earlier, involving an interaction between the two medial temporal lobe groups, where the high medial temporal lobe group showed more overall 'recollective' responses and the low group more overall 'familiar' responses. Frontal lobe status did not show a difference in component positivity for familiar events in any electrode channel, all *p*s

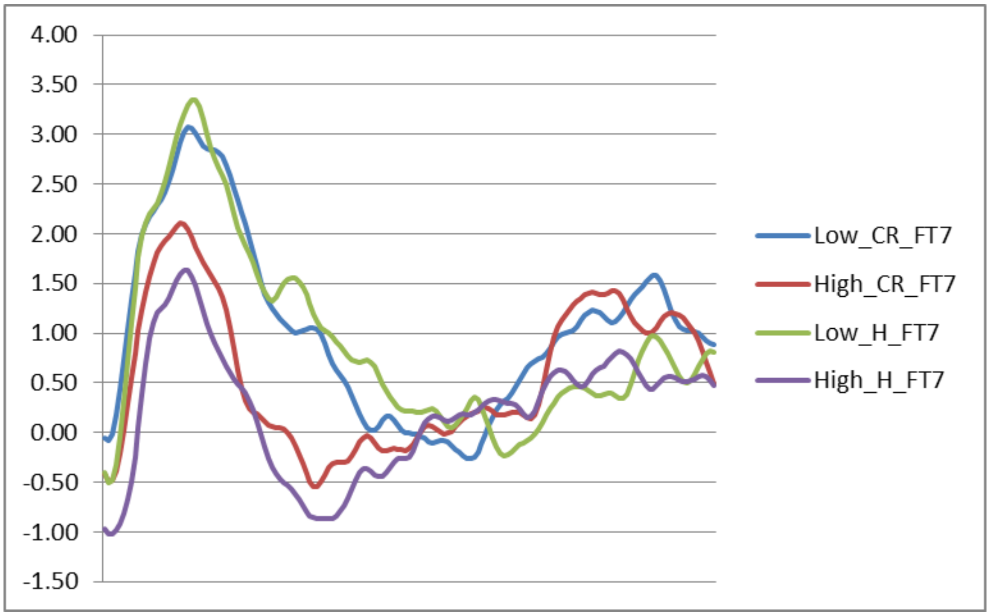

FIGURE 5. A computed ERP graph illustrating the medial temporal lobe groups for the electrode FT7 during the time epoch of 100-900 ms post-stimulus. This figure illustrates that, overall, low medial temporal lobe individuals, for both correct rejections and hits, elicit a wave with early, higher positivity (blue and green lines). This graph also illustrates that the high medial temporal lobe group (blue and purple) show the opposite pattern expected from an old/new effect, where the correct rejections are actually more positive than the hits. However, we do see the expected old/new effect in the low medial temporal lobe group (red and green), where the hit wave is more positive than the correct rejection wave.

TABLE 10. An independent t-test of “hits” comparing all electrodes at 300-800 ms epoch of interest, grouped by medial temporal lobe status.

	Low MTL Mean	High MTL Mean	t	d
F3	0.45	0.14	1.09	0.52
F4	0.40	0.11	0.96	0.46
FT7	0.54	0.05	2.16*	1.01
FT8	0.52	0.11	1.98-	0.93
T3	0.46	0.13	1.87-	0.86
T4	0.53	0.21	1.45	0.67
P3	0.86	0.31	1.83-	0.82
P4	0.98	0.39	1.90-	0.89

* = 0.05, ** = 0.0, - = trending

TABLE 11. An independent t-test of “hits” comparing all electrodes at 300-800 ms epoch of interest, grouping by frontal lobe status.

	Low FL Mean	High FL Mean	t	d
F3	0.29	0.34	-0.18	0.08
F4	0.16	0.41	-0.84	0.40
FT7	0.33	0.34	-0.03	0.02
FT8	0.29	0.41	-0.54	0.24
T3	0.30	0.34	-0.25	0.10
T4	0.41	0.39	0.61	0.04
P3	0.69	0.49	0.65	0.29
P4	0.66	0.81	-0.43	0.21

* = 0.05, ** = 0.0, - = trending

TABLE 12. An independent t-test of “recollections” comparing all electrodes at early epoch of interest, grouping by frontal and medial temporal lobe status.

	MTL-Early component (300-500ms) – Effect Size (d)	FL-Early component (300-500ms) – Effect Size (d)
F3	1.66**	0.37
F4	0.88-	0.14
FT7	1.43**	0.51
FT8	0.639	0.39
T3	1.74**	0.30
T4	0.69-	0.70
P3	1.78**	0.02
P4	1.59**	0.49

* = 0.05, ** = 0.0, - = trending

TABLE 13. An independent t-test of “recollections” comparing all electrodes at later epoch of interest, grouping by frontal and medial temporal lobe status.

	MTL-Late component (500-800ms)– Effect Size (d)	FL-Late component (500-800ms)– Effect Size (d)
F3	0.58-	0.30
F4	0.04	0.20
FT7	0.47-	0.49
FT8	0.57	0.23
T3	0.39-	0.67-
T4	0.41	0.29
P3	0.05	0.40
P4	0.32	0.13

* = 0.05, ** = 0.0, - = trending

TABLE 14. An independent t-test of “familiarity” comparing all electrodes at early epoch of interest, grouping by frontal and medial temporal lobe status.

	MTL-Early component (300-500ms) – Effect Size (d)	FL-Early component (300-500ms) – Effect Size (d)
F3	1.65**	0.19
F4	1.50**	0.01
FT7	1.51*	0.01
FT8	1.15*	0.41
T3	1.24*	0.10
T4	1.25*	0.47
P3	1.61**	0.30
P4	1.74**	0.67

* = 0.05, ** = 0.01, - = trending

TABLE 15. An independent t-test of “familiarity” comparing all electrodes at later epoch of interest, grouping by frontal and medial temporal lobe status.

	MTL-Late component (500-800ms)– Effect Size (d)	FL-Late component (500-800ms)– Effect Size (d)
F3	0.40	0.92-
F4	0.15	1.27**
FT7	0.15	0.89-
FT8	0.10	1.09**
T3	0.21	0.77-
T4	0.29	0.85*
P3	0.32	0.73-
P4	0.37	1.07*

* = 0.05, ** = 0.0, - = trending

greater than 0.32 and all *d*s smaller than 0.70 (see Table 14).

All “familiar” events were then considered in the later epoch of interest (500-800ms). An independent t-test was performed comparing all electrodes at this early epoch of interest, grouping them by frontal and medial temporal lobe status. Literature has suggested that the familiarity component is usually not implicated in this later epoch. In this epoch, the medial temporal lobe status did not show a difference in component positivity for familiar events for any electrode channel of interest (all *p*s above .52 and *d*s below .29). However, frontal lobe status was significant and trending across some electrodes, indicating that the high frontal lobe group showed greater activation for items subsequently labeled as familiar than the low group in this late epoch (see Table 15): **F3** (High *M*=.97, *SD*=1.44; Low *M*=.06, *SD*=.84), *t* (19) = -1.83, *p* = .08, *d* = 0.80; **F4** (High *M*=1.37, *SD*=1.34; Low *M*=.09, *SD*=.49), *t* (19) = -3.08, *p* < .001, *d* = 1.40; **FT7** (High *M*=.89, *SD*=1.36; Low *M* < 0.001, *SD*=.95), *t* (19) = -1.78, *p* = .09, *d* = 0.77; **FT8** (High *M*=1.30, *SD*=1.21; Low *M*=.18, *SD*=.48), *t* (19) = -2.95, *p* = .01, *d* = 1.33; **T3** (High *M*=.76, *SD*=1.28; Low *M*=-.01, *SD*=.91), *t* (19) = -1.61, *p* = .12, *d* = .70; **T4** (High *M*=1.03, *SD*=1.30; Low *M*=.16, *SD*=.43), *t* (19) = -2.18, *p* = .04, *d* = 1.01; **P3** (High *M*=.89, *SD*=1.38; Low *M*=.16, *SD*=.69), *t* (19) = -1.59, *p* = .13, *d* = 0.71; **P4** (High *M*=1.21, *SD*=1.29; Low *M*=.14, *SD*=.67), *t* (19) = -2.48, *p* = .02, *d* = 1.09.

Thus, it was shown that medial temporal lobe status made a difference in component positivity towards hits marked as ‘familiar’ only in the early component of familiarity (which is the most implicated time epoch for this effect). Specifically, the low medial temporal lobe group showed greater component positivity for items given a ‘familiar’ response than the high status group in this time period. We also saw an interesting frontal lobe status effect in the late component of familiarity (not often a time epoch implicated in the ‘familiarity’ decision), where the majority of electrodes indicated that high frontal lobe individuals elicited more positive components to test items subsequently labeled ‘familiar’ in this later epoch as compared to lower frontal lobe individuals.

Recollection. All “hit” events marked as “recollections” (in the memory paradigm, those words either marked as remembered with ‘few’ or ‘lots of details’) were considered in the early epoch of interest (300-500ms). An independent t-test was performed comparing all electrodes at this early epoch of interest, grouping them by frontal and medial temporal lobe status. Aging literature has suggested that the recollection component is not usually implicated in this early epoch. However, the independent t-test implicated all electrode channels of interest where the medial temporal lobe status elicited significantly different ‘recollective’ components: **F3** (High *M*=-.75, *SD*=1.27; Low *M*=1.14, *SD*=1.24), *t* (19) = 3.42*, p* < .001, *d* = 1.51; **F4** (High *M*=-.75, *SD*=1.04; Low *M*=.14, *SD*=1.04), *t* (19) = 1.94*, p* = .07, *d* = 0.86; **FT7** (High *M*=-.52, *SD*=.95; Low *M*=.97, *SD*=1.19), *t* (19) = 3.09*, p* < .001, *d* = 1.40; **FT8** (High *M*=-.80, *SD*=.81; Low *M*=-.16, *SD*=1.01), *t* (19) = 1.58*, p* = .131, *d* = 1.05; **T3** (High *M*=-.37, *SD*=.68; Low *M*=1.00, *SD*=.79), *t* (19) = 4.17*, p* < .01, *d* = 1.86; **T4** (High *M*=-.58, *SD*=.85; Low *M*=.11, *SD*=1.13), *t* (19) = 1.54*, p* = .14, *d* = 0.70; **P3** (High *M*=-.28, *SD*=1.03; Low *M*=1.36, *SD*=.79), *t* (19) = 4.15*, p* < .001, *d* = 1.80; **P4** (High *M*=-.14, *SD*=.99; Low *M*=1.41, *SD*=.96), *t* (19) = 3.61*, p* < .001, *d* = 1.59. As is obvious, the lower medial temporal lobe group showed more component positivity for recollection responses during this time epoch (see Table 12). Frontal lobe status did not show a difference in component positivity for recollected events (all *p*s above .29, all *d*s below .48).

These “recollection” events were also considered in the late epoch of interest (500-800ms). An independent t-test was performed comparing all electrodes at this late epoch of interest, grouping them by frontal and medial temporal lobe status. Aging literature has suggested that the recollection component is usually illustrated in this later epoch, maximal over parietal electrodes. We found that the medial temporal lobe status trended toward significance for three electrodes, with the high group eliciting more positive components related to recollections than the low group for this time epoch (see Table 13): **F3** (High *M*=.68, *SD*=.72; Low *M*=.09, *SD*=1.02), *t* (19) = -1.49*, p* = .15, *d* = 0.68; **FT7** (High *M*=.43, *SD*=.49; Low *M*=-.02, *SD*=.83), *t* (19) = -1.46*, p* = .16, *d* = 0.68; **T3** (High *M*=.41, *SD*=.56; Low *M*=.01, *SD*=.66), *t* (19) = -1.45*, p* = .16, *d* = 0.66. Frontal lobe status did not show a difference in component positivity for recollected events except in T3, which approached significance (High *M*=-.07, *SD*=.63; Low *M*=.37, *SD*=.60), *t* (19) = 1.61*, p* = .12, *d* = 0.72. All other electrode channels for frontal lobe groups showed *p*s above .26, with all *d*s below .51.

Thus, we see that in recollection, the medial temporal lobe status makes a difference in component positivity while the frontal lobe status does not. Specifically, the low medial temporal lobe group is significantly more positive (with large effect sizes) for most of the electrodes in the early component of recollection, suggesting an earlier peak of positivity/activation for events subsequently designated as “recollected.” The high group, however, shows trending effects in greater activation for recollected events in comparison to the low group in the later component of recollection (the component most usually associated with recollection).

DISCUSSION

The first analysis examined variability in younger adults’ performance on the frontal and medial temporal lobe measures. The results revealed that young adult participants could be reliably differentiated by their frontal lobe and medial temporal lobe functioning. Specifically, the high frontal lobe group had a significantly higher z-score than the low frontal lobe group. A similar pattern was observed with the medial temporal group.

We examined whether the high/low frontal lobe and high/low medial temporal lobe groups differed in their overall recognition memory performance. Results did not illustrate significant differences either between the low versus high frontal group or the low versus high medial temporal lobe group, though we noted that the medial temporal lobe high individuals were always better than the low individuals at correct rejections.

We examined potential differences in the subjective judgments underlying memory performance. It was noted that all individuals in the study tended to make more ‘recollect’ than ‘familiar’ responses. The main difference revolved around the fact that high medial temporal lobe individuals made more ‘recollect’ responses than low medial temporal lobe individuals, and high individuals made fewer familiarity judgments than low medial temporal lobe individuals. There were no obvious trends between the frontal lobe groups, as was seen in the medial temporal lobe group, most likely due to lack of sensitivity for the frontal lobe group.

We also examined these potential differences in subjective judgments for newness judgments. In the frontal lobe, there was not a difference between groups as to what type of ‘newness’ response was made. For the medial temporal lobe group, there was no difference between the groups regarding the type of ‘newness’ response, but we did again see that the high group showed a higher overall correct rejection percentage than the low medial temporal lobe group.

Results investigating the old/new effect utilizing ERP found that, within the medial temporal lobe functional groups in electrodes P3 and FT7, those in the low medial temporal lobe condition elicited greater activation for hits than correct rejections, while the high medial temporal lobe condition showed the opposite pattern, eliciting greater activation for correct rejections than hits.

When looking just at “hits” between these groups, we see that the low medial temporal lobe group showed more positive components/greater activation early on in relation to these “old” items as compared to the high medial temporal lobe group. Frontal lobe status did not show a significant difference between “hit” components for this early time epoch.

Having found a significant difference in the pattern of hits, in that there was a group difference revolving around activation levels of “hit” components at differing time epochs within the medial temporal lobe, the third hypothesis of this study (concerning recollection and familiarity components) could be addressed. Looking at recollection in the early time epoch (300-500ms), we found that the lower medial temporal lobe group showed more component positivity for recollection responses. Frontal lobe status did not show a difference in component positivity for recollected events. In the later time epoch of recollection (500-800ms), the time period usually implicated for this effect, we found that the high medial temporal lobe group (for some electrodes) showed more positive components related to recollections than the low group. Frontal lobe status did not show a difference in component positivity for recollected events. Looking at familiarity in the early time epoch (300-500ms), the epoch most associated with the familiarity effect, we found that the low medial temporal lobe group showed greater activation associated with old words subsequently designated as “familiar” than the high group. Frontal lobe status did not show a difference in component positivity for familiar events. In the later time epoch of familiarity (500-800ms), the medial temporal lobe status did not show a difference in component positivity. The high frontal lobe group showed greater activation for items across some electrodes for items subsequently labeled as familiar than the low group.

CONCLUSION

It is important to note that the medial temporal lobe group differentiation was due to sensitivity changes within the group, rather than bias changes within the group. This signal detection measure utilizes the conditional probability that the observer says “yes” when a stimulus is present (in our case, saying that the word is “old” when it is actually “old”) and also takes into account the conditional probability when the observer says that the word is “old” when it actually is not (the false alarm rate). Thus, finding that the high and low groups were differentiated according to sensitivity level rather than bias indicated that the high group was better at filtering the ‘noise’ than the low group. This was supported in the behavioral data, which showed more correct ‘old’ (hits) and ‘new’ (correct rejections) responses in the high group in comparison to the low group, and in the ERP data, with illustration of an old/new effect occurring for the low medial temporal lobe group.

The ERP group differentiation brought up an unexpected trend in the high and low medial temporal lobe groups in reference to the old/new effect in P3 and FT7 and to the pattern of positivity directed toward events marked as “hits.” The old/new effect usually presents as greater activation for hit than correct rejection responses (Kahn, Davachi, & Wagner, 2004; Konishi, Wheeler, Donaldson, & Buckner, 2000; Wheeler & Buckner, 2004; Skinner & Fernandes, 2007). We saw this pattern in the low medial temporal lobe group, but surprisingly, we saw the opposite pattern (greater activation for correct rejection than hit responses) for the high group. This is a finding worth exploring with replication. Wanting to elaborate on this finding further, we looked deeper into events designated as "hit" events—those events where a word was designated as 'old' when it was actually 'old'—and subsequent judgments concerning "hit" events, such as recollection and familiarity judgments. In the time epoch of 300-800ms, we found that, overall, the low medial temporal lobe group showed greater positivity/activation early on as compared to the high medial temporal lobe group in this cumulative "hit" analysis. This effect of the low medial temporal lobe group eliciting greater positivity/activation early on persisted when we looked more specifically into just recollection and familiar events, leading us to believe that eliciting earlier activation across all conditions was a defining factor of our low medial temporal lobe group, though the driving forces behind this are unknown and should be elaborated on further in future young adult studies utilizing this method. One suggestion is that this memory task is much harder for the low medial temporal lobe group, thus eliciting early, higher positive activation, while the high medial temporal lobe group may have an easy time with the memory paradigm, exhibiting comparably less activation early on.

Differentiation of the groups allowed us to further explore their subsequent judgments. The data implicating high medial temporal lobe individuals in eliciting more 'recollection' responses than the low group trended toward significance, as did the data implicating fewer 'familiar' responses in the high medial temporal lobe individuals as compared to the low group. The effect sizes were moderate, and thus we can assume that, with more power, these trends would be significant. This is mirrored in the ERP results, where medial temporal lobe status was significant for all electrodes in the early epoch of familiarity (300-500ms), indicating that the low status group showed more positive ERP components associated with familiar judgments than the high group, and in the late epoch of recollection (500-800ms), with the high group eliciting more positive components related to recollection than the low group for this time epoch. These results together implicate the very interesting finding that the medial temporal lobe, at least in young adults, is heavily implicated in *both* the foremost old/new judgment and the subsequent recollect/familiar judgments. This finding contrasts to cognitive aging literature, which argues that the medial temporal lobe's main role is mostly old/new judgment with lesser input into recollection and familiarity.

The frontal lobe status was not shown to impact the recollect/familiar judgment, which seemed to be dictated almost exclusively by medial temporal lobe status. The only frontal lobe ERP contribution with significant differences in activation was found in the late time epoch of 'familiar' events, though the fact that we did not find statistical behavioral differences between the low and high frontal lobe groups does not allow for much elaboration on the meaning of this finding—it is unclear why the high frontal lobe group may have shown greater activation for familiar stimuli in this later time epoch. The finding that, overall, the medial temporal lobe showed the greatest contribution in both the old/new effect and in subsequent recollection and familiarity responses was highly interesting, considering the fact that cognitive aging literature suggests that recollection depends on the status of the frontal lobe: individuals with low frontal lobe function exhibit "recollect" responses far less than older individuals designated as high in frontal lobe functioning. Old age literature does corroborate our finding of the medial temporal lobe's greater contribution to the old/new effect.

Interestingly enough, it has been shown in a large study that young adults' (aged 18-23) mean frontal lobe factor was highly comparable to the mean frontal lobe factor of an older-age population (between the ages of 65 and 90) – far more comparable to this older population than a closer age-relation population of young-olds, those between the ages of 21 and 34 (Glisky and Kong, 2008). However, despite the closeness of proposed frontal lobe average scores between young and older adults, we saw a stark difference in our young adult frontal lobe contribution to recollection—or lack thereof—in this study as compared to studies implicating heavy frontal lobe contribution to recollection in older adults. In summary, the frontal lobe plays a great role in the differentiation of recollect/familiar responses in older adults. We do not see this pattern in the young adults, where the medial temporal lobe seems to play the prominent role in both the original old/new judgment and in the subsequent judgment of recollection/familiarity. This suggests a developmental change occurring in the frontal lobe in older adulthood, where the frontal lobe assumes a bigger role in judgments succeeding the old/new judgment, either due to compensatory mechanisms or dedifferentiation.

Limitations

During the memory paradigm, participants often shifted their eyes horizontally and downward, presumably to reassure themselves that they were pressing the key that correctly corresponded to their intended answer. This was not seen as often in the first old/new response, as these keys were pressed the most often (m=old, z=new), due to participants tending to keep their fingers stable on these with each trial. However, in subsequent judgments (recollect/familiar and newness), participants had to shift their fingers and eyes in order to choose the right key (z, x and c for newness; n, m, b and v for recollect/familiar continuum). This eye movement elicited an unexpected, large horizontal movement in the ERP data that had to be corrected. However, it was found that this correction dramatically smoothed some curves, and may have led to the inconclusiveness of the parietal old/new effect in the high medial temporal lobe group. After running the data with horizontal movements untouched, and with them subsequently retouched, it was found that the two data sets did not significantly differ and neither showed the expected parietal old/new effect in the high medial temporal lobe group.

An interesting question arises concerning the population in use in this study regarding the closeness of low and high groups within the frontal lobe group. In most conditions (and indeed, in the Glisky and Kong large study of 2008), young adults were successfully separated into statistically different low and high frontal lobe groups (Glisky and Kong, 2008). However, our study did not show this statistical difference; in fact, our frontal lobe groups looked remarkably similar to one another and only differed (though not significantly) in their types of bias. This was presumably due in large part to lack of power, but perhaps also reliant upon the population from which we drew. It is our best assumption that the population from which our participants were drawn—that of a very selective liberal arts college comprising entirely of women—attracted individuals whose frontal lobe calibers were quite similar than what we might have seen drawing from a more diverse intellectual, socioeconomic status and sex population. We did see a medial temporal lobe score difference, but again, if drawn from another more diverse population, it is expected that this group difference would be even larger.

Finally, our study lacked sufficient power to provide statistical significance for many of the trends seen. This was undoubtedly due to the small number of participants that could be obtained and tested during the course of a busy semester. However, many of our effect sizes were very large, indicating that replication with more participants would be highly beneficial.

Future Directions

Our frontal lobe groups were not statistically different, most probably from the lack of power and the very homogenous population that we worked with. Future studies should draw from a more diverse population, to see if, first, they obtain a population whose frontal lobe scores can be successfully divided into statistically different low and high groups, and second, to see if this successful difference contributes at all to overall memory judgments (hits and correct rejections) and to subsequent judgments of familiarity/recollection. As we said, we did not find any frontal lobe contribution to either the old/new judgment or subsequent judgments, though this finding may differ with a larger population and more qualitatively/quantitatively different low and high groups.

In the future, a method that does not rely so much on checking oneself during the memory paradigm—and therefore causing unnecessary horizontal and downward eye movements—should be investigated. Thorough cleaning of the ERP data may have contributed to the surprising high medial temporal lobe parietal old/new effect seen in our study, as much of the data may have been averaged to the point where significant differences were lost.

Finally, the most broad take-away of our study revolves around determining if the developmental change in older adults' frontal lobes—from having supposedly little contribution to old/new or subsequent judgments to having large contributions to recollection as one ages—is compensatory or due to dedifferentiation of the brain's systems.

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