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Ambiguity's aftermath: How age differences in resolving lexical ambiguity affect subsequent comprehension

Chia-lin Lee[1] and **Kara D. Federmeier**[1,2,3]

[1]Department of Psychology, University of Illinois

[2]Neuroscience Program, University of Illinois

[3]the Beckman Institute for Advanced Science and Technology, University of Illinois

Abstract

When ambiguity resolution is difficult, younger adults recruit selection-related neural resources that older adults do not. To elucidate the nature of those resources and the consequences of their recruitment for subsequent comprehension, we embedded noun/verb homographs and matched unambiguous words in syntactically well-specified but semantically neutral sentences. Target words were followed by a prepositional phrase whose head noun was plausible for only one meaning of the homograph. Replicating past findings, younger but not older adults elicited sustained frontal negativity to homographs compared to unambiguous words. On the subsequent head nouns, younger adults showed plausibility effects in all conditions, attesting to successful meaning selection through suppression. In contrast, older adults showed smaller plausibility effects following ambiguous words and failed to show plausibility effects when the context picked out the homograph's non-dominant meaning (i.e., they did not suppress the contextually-irrelevant dominant meaning). Meaning suppression processes, reflected in the frontal negativity, thus become less available with age, with consequences for subsequent comprehension.

Keywords

ERP; Frontal negativity; N400; Aging; Inhibition; Lexical ambiguity resolution

1. Introduction

One of the distinguishing features of human language is its tolerance of one-to-many relations between a form and its referents. For example, the letter string '*bluff*' could mean a cliff or an action of misleading others; the way a listener or reader should interpret this word thus depends heavily on the context in which it is used. Ambiguities of this kind are not uncommon in language. In English, for example, 85% of a sample of high-frequency words was found to have more than one meaning (Twilley, Dixon, Taylor, & Clark, 1994). Although ambiguity contributes to the richness and flexibility of human language, it also can create processing difficulties and complicate communication. Behavioral (e.g., Rodd,

Corresponding author: Chia-lin Lee, University of Illinois, Psychology Department, 603 East Daniel St., Champaign, IL 61820, phone: (217) 244-7334, leechial@einstein.edu.

Gaskell, & Marslen-Wilson, 2002), electrophysiological (e.g., Hagoort & Brown, 1994) and hemodynamic (e.g., Gennari, MacDonald, Postle, & Seidenberg, 2007) measures have all shown that comprehending word forms associated with multiple distinct meanings imposes processing loads relative to comprehending unambiguous words.

The processing costs associated with lexical ambiguity, however, are not unitary in nature. Comprehending lexical ambiguity appears to involve multiple mechanisms with different functional and neural characteristics, and the nature and strength of available context information, among other factors, seems to importantly determine which mechanisms are recruited. In a series of event-related potential studies, we have shown that younger adults' responses to noun/verb (NV-) homographs (as compared with unambiguous words) in contexts providing structural, but not semantic, cues for ambiguity resolution (e.g., "John wanted to/the *duck* …") include a sustained negativity over frontal-central scalp regions (Federmeier, Segal, Lombrozo, & Kutas, 2000; Lee & Federmeier, 2006, 2009). However, when disambiguating semantic information is available, the frontal negativity is not apparent, and the processing of ambiguous words is qualitatively similar to that for unambiguous words, albeit showing residual activation of dominant meanings in contexts picking out subordinate senses, as reflected in larger N400 amplitudes (a component linked to semantic access).

1.1 Functional role of the frontal negativity during meaning selection

Sustained frontal negativities have been seen for all types of semantically ambiguous wordforms, including the NV-homographs already described, as well as noun/noun (NN-) homographs, such as *organ*, and referential ambiguities. The effect holds across languages (e.g., Dutch and English), types of linguistic context (e.g., phrasal, sentential, and discourse), and input modality (auditory and visual) (Federmeier, Segal, Lombrozo, & Kutas, 2000; Hagoort & Brown, 1994; Lee & Federmeier, 2006, 2009; Nieuwland, Otten, & Van Berkum, 2007; Nieuwland & Van Berkum, 2006; van Berkum, Brown, Hagoort, & Zwitserlood, 2003). We have suggested that this brain activity reflects frontally mediated executive processes engaged during lexical ambiguity resolution (Lee & Federmeier, 2009). However, it is still not clear what specific aspect of ambiguity processing this frontal negativity indexes.

Two different kinds of cognitive mechanisms have been posited to be important for processing when multiple potential referents are activated. Some researchers suggest that successful language processing requires a mechanism of actively suppressing contextually irrelevant information (Gernsbacher, 1997a, 1997b), and such deactivating processes have been shown to play a critical role in rapid meaning selection (Gernsbacher, Robertson, & Werner, 2001; Simpson & Adamopoulos, 2001). Whereas skilled readers can quickly suppress the contextually inappropriate meaning of a homograph, less skilled readers are less effective in meaning suppression and tend to maintain activation of the contextually irrelevant semantic features for a longer time (Gernsbacher, 1993). Furthermore, recent hemodynamic imaging studies have highlighted the role of meaning selection in comprehending lexical ambiguity. In response to lexical ambiguity, several studies have found activation in frontal brain areas (Ihara et al., 2007; Gennari, MacDonald, Postle & Seidenberg, 2007; Mason & Just, 2007; Rodd et al., 2005; Zempleni et al., 2007), specifically the left inferior frontal gyrus, an area that has been associated with the selection of task-relevant information from irrelevant competing representations (Gennari et al., 2007; Thompson-Schill, D'Esposito, Aguirre & Farah, 1997; Thompson-Schill, D'Esposito & Kan, 1999; Mason, Just, Keller & Carpenter, 2003; Stowe, Paans, Wijers & Zwarts, 2004; also see Novick et al. 2010 for a review). It is possible, then, that the frontal negativity reflects neural resources recruited to aid meaning selection by actively suppressing the contextually

inappropriate meaning, especially under conditions in which semantically-biasing information is not available to constrain meaning activation during initial semantic access.

Alternatively, it has been found that when ambiguous words are preceded by neutral context and disambiguated later, multiple potential interpretations may be maintained in working memory until more disambiguating information becomes available (e.g., Miyake, Just, & Carpenter, 1994; also see Frazier & Rayner, 1987, for similar findings with syntactic category ambiguities). Thus, it is possible that, although the syntactic contexts in our previous studies disambiguate the word class of the NV-homographs (e.g. in '*the train*', the function word '*the*' highlights that the homograph should be interpreted as its noun meaning sense), that information alone is not sufficient to allow semantic selection. In particular, because word class and meaning sense can at times be dissociated (e.g., in the gerund form: "*the training program*"), the comprehension system may not be able to use syntactic context information as a reliable disambiguating cue for selecting the meaning features of these cross-class ambiguous words, and, consequently, may maintain both meanings for later disambiguation. If this is true, then the frontal negativity may reflect the neural resources that are called upon to hold on to both interpretations of the homographs until further disambiguating information becomes available.

1.2 Age-related differences in eliciting the frontal negativity effect

The neural resources younger adults recruit to aid difficult ambiguity comprehension appear to become less available as the brain and cognition change during normal aging. In the aging literature, there has been evidence suggesting that the challenges associated with rapidly mapping an ambiguous word form onto its proper interpretation can be amplified by advancing age. Although in some studies older and younger adults have been found to be similar in their use of lexical/semantic constraints for disambiguation (Balota & Duchek, 1991; Hopkins, Kellas, & Paul, 1995; Swaab, Brown, & Hagoort, 1998), other work has suggested that older adults are impaired relative to younger adults in their use of other types of contextual information, such as syntactic cues (Dagerman, MacDonald, & Harm, 2006). This interaction of age-related differences in ambiguity resolution and context type has been demonstrated within subjects using event-related potential (ERP) measures. When older adults encounter ambiguity in the presence of semantically biasing sentence context information, their responses pattern like those of younger adults, suggesting relatively age-constant abilities to resolve ambiguity with semantic constraints (Lee & Federmeier, 2011). However, age-related differences are observed in cases when semantic support is lacking: older adults as a group fail to elicit the sustained frontal negative response, although a subset of older adults with higher scores on a verbal fluency test maintain a young-like frontal negativity effect pattern. These findings suggest that the tendency and/or ability to recruit resources important for processing ambiguity under more difficult conditions is diminished with advancing age.

The failure to find a frontal negativity in older adults as a group was observed for the processing of NV homographs embedded in syntactic prose sentences—sentences with well-formed syntactic structure but incoherent semantics (e.g., '*I knew the girl threatened more teammates, but commented that it wasn't all that willing to season*', Lee & Federmeier, 2011). Syntactic prose sentences have been widely used in psycholinguistic studies to examine the effects of syntactic context and/or absence of coherent semantic context (e.g., Van Petten & Kutas, 1991; Marslen-Wilson & Tyler, 1980; Tyler & Warren, 1987). However, syntactic prose sentences are obviously atypical, and the semantic conflict in these sentences tends to increase the overall processing load, which may make it more difficult for older adults to recruit the cognitive resources underlying the frontal negativity in response to lexical ambiguity. One goal of this study, therefore, is to examine whether this age-related difference also obtains under more normal processing conditions, in sentences with

disambiguating syntactic cues and neutral (but coherent) semantics up to the point wherein participants encounter the lexical ambiguity.

1.3 Examining the downstream effects of age-related differences in ambiguity processing

Given the prevalence of lexical ambiguity in language and the rapid pace at which language comprehension unfolds, ineffective lexical ambiguity resolution would seem likely to have important consequences for the processing of subsequent words. To our knowledge, however, no study has empirically evaluated the downstream consequences of age-related declines in ambiguity resolution. Therefore, another goal of this study is to investigate whether—and, if so, how –age-related changes in the processes reflected in the frontal negative effect give rise to disruptive influences on the comprehension of subsequent text. Because the two hypotheses about the functional significance of the frontal negativity (suppression vs. maintenance) make different predictions about whether the contextually inappropriate interpretation of an ambiguous word should be deactivated or remain accessible subsequent to its apprehension in a syntactically constrained but semantically neutral context, measuring processing downstream of the ambiguity can elucidate the functional significance of the processing reflected in the frontal negativity.

More specifically, to adjudicate between these two accounts, we will probe the activation status of potential interpretations of the NV-homographs at a later time point. In the extant literature, this has typically been done through the use of a priming paradigm, in which an ambiguous word is followed by a probe word associated with one of its meanings (see Van Petten, 2002 for a review). Although this paradigm provides a means of assessing meaning activation after the presentation of an ambiguous word, it has been subject to the criticism of possible confounds from backward priming. For example, Van Petten and Kutas (1987) argue that some of the results showing that multiple meanings of ambiguous words are active even in the presence of biasing context (the “multiple activation view”) might have arisen through rapid activation of the contextually irrelevant meaning in response to the probe, rather than the continuation of activity evoked by the ambiguous word itself. To avoid such potential confounds, the current design instead exploits plausibility as a means of tapping into the activation status of the meanings associated with previously encountered homographs.

In particular, in the present study NV-homographs and unambiguous words are embedded in the middle of sentences that provide syntactically specified but semantically neutral context information. Each homograph and unambiguous control word is then followed by a prepositional phrase whose head noun is much more plausible for one reading of the homograph. For example, whereas a sentence like *“Ben tried the duck in the **dish** prepared by a famous chef.”* is plausible, a sentence like *“Ben tried to duck in the **dish** prepared by a famous chef.”* is implausible, beginning with the critical noun in the prepositional phrase. Importantly, both sentences can be continued plausibly up through the critical head noun (e.g., “*Ben tried to duck in the alley to avoid the paparazzi.*”). Thus, the head noun can serve as a probe of the outcome of ambiguity resolution and can do so despite having little or no direct association with either of the ambiguous word’s meanings (e.g., neither *dish* nor *alley* is a lexical/semantic associate of *duck* in the USF free association norms), thus avoiding the possibility of backward priming from the probe to the ambiguous word. With this design, then, we are able to exploit one of the most appealing characteristics of ERPs, in that we can measure and compare responses to ambiguous and unambiguous words as well as to subsequent linguistic material that probes for plausibility without imposing a secondary task or requiring participants to make behavioral responses at either point in the sentence.

If the frontal negativity indexes a process that serves to suppress the contextually irrelevant meaning features of a homograph, then, when this process is effectively employed, only

semantic features associated with the contextually appropriate meaning should remain active by the time the head noun of the prepositional phrase is encountered. In this case, semantic access, as indexed by the N400 component of the ERP (Kutas & Federmeier, 2011), will be facilitated only for the plausible head nouns, creating an N400 plausibility effect: an amplitude difference between the implausible and plausible head nouns, with reduced (more positive) responses to the plausible words. Assuming suppression is effective in fully resolving the ambiguity, these plausibility effects for ambiguous words should be similar in size to those following unambiguous words. On this view, then, reduced or absent frontal negativity – as predicted for older adults – indicates less effective semantic suppression. If the contextually irrelevant meaning features are therefore still active when the head noun of the prepositional phrase is apprehended, the processing of both the plausible and the implausible nouns would be facilitated, consequently reducing the size of the N400 plausibility effect.

This effect pattern may also be influenced by meaning frequency/dominance. It has been shown that, compared to non-dominant meanings of a homograph, dominant meanings are activated faster, to a greater degree, and for a longer time (Simpson & Burgess, 1985), and therefore are harder to suppress when the context favors the subordinate interpretation (Duffy, Kambe, & Rayner, 2001; Paul, Kellas, Martin, & Clark, 1992; Rayner, Pacht, & Duffy, 1994; Tabossi, 1988; Tabossi & Zardon, 1993). Thus, in the absence of effective suppression, contextually irrelevant dominant meaning features would be especially likely to remain active. Consequently, in the cases in which frontal negativity is reduced or absent, the reduction in the N400 plausibility effect would be expected to be particularly notable for cases in which the syntactic contexts pick out the subordinate meanings of the ambiguous words.

Very different predictions arise if the frontal negativity indexes the maintenance of multiple meanings associated with ambiguous word forms until further semantic disambiguation is provided. On this hypothesis, enhanced frontal negativity to NV-homographs would be expected to lead to very small or absent N400 plausibility effects following ambiguous words (and thus a pattern quite different from that predicted following unambiguous words), since semantic access should be facilitated for continuations related to both meaning senses. In this case, then, reduced or absent frontal negativity would suggest that both meanings are not being maintained, leading to sizeable N400 plausibility effects. On the assumption that dominant meaning features are more likely to remain active than subordinate meaning features and would therefore be facilitated even when contextually inappropriate, reduced or absent frontal negativity may lead to young-like reduced N400 plausibility effects for nouns appearing in contexts supporting the subordinate-biasing contexts, but, different from the predicted pattern in younger adults, reliable N400 plausibility effects for nouns in dominant-biasing context.

2. Methods

2.1 Materials

Two different types of words were each embedded in sentence medial position, with prior context being semantically neutral but syntactically specified (e.g. *Peter liked the/to park…*). Word types included **NV-homographs**, which are both syntactically and semantically ambiguous (e.g., *the watch/to watch)*, and **semantically and syntactically unambiguous words** (e.g., *the logic/to choose*). These words were then followed by a prepositional phrase in which the head noun was either plausible or implausible. For sentences containing NV-homographs, plausible nouns were congruent only with the syntactically designated interpretation, as illustrated in examples (1) and (2), below. Implausible continuations were then derived by swapping the syntactic cues immediately preceding the NV-homographs, as

in examples (3) and (4). In these cases, then, the head noun of the preposition is incongruent with the contextually supported interpretation of the NV-homographs but congruent with the homograph's alternate meaning (in its other syntactic class). Care was taken to ensure that there is little lexical/semantic association between the NV-homographs and the head nouns of the preposition. According to the University of South Florida free association norms, both forward and backward association strength between the ambiguous words and subsequent disambiguating words is 0.01. Similar sets of plausible and implausible sentences were then created for matched unambiguous nouns and verbs, with implausible continuations derived by substituting nouns from other plausible sentences containing unambiguous words (illustrated in examples (5)–(8)). Hence, for both ambiguous and unambiguous sentences, we are able to compare the brain responses to plausible and implausible nouns by analyzing the responses to the same set of words as a function of prior context.

Examples for each condition are listed below (NV-homographs and matched unambiguous words are in bold italic; plausible and implausible nouns are underscored):

NV-homographs—

Plausible (1) Brad hated to ***trip*** over the cord in front of all his classmates.
(2) Sam hated the ***trip*** over the river because he hated getting wet.
Implausible (3) Brad hated to ***trip*** over the river because he hated getting wet.
(4) Sam hated the ***trip*** over the cord in front of all his classmates.

Unambiguous words—

Plausible (5) Audrey had to ***lean*** on her friend for support after straining her ankle.
(6) Bob knew the ***lady*** down the hall liked poinsettias.
Implausible (7) Audrey had to ***lean*** on her room for support after straining her ankle.
(8) Bob knew the ***lady*** down the word liked poinsettias.

Each ambiguous and unambiguous word was repeated once, with different continuations, and with a lag of at least 50 sentences. In order to make the plausibility of the text subsequent to each repetition unpredictable, across lists sentences containing the first and second appearance of a particular NV-homograph or matched unambiguous word were either both plausible, both implausible, or one of each. In addition, the order of each pair of sentences was counterbalanced, creating a total of eight lists.

Each participant read 192 sentences, consisting of equal numbers of sentences containing ambiguous and unambiguous words and equal numbers of plausible and implausible continuations. In addition, although we did not specifically look into the factor of word class in this experiment, within each list the number of nouns and verbs was also matched across the ambiguous and unambiguous word sets in order to reduce the possibility of any word class influences on the ambiguity effect.

Ambiguous and unambiguous words were matched for lexical features including log frequency (Kucera & Francis, 1967), word length, and usage-specific concreteness (Lee & Federmeier, 2008; see Table 1). Both the sentence constraint up to the head nouns of the

prepositional phrase and the cloze probability of the head nouns were not significantly different across conditions (all *p*'s > 0.1). Plausibility of the head nouns of the prepositional phrases was also controlled, such that plausibility ratings were over 75% for plausible sentences and lower than 35% for implausible sentences for both ambiguity conditions (Table 2). Cloze probability and plausibility norming procedures are described in the next section.

To allow analyses based on meaning dominance, sentences were sorted on the basis of whether the syntactic context picks out the dominant or non-dominant meaning of the NV-Page homographs. Because syntactic information is the only available disambiguating context in our sentences, meaning dominance was estimated by comparing the sense frequency of the noun and verb usages of the homograph listed on the English WordNet 3.0 online database (see Fellbaum, 1998) while taking into account the total frequency of the homograph. Specifically, a homograph is classified as biased if the absolute value of the difference between the two word class usages is greater than 30% of the total usage of that particular word. Based on this criterion, 33 out of the 48 homographs were classified as biased homographs, and the rest were classified as balanced homographs. The averaged dominance scores (averages of the difference scores subtracted between the noun and verb usages and adjusted by the total frequency of each homograph) are 0.69 and 0.13 for the biased and balanced homographs respectively. The dominant condition included biased homographs used in their dominant sense, and the non-dominant condition included biased homographs used in their subordinate sense as well as balanced homographs. Sentential features for NV-homograph sentences picking out dominant meanings (which, when implausible, contain critical head nouns associated with the non-dominant meaning of the homograph) and non-dominant meanings (which, when implausible, have critical head nouns associated with the dominant meaning) are provided in Table 3.

Cloze probability—Three hundred and twenty-eight sentence contexts (sentences up to the point just before the head noun of the prepositional phrases: e.g. *Mia wanted to sit by the*_____ …) were normed for cloze probability. The cloze probability norming was completed by 60 monolingual English speakers at the University of Illinois (27 men and 33 women; mean age 19.2 years, range 18–22 years). The sentence frames were divided into three lists, with 20 participants completing each list. In the norming booklet, participants were given sentences with the head noun of the prepositional phrases replaced by a blank line. Next to the column of sentence frames were three columns for potential continuations. Participants were told explicitly that the sentences continue after the blanks, and were asked to write down, in the first column, the first word that came to mind that could plausibly continue the sentence at the blank line. If multiple words came to mind, they were told to write down the one they think fits best in the first response column and to then list the additional continuations that came to mind in the second and third response columns. Cloze probability for a given word was calculated as the percentage of people who provided that word as their first response. The constraint of the sentence context was then given by the cloze probability of the highest probability completion.

Plausibility—Sentence contexts were then assigned plausible and implausible nouns and continuations, resulting in a total of 656 sentence fragments. The plausibility of these fragments was rated in a paper-and-pencil norming procedure completed by a different set of 60 monolingual English speakers at the University of Illinois (21 men and 39 women; mean age 18.7 years, range 18–23 years). These sentence frames were divided into four lists, with 15 participants rating each list. The syntactic cues were shown in upper case letters to ensure that the plausibility of the sentence fragments was rated based on the correct syntactic context; the plausible and implausible nouns were underscored (e.g., 'Tom wanted TO fan with the paper……' and 'Fred tried THE rate with a metronome……'). Participants were

told to indicate, from 0% to 100%, how much sense they thought each sentence made with the underlined word in it.

The results from the cloze probability and plausibility norming were then used to select the final set of 384 sentences, 192 containing NV-homographs (one for the noun and verb meaning of each homograph) and 192 containing unambiguous words. Both sets of sentences contained equal numbers of plausible and implausible continuations.

2.2 Participants

Sixteen University of Illinois undergraduate students (8 males and 8 females; mean age 19 years, range 18–22 years) and twenty-four healthy older adults (12 males and 12 females; mean age 66 years, range 61–76 years) participated in the ERP phase of the study for course credit or cash. All participants were right-handed as assessed by the Edinburgh inventory (Oldfield, 1971); 20 reported having left handed family members (6 younger adults and 14 older adults). All were monolingual speakers of English with no consistent exposure to other languages before age 5. Participants had no history of neurological/psychiatric disorders or brain damage, and all older adults scored in the normal range on screening for cognitive impairment (average modified Mini Mental Status Examination score: 54.8 (maximum score 57), range 51–57; Mayeux, Stern, Rosen, & Leventhal, 1981) as well as on the neuropsychological battery. On average, the older adults were more educated then were the younger adults (average years of education was 16 for the older adult sample and 13 for the younger adult sample). Participants were randomly assigned to one of the eight experimental lists.

2.3 Procedure

Participants were seated 100 cm in front of a 21” computer monitor in a dim, quiet testing room. They were given written instructions and a 10-trial practice session before the experiment to familiarize them with the experimental environment and the task. At the start of each trial, a series of plus signs appeared in the center of the screen for 500 ms. After an SOA ranging randomly between 1000 and 1500 ms (jittered to lessen the influence of slow, anticipatory potentials on the average ERPs), a sentence was displayed word by word in upper case in the center of the screen. Each word was presented for 200 ms, followed by a 300 ms blank screen. At the end of the sentence, the screen went blank for one and a half second before a probe word appeared in upper case, red letters. Half of the probe words were new words; the old probe words were randomly chosen from the syntactic cues, NV-homographs and matched unambiguous words, critical nouns, and the rest of the words in the sentence. Participants were instructed to judge whether or not that probe word had appeared in the immediately preceding sentence and to indicate their response by pressing one of two buttons, held in each hand; hand used to respond “yes” was counterbalanced. The probe disappeared upon the participant’s button-press response. The next trial then began one and a half seconds after the offset of the probe. A small square (3 by 3 pixels) remained on throughout the experiment, positioned just below the center of the screen, in order to help participants keep their gaze centered.

The whole experiment was divided into four blocks, each lasting about seven minutes. A paper-and-pencil sentence recognition task was administered at the end of each block. The sentence-recognition test contained 96 sentences in total, half of which were old sentences (drawn in equal numbers from plausible and implausible sentences containing NV-homographs and unambiguous words) and half of which were new (with equal numbers of plausible and implausible sentences). Participants were told to mark whether they thought they had seen each sentence in the previous block or not. Because many of the same words were used in the new sentences as in the experimental ones, word level recognition alone

would not allow participants to score well on this test. The word and sentence recognition tasks were used in tandem to keep the task demands as similar as possible to our prior study (Lee & Federmeier, 2009, 2011) and to ensure that participants were carefully attending to each individual word while also attempting to integrate those words into a holistic unit.

2.4 EEG recording and data analysis

The electroencephalogram (EEG) was recorded from twenty-six evenly-distributed silver/silver-chloride electrodes attached to an elastic cap. All scalp electrodes were referenced on-line to the left mastoid and re-referenced off-line to the average of the right and the left mastoids. In addition, one electrode (referenced to the left mastoid) was placed on the left infraorbital ridge to monitor for vertical eye movements and blinks, and another two electrodes (referenced to one another) were placed on the outer canthus of each eye to monitor for horizontal eye movements. Electrode impedances were kept below 3kΩ. The continuous EEG was amplified through a bandpass filter of 0.02–100Hz and recorded to hard disk at a sampling rate of 250Hz.

Epochs of EEG data were taken from 100 ms before stimulus onset to one and a half seconds after. Those containing artifacts from amplifier blocking, signal drift, eye movements, or muscle activity were rejected off-line before averaging, using thresholds selected for each participant through visual inspection of the data. Trials contaminated by eye blinks were corrected for 8 participants (3 younger and 5 older adults) who had enough blinks to obtain a stable filter (Dale, 1994); for all other participants, trials with blink artifacts were excluded from analysis. Trial loss averaged 19% for younger adults and 12% for older adults. Artifact-free ERPs were averaged by stimulus type after subtraction of the 100 ms pre-stimulus baseline. Prior to statistical analyses, ERPs were digitally filtered with a bandpass of 0.2–20 Hz. To correct for violations of sphericity associated with repeated measures, the Huynh–Feldt adjustment to the degrees of freedom was applied for each analysis of variance (ANOVA). Consequently, for all *F* tests with more than 1 degree of freedom in the numerator, the corrected *p* value is reported. For all analyses, main effects of electrode and interactions with electrode sites are not reported unless they are of theoretical significance.

3. Results

3.1 Behavior

The purpose of the word and sentence recognition tests was to encourage participants to attend to the stimuli at both word and sentential levels. The overall results indicated that both groups of participants indeed paid attention to individual words and processed them for meaning. Averaged accuracy was 94% (d'=3.4) for the younger adults and 90% (d'=2.9) for the older adults on the word recognition test and 86% (d'=2.5) for younger adults and 84% (d'=2.3) for older adults on the sentence recognition test.

3.2 ERPs

Figure 1 shows (at a representative sample of scalp channels) ERP responses time-locked to the onset of NV-homographs and matched unambiguous words and continuing through the onset of the critical nouns in the prepositional phrases. The overall morphology of the brain responses from younger and older adults is similar: both groups show early sensory responses followed by a wide-spread negativity (N400). However, consistent with prior observations of ERP responses from healthy older adults (e.g., Federmeier & Kutas, 2005; Federmeier, McLennan, De Ochoa, & Kutas, 2002; Kemmer, Coulson, De Ochoa, & Kutas, 2004; Kutas & Iragui, 1998), N1 responses (around 160 ms over posterior sites and 110 ms over frontal sites) appear to be enhanced while P2 responses (around 200–250 ms over

posterior sites and 150–200 ms over frontal sites) are notably reduced in the older sample; in addition, the amplitude of the N400 is smaller for older adults.

3.2.1 Ambiguity effects—Results from younger adults (Figure 1, left panel) replicate our prior findings (Federmeier, Segal, Lombrozo, & Kutas, 2000; Lee & Federmeier, 2006, 2009), with NV-homographs eliciting more negative brain responses than unambiguous words, beginning after the P2 time window (around 250 ms) and continuing over the next two words in the sentence (i.e., to 1500 ms). The negativity in younger adults is widespread but particularly prominent over fronto-central regions. For older adults (Figure 1, right panel), NV-homographs did elicit slightly more negative responses than unambiguous words. However, this response was more restricted than that seen for younger adults, both in terms of magnitude and duration. In addition, the scalp distribution of the effect was different, being largest over central/posterior scalp channels.

To characterize these effects, omnibus ANOVAs with 2 levels of Age (younger vs. older), 2 levels of Ambiguity (Ambiguous vs. Unambiguous words), 2 levels of Repetition (First vs. Second presentation), and 22 levels of Electrode Site (frontal electrode sites: MiPf, LLPf, RLPf, LMPf, RMPf, LDFr, RDFr, LMFr, RMFr, LLFr, and RLFr; central/posterior electrode sites: MiCe, LMCe, RMCe, LDCe, RDCe, MiPa, LDPa, RDPa, MiOc, LMOc, and RMOc) were conducted on mean amplitudes of data measured between 250–500 ms, 500–1000 ms, and 1000–1500 ms after the onset of ambiguous/unambiguous words.

Between **250 and 500 ms**, the results revealed a significant main effect of Age [$F(1,38)=7.04$, $p=.01$] and a main effect of Ambiguity [$F(1,38)=22.37$, $p<.001$]. There was a marginally significant interaction between Age and Ambiguity [$F(1,38)=2.96$, $p=0.09$], with a larger Ambiguity effect for the younger adults than the older adults (mean amplitude differences between ambiguous and unambiguous words were 0.93 μV for younger adults and 0.46 μV for older adults). The effect of Repetition was not significant [$F<1$] and did not interact with other factors [$Fs<1$]. Results from the **500 to 1000 ms** and **1000 to 1500 ms** time windows were identical, with a significant main effect of Ambiguity [$F(1,38)=9.9$, $p<.01$ and $F(1,38)=10.7$, $p<.01$], which interacted with Age [$F(1,38)=8.6$, $p<.01$ and $F(1,38)=4.5$, $p<.05$]. Follow up comparisons in both time windows showed a significant Ambiguity effect for younger adults [$F(1,15)=11.8$, $p<.01$ and $F(1,15)=7.4$, $p=.02$], but not for older adults [$F<1$ and $F=1.4$]. There were no other significant effects or interactions in either time window.

In summary, younger and older adults showed distinct patterns in their brain responses to NV-homographs and matched unambiguous words, which replicate prior findings (Lee & Federmeier, 2011). Younger adults elicited a robust, sustained fronto-central negativity to NV-homographs relative to unambiguous words from around 250ms to at least one and a half seconds after the onset of the homographs (i.e., until the critical noun in the prepositional phrases was presented). This effect was markedly reduced in healthy older adults (c.f., Lee & Federmeier, 2011) and was seen in the much more restricted time window of 250 – 500 ms after the onset of the ambiguous words. Given this (predicted) difference in response to ambiguous words, additional analyses characterized the pattern of responses to the subsequent critical head nouns of the prepositional phrases as a function of ambiguity and age group.

3.2.2 Plausibility effects

3.2.2.1 Plausibility effects without preceding ambiguity: To examine plausibility effects in sentences that did not contain an NV-homograph, mean amplitudes of data collected from 11 central/posterior sites (where N400 effects are typically most prominent) between 300–600 ms after subtraction of the 100 ms pre-stimulus baseline were subject to an omnibus

ANOVA with Age as a between subject factor (older vs. younger) and 2 levels of Plausibility (plausible vs. implausible) and 11 levels of Electrodes site (including MiCe, LMCe, RMCe, LDCe, RDCe, MiPa, LDPa, RDPa, LMOc, RMOc, and MiOc) as within-subject factors. The results showed a significant main effect of Plausibility [$F(1,38)=28.50, p<.001$], with reduced negativity to plausible than to implausible continuations, and a significant main effect of Age [$F(1,38)=17.51$, $p<.001$], with overall smaller amplitude waveforms in the older group. Age and Plausibility did not interact [$F=3.36$]. Thus, as expected, both younger and older adults' N400 responses are sensitive to the plausibility of words in normal sentences without high levels of lexical ambiguity. Figure 2 shows the brain responses to plausible and implausible nouns preceded by unambiguous words separately for each age group.

3.2.2.2 Plausibility effects with preceding ambiguity: Having established that the plausibility effects in sentences without preceding ambiguity did not interact with age, we next compared the plausibility effects within sentences containing ambiguity. An omnibus ANOVA with Age as a between subject factor (older vs. younger), and 2 levels of Plausibility (plausible vs. implausible) and 11 levels of Electrode Site as within subject factors was conducted on the mean amplitude of data collected from central/posterior sites between 300–600ms post stimulus onset (after subtraction of the 100 ms pre-stimulus baseline). The results revealed a significant main effect of Plausibility [$F(1,38)=18.22$, $p<.001$], reflecting smaller (more positive) amplitude responses to plausible than implausible words, and a significant main effect of Age [$F(1,38)= 15.08$, $p=.001$], with overall smaller amplitude N400s in older adults. The effect of Plausibility interacted with Electrode [$F(10, 380)=5.45$, $p<.001$] and further interacted with the effect of Age [$F(10, 380)=3.54$, $p<.01$], revealing a smaller amplitude plausibility effect for older adults than younger adults (mean amplitude differences between plausible and implausible head nouns are 0.53μV for older adults and 1.32μV for younger adults).

Figure 3 shows the comparison between the plausible and implausible continuations following NV-homographs, split into cases in which the sentence contexts support the dominant interpretation versus the non-dominant interpretation of the NV-homograph. The comparisons show robust plausibility effects for younger adults irrespective of the context type. However, for older adults, the plausibility effect is much reduced when the context supports the non-dominant interpretation of the homographs. To examine these effects, for each group, an omnibus ANOVA with 2 levels of Dominance (dominant vs. non-dominant), 2 levels of Plausibility (plausible vs. implausible) and 11 levels of Electrode Site was conducted on the mean amplitude of data collected from central/posterior sites between 300–600ms post stimulus onset. The results for younger adults revealed a main effect of Plausibility [$F(1,15)=10.55$, $p=.005$] and no Plausibility by Dominance interaction [$F=2.41$, $p=.1$]. The marginal trend reflected a slightly decreased plausibility response for sentences that picked out the non-dominant interpretation (mean amplitude differences between plausible and implausible nouns in the non-dominant-biasing context and the dominant-biasing context are 0.97μV and 1.97μV). However, neither the responses in the two implausible conditions nor the responses in the two plausible conditions differed significantly across dominance [$Fs<1$].

For older adults, however, the effect of Plausibility [$F(1,23)=10.61$, $p<.005$] was modulated by Dominance [$F(1,23)=4.45$, $p<.05$]. This interaction is mainly driven by the reduction of N400 amplitude to implausible nouns in the non-dominant biasing context (thus, where the implausible noun is congruent for the dominant meaning); mean amplitudes for plausible and implausible nouns in the dominant-biasing context and the non-dominant-biasing context are 0.80μV and −0.43μV (dominant-biasing), and 0.53μV and 0.30μV (non-dominant-biasing), respectively. Follow-up pair-wise comparisons showed a significant

plausibility effect when the context picks out the dominant meaning sense [F(1,23)=9.12, p<.01], but no effect when the context picks out the non-dominant meaning sense [F=1.17]. There are no reliable differences between the responses to the two plausible nouns across dominance [F<1], but the response to implausible nouns is significantly more positive in the non-dominant-biasing context than in the dominant biasing context [F(1,23)=5.55, p<.05], suggesting residual activation of the implausible dominant sense in the non-dominant-biasing contexts.

To summarize, whereas the two groups show no reliable differences in N400 plausibility effects when the preceding context is unambiguous, older adults show a reduced plausibility effect compared to younger adults for continuations following an ambiguous word. This suggests that contextually irrelevant meanings are not as effectively suppressed in older adults, reflecting the consequences of the reduced frontal negativity in this group. In both age groups, plausibility effects are numerically reduced in contexts picking out a nondominant sense of the NV-homograph (i.e., when the context irrelevant meanings are more dominant), consistent with findings in the literature suggesting that dominant meanings tend to be activated more strongly and in a more sustained fashion and are therefore harder to suppress. Of critical interest to our study, however, is that despite this greater difficulty, younger adults were able to suppress the context-irrelevant dominant meanings to the extent that reliable differences are obtained between the plausible and implausible continuations. However, this is not the case for older adults, where implausible dominant meanings were not reliably different from plausible non-dominant meanings because of the facilitation of the implausible dominant meanings (compared to implausible non-dominant meanings).

3.2.3 Correlating ambiguity effects with subsequent plausibility effects—Our results suggest that the frontal negativity indicates a process that actively suppresses the contextually inappropriate meaning of an ambiguous word. Older adults are less likely or less able to recruit this process, and, as a consequence, show erroneous downstream activation of contextually inappropriate word meanings. Together, these findings suggest that the size of the frontal negativity effect to the ambiguous words should predict the size of the subsequent plausibility effect to the head nouns. To test this, we examined the correlation between the magnitude (averaged over all 22 channels) of the frontal negativity between 250–1500 ms post onset of the NV homographs and the plausibility effect following NV homographs (300–600 ms post onset of the head nouns). As predicted, for younger adults, we found a positive correlation between the magnitude of the frontal negativity and the magnitude of the subsequent plausibility effect (r=0.46, one-tailed p<.05). For older adults, the correlation did not reach statistical significance (r=0.15, one-tailed p=0.2), likely because of the substantially smaller range of negativity magnitudes in this sample. However, the positive correlation between the magnitude of the frontal negativity and the subsequent plausibility effect holds when the data from both groups are considered together (r =0.44, one-tailed p<.005) (Figure 4). This correlation adds to the evidence linking the frontal negativity to a mechanism that actively suppresses contextually irrelevant meanings during meaning selection.

4. Discussion

Lexical ambiguity processing when disambiguating semantic constraints are lacking has been shown to elicit a sustained frontal negativity in younger adults that is less likely to be seen in healthy older adults (Federmeier et al, 2000; Hagoort & Brown, 1994; Lee & Federmeier, 2006, 2009, 2011; Nieuwland et al., 2007; Nieuwland & Van Berkum, 2006; van Berkum et al., 2003). The underlying neural correlates and the specific functional role of the sustained frontal negativity are not yet well understood. Furthermore, it is not clear

whether—and, if so, how – age-related changes in the processes reflected in the frontal negative effect may lead to disruptive influences on comprehending subsequent text. In light of this, the current study was designed to (1) elucidate the functional significance of the frontal negativity (suppression vs. maintenance), (2) further investigate age-related changes in the frontal negativity effect using more natural sentences with coherent but neutral semantic context, and (3) determine the corresponding consequences of age-related changes in lexical ambiguity resolution on subsequent text processing.

In the present study, NV-homographs and unambiguous words occurred in mid-sentence position, with disambiguating syntactic cues and coherent semantic information that did not bias toward either meaning sense. We probed the outcome of lexical ambiguity resolution in such contexts with a plausibility manipulation on the head noun of a following prepositional phrase. Because the head noun was plausible for only one interpretation of the homograph, an N400 plausibility effect was expected to the degree that only the contextually appropriate meaning was being maintained. As such, very different predictions about the pattern of plausibility effects are made on the hypothesis that the sustained frontal negativity indexes processes related to suppressing the contextually irrelevant meaning as opposed to on the hypothesis that this activity reflects the active maintenance of both meanings.

The results from younger adults strongly suggest that the processes underlying the enhanced frontal negativity are more related to suppression than maintenance. Replicating our prior studies (Lee & Federmeier, 2006, 2009, 2011), we found that young adults elicit a sustained fronto-central negativity to syntactically well-specified NV-homographs (measured between 250ms to 1500ms post onset of the NV-homographs). Downstream of the negativity, then, younger adults showed more negative N400 responses for nouns associated with the contextually irrelevant meaning (implausible nouns) than the contextually relevant ones (plausible nouns), suggesting that the contextually irrelevant meaning has been suppressed and is therefore notably less active than the relevant meaning downstream of an ambiguous word. This conclusion is bolstered by the significant positive correlation between the ability to effectively recruit the suppression process (as reflected in the frontal negativity) and the ability to subsequently discriminate plausible and implausible interpretations (as reflected in the N400 plausibility effect).

If the frontal-central negative ERP ambiguity effect indeed indexes suppression, then this provides additional constraints on its likely brain sources. The neural generators of the frontal negative ERP ambiguity effect have not been directly investigated. However, several imaging studies on lexical ambiguity resolution that used contexts similar to those eliciting the sustained frontal negative ERP effect (Federmeier et al., 2000; Lee & Federmier, 2006, 2009; Hagoort & Brown, 1994) have found enhanced activity in the left inferior frontal gyrus (LIFG) (Gennari et al., 2007; Mason and Just, 2007; Rodd et al., 2005; Zempleni et al., 2007). Thus, it is reasonable to hypothesize that the frontal negative effect might arise from selection-related activity widely observed in LIFG (for reviews, see Novick et al. 2010 and Thompson-Schill, Bedny, & Goldberg, 2005). This hypothesis is corroborated by our finding that the frontal negativity is specifically linked to meaning suppression, given that prior work has argued for an inhibitory role of LIFG during language comprehension (Bedny, Hulbert, & Thompson-Schill, 2007; Cardillo et al., 2004). Moreover, work outside of the domain of language processing has also indicated a critical role for the LIFG in overriding highly routinized representations (Jonides et al. 1998; Nelson et al, 2003; Jonides and Nee 2006) and inhibiting inappropriate motor responses (Swick, Ashley, & Turken, 2008). Our results are thus consistent with this view of LIFG.

The results from older adults replicated our prior finding (Lee & Federmeier, 2011) that selection-related neural resources, as indexed by sustained frontal negativity to NV-

homographs, are less available with advancing age. Compared to the negativity observed in younger adults, which was quite sustained (seen from 250 ms after the onset of the stimulus and continuing through 1500 ms, and thus through the presentation of the next two words), effects in older adults were significantly smaller and restricted to the 250–500 ms time window (thus, terminating by the time the next word appeared). Therefore, although older adults did indeed seem to perceive the ambiguity induced by NV-homographs in syntactically specified but semantically neutral context, they were nevertheless less likely or less able than young adults to recruit and maintain additional processes associated with processing that ambiguity.

This is consistent with our prior study showing age-related differences in lexical ambiguity processing when semantic constraints are lacking (Lee & Federmeier, 2011), which also showed that older adults exhibit young-like processing patterns to lexical ambiguity in semantically constraining context, when the semantic system can settle down to a single interpretation of an ambiguous word in a more implicit manner in the temporal brain region. Jointly, our current and prior study support the findings of disproportional age-related changes in the aging literature that frontal lobe regions tend to undergo more age-related deterioration than other brain areas (Raz et al., 2005; Moseley, 2002; Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003; Head et al., 2004; Sullivan & Pfefferbaum, 2006) and executive/controlled processes tend to be more affected than stimulus-driven ones by age (DiGirolamo et al., 2001; Foster, Black, Buck, & Bronskill, 1997; Hasher, Zacks, & May, 1999; Jonides et al., 2000; Vanderaspoilden, Adam, Van Der Linden, & Morais, 2007).

Our results showed that age-related decline in recruiting suppression-related resources indeed resulted in downstream processing difficulties, especially when the contextually irrelevant meanings are dominant and therefore taxing to suppress. Overall, older adults showed weaker plausibility effect to nouns following ambiguous words than did younger adults, suggesting that contextually irrelevant meanings are not suppressed as effectively. When the syntactic context picked out the dominant meanings of the NV-homographs, older adults showed N400 plausibility effects that were smaller than those in younger adults, yet statistical reliable. It is possible that although older adults seemed less able to recruit the processes reflected in the frontal negativity, the more restricted activity that we observed was sufficient to suppress the weaker, contextually irrelevant nondominant meaning features. Alternatively, it may be that non-dominant meanings elicit weaker activation that is less likely to last over the intervening words between the NV-homograph and the disambiguating head noun. It has been shown that, without supporting context, the subordinate meaning of a homograph tends to fade by 750 ms after the onset of a homograph (Simpson and Burgess, 1985). It is therefore possible that the weak plausibility effect we observed from the older adults is a consequence of the passively fading activation level of the non-dominant meanings. These two possibilities need not be mutually exclusive and may be difficult to tease apart.

Older adults' diminished ability to recruit the cognitive and neural processes reflected in the frontal negativity had more notable consequences when the context picked out the non-dominant meaning of an ambiguous word. Our prior work (Lee & Federmeier, 2009), along with many other studies in the literature (e.g., Duffy, Kambe, & Rayner, 2001; Hogaboam & Perfetti, 1975), has shown that dominant meaning features of ambiguous words become active – at least briefly – even when semantic context information strongly constrains for the subordinate interpretation. In the data from younger adults in the current study, therefore, the fact that, with subordinate-biasing syntactic context and no biasing semantic information, dominant meaning senses are no longer active by the time the head noun is encountered strongly suggests that this activated meaning has been effectively suppressed and that the frontal negativity reflects brain activity involved in such suppression. Critically,

however, older adults did NOT show a significant plausibility effect when the syntactic context supported the less frequent meaning of the homograph, in which selection due to suppression can be dissociated from the passive fading of activation. The results show that the lack of a significant plausibility effect was due to facilitation (amplitude reduction) of the N400 to the implausible nouns. This shows that both meanings of the ambiguous word were still active at this downstream point and thus that the contextually-irrelevant dominant meaning senses were not suppressed effectively enough to be distinguished from the contextually relevant meaning.

These result patterns resemble the findings from a study by Gunter and colleagues in pointing to an important role for inhibitory processes in lexical ambiguity resolution (Gunter, Wagner, & Friederici, 2003). In that study, participants read sentences containing German NN-homographs with subsequent semantic context biasing to either the dominant or subordinate meaning and then immediately followed by a disambiguating verb converging with either meaning (e.g. *Der Ton wurde vom Sänger gesungen, als…* '*The tone/clay was by the singer sung…*' vs. *Der Ton wurde vom Töpfer gebrannt, weil…* '*The tone/clay was by the potter sung, because…*'). Results on the disambiguating verbs showed that when the semantic context biased the dominant reading of the homograph, N400 responses were larger to verbs related to the non-biased meaning than to those that cohered with the semantic bias. This pattern held irrespective of participants' working memory span. However, when the semantic context favored the subordinate meaning, **only** people with higher working memory span showed analogous N400 mismatch effects at the verb. These results were taken to suggest that people with lower working memory span are less able to rapidly suppress contextually irrelevant meanings associated with the dominant use of an ambiguous word. People with higher working memory capacity, however, can more effectively suppress the meanings that are not selected by the context, even against meaning frequency.

In sum, the current study provides an on-line, continuous characterization of brain responses to lexically ambiguous words and subsequent linguistic material. In particular, our results showed that neural resources that are routinely recruited by younger adults to help suppress contextually-irrelevant meaning features when semantic constraints are lacking tend to become less available and effective with advancing age. We further showed that such decline impacts meaning processing for linguistic material that comes after the not-yet-resolved lexical ambiguity. To our knowledge, this is one of the first pieces of empirical evidence to directly show the downstream consequences of inefficient lexical resolution in healthy older adults.

Highlights

- Continuous characterization of ERPs to ambiguous words and subsequent text
- Functional role of the sustained frontal negativity younger adults elicit during difficult meaning selection
- Age-related neuro-cognitive differences in lexical ambiguity resolution
- Aging affects the suppression mechanisms involved in meaning selection
- Such decline impacts comprehending text following the not-yet-resolved ambiguity

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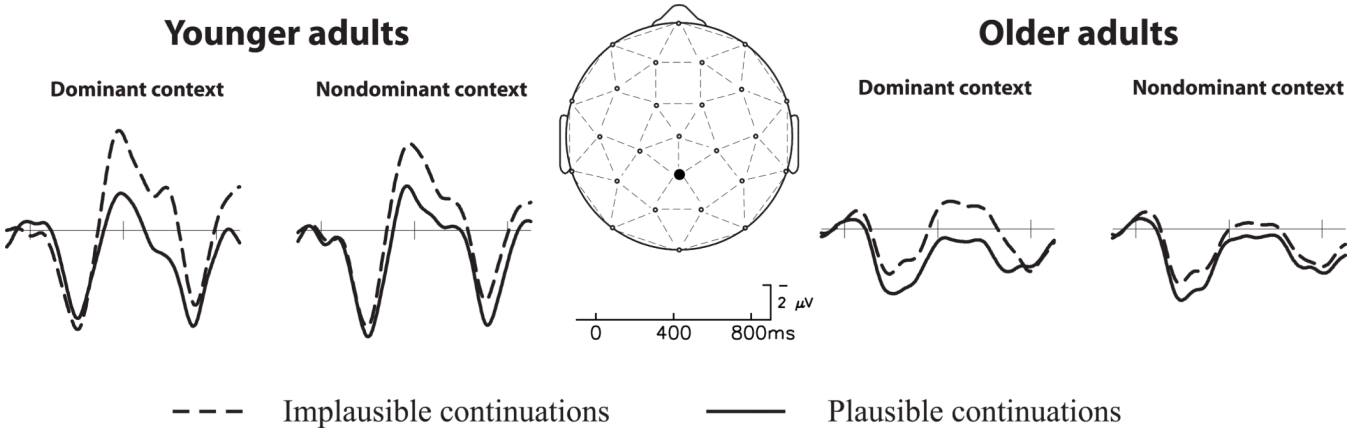

Figure 1.

Grand average ERPs to ambiguous and unambiguous words at 8 representative electrode sites are plotted for both younger and older adults using 100 ms pre-stimulus baseline. Positions of the plotted sites are indicated by filled circles on the center head diagram (nose at top). Negative is plotted up for this and subsequent figures. Younger adults elicited more negative responses to ambiguous words than to unambiguous words, starting from 250ms post stimulus onset and continuing for at least one and a half second (up to when the head noun in the prepositional phrase is presented). In older adults' data, however, this effect is notably reduced in terms of both amplitude and duration.

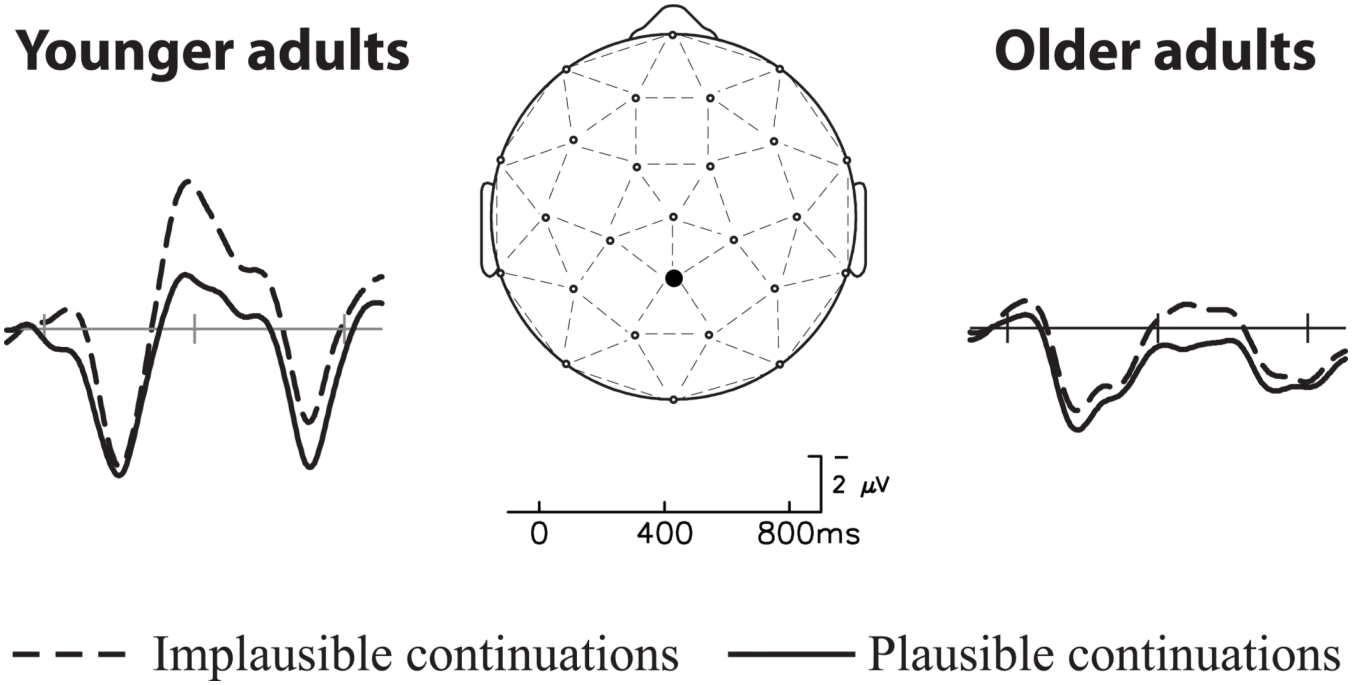

Figure 2.
Shown are brain responses (at a representative electrode site) in each age group to plausible (solid lines) and implausible nouns (dashed lines) preceded by unambiguous words using 100 ms pre-stimulus baseline. For both age groups, an N400 plausibility effect (more positive responses to plausible than implausible nouns) could be observed.

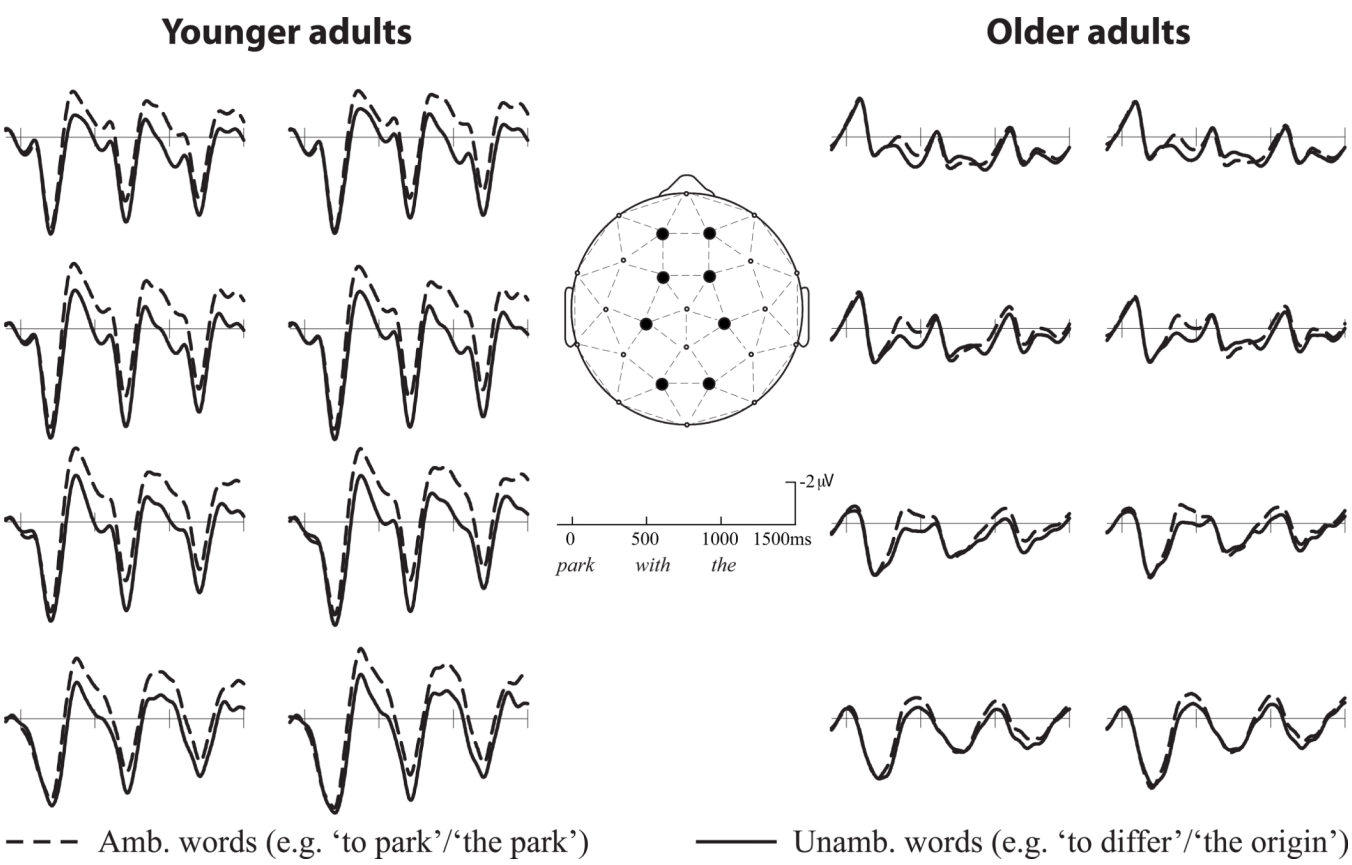

Figure 3.
Shown are brain responses to plausible (solid lines) and implausible (dashed lines) continuations of sentences containing ambiguous words, split into cases in which the syntactic context picked out the dominant versus the non-dominant interpretation of those words using 100 ms pre-stimulus baseline. Whereas younger adults show robust plausibility effects for both context types, older adults show a reliable plausibility effect only when the syntactic context picks out the dominant sense, but not when the syntactic context picks out the nondominant sense (i.e., when the contextually-irrelevant meaning is the dominant one).

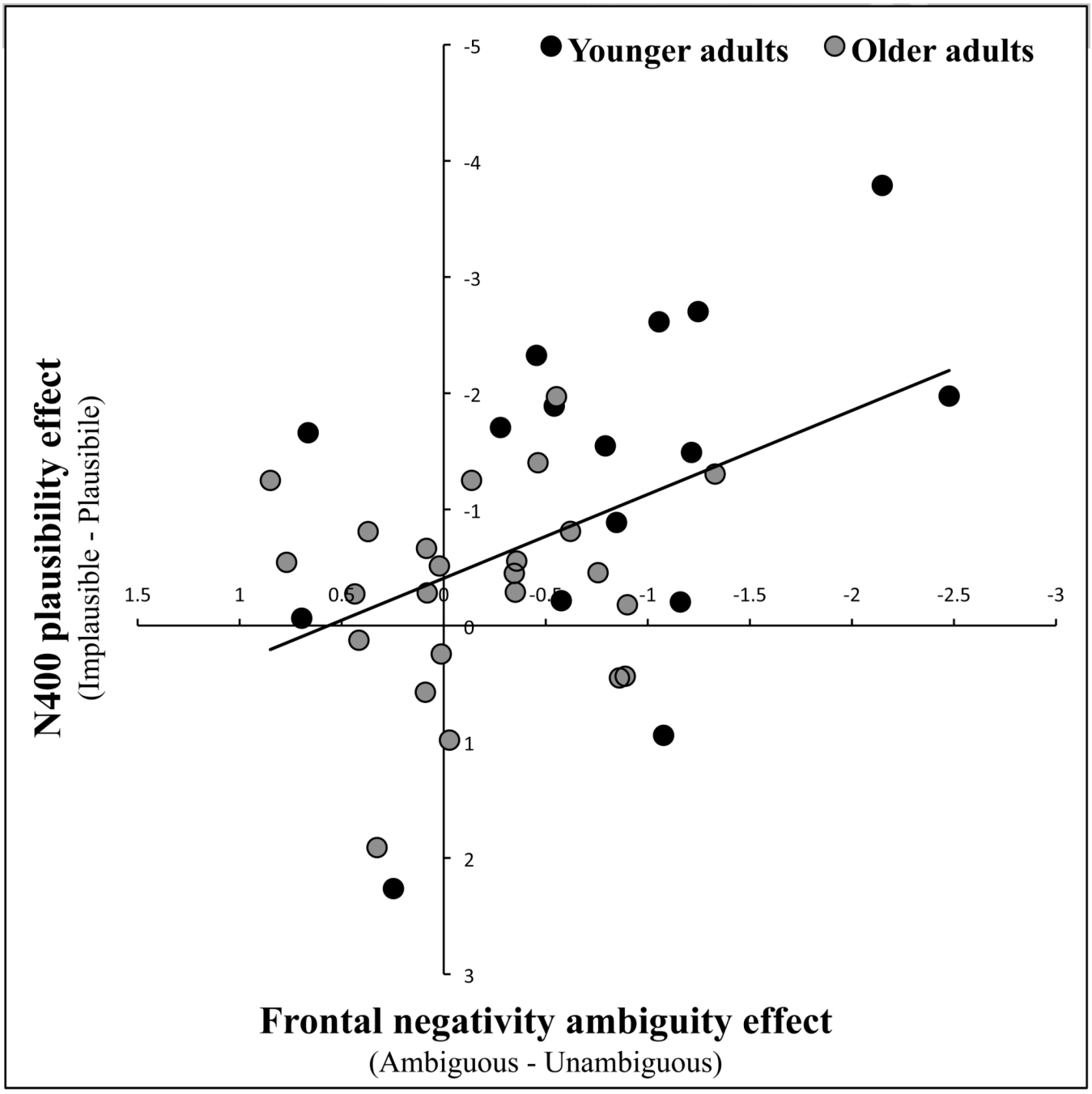

Figure 4.

The magnitude of each participant's frontal negativity effect (250–1500 ms post onset of the NV-homographs) is plotted on the X axis against their subsequent N400 plausibility effect (300–600 ms post onset of the head nouns) on the Y axis (negativity is plotted up). The trend line plots the correlation between the two effects for the whole group. The scatter plot shows that larger frontal negativity effects (more negative values) are associated with larger N400 plausibility effects (more negative values), and thus that enhanced recruitment of the processes indexed by the frontal negativity leads to better downstream discrimination between contextually relevant and irrelevant meanings.

Table 1

Mean values of lexical features of NV-homographs and matched unambiguous words (standard deviations in parentheses).

	Unambiguous words	NV-homographs
Log frequency	1.6 (0.5)	1.6 (0.5)
Word length	5.3 (1.0)	4.5 (1.1)
Concreteness (1=very abstract; 7=very concrete)	4.8 (0.9)	5.0 (1.0)
Semantic distinctiveness (1=very different; 7=very similar)	N/A	2.5 (0.8)

Table 2

Mean values of sentential features of sentences continued with plausible or implausible nouns (standard deviations in parentheses).

	Following unambiguous words		Following NV-homographs	
	Plausible	**Implausible**	**Plausible**	**Implausible**
Sentence constraint before the head nouns	24% (14)	24% (14)	25% (15)	25% (15)
Head noun cloze probability	12% (15)	0% (0)	16% (17)	0% (0)
Plausibility	80% (14)	29% (16)	76% (20)	33% (17)

Table 3

Mean values of sentential features of the sentences separated according to whether the syntactic context supports the dominant or the non-dominant meaning sense of the NV-homograph.

	Dominant		Non-Dominant	
	Plausible	**Implausible**	**Plausible**	**Implausible**
Sentence constraint before the head nouns	24% (11)	24% (11)	25% (17)	25% (17)
Head noun cloze probability	16% (15)	0% (0)	15% (18)	0% (0)
Plausibility	80% (19)	33% (18)	74% (20)	34% (17)