1. Introduction

Homonyms are words that have at least two distinct meanings in a given language, such that the same lexical form, with identical orthography and phonology, can be semantically interpreted in different ways (e.g., Weinreich, 1964). For example, the English homonym ruler can refer to either a measuring device or someone who governs. Linguistically, homonyms are classified as biased (i.e., having one frequent dominant meaning and a markedly less frequent subordinate meaning) or balanced (i.e., the two meanings occur with about the same frequency). Theoretically, meaning frequency interacts with context to influence lexical access and selection of homonyms (Duffy, Morris, & Rayner, 1988). For example, according to the reordered access model, homonym meaning representations are automatically, exhaustively accessed in order of frequency, resulting in a processing advantage — faster access and more robust activation — for the dominant meaning; however, context can interact to “reorder” access such that the contextually-appropriate meaning is more quickly available, potentially speeding access to and selection of the subordinate meaning of the homonym and increasing competition between the two meanings (Colbert-Getz & Cook, 2013; Dopkins, Morris, & Rayner, 1992; Duffy, Kambe, & Rayner, 2001; Duffy et al., 1988).

Thus, in text, the context provides disambiguating information and aids in the selection of the appropriate meaning of a homonym. Indeed, context may “override” the effect of dominance (Kotchoubey & El-Khoury, 2014; Martin, Vu, Kellas, &
Metcalfe, 1999; Simpson, 1981), making it imperative to study homonym processing in reduced context in order to understand the effects of meaning frequency — absent the known interactive effects of preceding sentential context — in the lexical representation of homonyms. It is somewhat surprising, then, that only two published event-related potential (ERP) studies, to our knowledge, have investigated homonym processing under conditions of minimal context, in a word–pair priming paradigm (Klepousniotou, Pike, Steinhauer, & Gracco, 2012; MacGregor, Bouwsema, & Klepousniotou, 2015). In the present study, we attempted to partially replicate the N400 effects reported by Klepousniotou et al. (2012) using a similar word–pair priming paradigm with the same short stimulus onset asynchrony (SOA) of 250 ms and a similar, although not delayed, lexical decision task (LDT). In addition, we extended the analyses to include the LPC. However, we focused exclusively on biased homonyms rather than analyzing both balanced and biased homonyms, as well as other types of ambiguous words, as in Klepousniotou et al. (2012). Using homonyms as stimuli provided an opportunity to explore lexical representation of multiple meanings while holding orthography and phonology constant. Using biased homonyms in minimal context allowed for controlled consideration of the role of meaning frequency in homonym processing as indexed by the N400 and LPC, as well as response time (RT) and accuracy in the LDT.

1.1. Behavioral studies of homonym processing in minimal context

 Behaviorally, homonym processing has been investigated in a number of studies using a LDT in which a homonym prime (e.g., ruler) precedes either a nonword target (e.g., smole) or a word target related to one of its meanings (e.g., inch), related to the other meaning (e.g., king), or not related to either meaning (e.g., claw, Nievas & Justicia, 2004; Nievas, Justicia, Canas, & Bajo, 2005; Simpson & Burgess, 1985). Priming, as indexed by faster RTs and higher accuracy for words associated with one of the meanings of the homonym, as compared to unrelated control words, is considered evidence that that meaning was activated. In paradigms with a short SOA (<300 ms), priming occurs through automatic spreading of activation from the nodes representing the homonym prime to nearby nodes, pre-activating and thereby reducing thresholds for associated targets (e.g., Collins & Loftus, 1975; Neely, 1991).

 Despite the predictions of the reordered access model (e.g., Duffy et al., 1988), the degree to which automatic activation is similar for the dominant and subordinate meanings of a homonym in such studies is equivocal. For example, consistent with the dominant advantage proposed in the reordered access model (e.g., Duffy et al., 1988), there are some reports of greater RT priming for dominant, as compared to subordinate, meanings at short SOAs (e.g., Copland et al., 2003; Nievas et al., 2005; Simpson & Burgess, 1985); however, there are also reports of indistinguishable RT priming for targets related to each meaning (e.g., Frenck-Mestre & Prince, 1997; Nievas & Justicia, 2004). Similarly, there some reports of accuracy priming only for dominant associates (e.g., Simpson & Burgess, 1985), and other reports of indistinguishable accuracy priming effects for dominant and subordinate associates (e.g., Nievas & Justicia, 2004). These inconsistent findings across behavioral measures do not clarify the role of meaning frequency and automatic spreading of activation in processing homonyms in minimal context, and suggest that other measures may be useful for providing complementary information.

1.2. Electrophysiological studies of homonym processing

1.2.1. N400

 Indeed, as mentioned, homonym priming effects have also been investigated using ERPs, with particular focus on the N400 component (for N400 reviews, see Kutas & Federmeier, 2000; Lau, Phillips, & Poeppel, 2008). Across many studies of semantic processing, words preceded by a related prime elicit a smaller amplitude N400 than unprimed words (e.g., Bentin, McCarthy, & Wood, 1985; Brown & Hagoort, 1993; Holcomb, 1988; Kutas & Hillyard, 1989), reflecting pre-activation and facilitated processing.

 A handful of studies has used the N400 in sentence contexts to investigate homonym processing at short SOAs (e.g., Elston-Güttler & Friederici, 2005; Kotchoubey & El-Khouri, 2014; Swaab, Brown, & Hagoort, 2003; Van Petten & Kutas, 1987). For example, Kotchoubey and El-Khouri (2014) analyzed N400 effects on subsequent target words related to the dominant and subordinate meanings of sentence-final biased homonym primes. They reported a smaller N400 (i.e., priming) for targets related to the meaning that was biased by the sentence context compared to targets related to the other meaning. Priming was similar overall for dominant and subordinate meanings, suggesting that the biasing effect of a strong context overrode lexical factors such as meaning frequency (p. 92), consistent with the predictions of the reordered access model (e.g., Duffy et al., 1988). Therefore, as noted, studies using minimal context are necessary to investigate possible separate, independent effects of meaning frequency in homonym representation, without the interactive influence of the effects of a biasing context.

 In one such study, designed to compare homonym and polysemy, Klepousniotou et al. (2012) investigated the effects of both balanced and biased homonym primes on word targets in a delayed LDT. N400 amplitude was reduced for targets related to both the dominant and subordinate meanings of the homonyms, as compared to unrelated word targets, indicative of priming. The N400 priming effect was widespread for dominant associates, but more localized for subordinate associates, consistent with both the dominant advantage proposed in the reordered access model (e.g., Duffy et al., 1988) and frequency-dependent N400 priming effects; however, the sizes of the priming effects for dominant and subordinate associates were not statistically compared across sites, and the N400s elicited by dominant and subordinate associates were similar in the only direct comparison, at midline sites. Further, the authors reported no significant differences in N400 priming effects for biased and balanced homonymous words. These findings suggest that N400 amplitude may not be sensitive to homonym meaning...
frequency in a word-pair priming paradigm with a short SOA. Here, in a partial replication focused only on biased homonym stimuli, which are defined by the marked frequency difference between dominant and subordinate meanings, we hoped to clarify the effects of meaning frequency on N400 amplitude in isolated homonym processing.

### 1.2.2. LPC

A few ERP homonym priming studies have also reported on a late positivity following the N400, alternately termed the LPC or P600 (e.g., Kotchoubey & El-Khoury, 2014; MacGregor et al., 2015; Meyer & Federman, 2007; Swaab, Brown, & Hagoort, 1998; Swaab et al., 2003; Van Petten & Kutas, 1987). In studies with unambiguous words, elicitation of the LPC is associated with conscious recollection of the prime-target relationship (e.g., Bouafire & Faîta-Ainsæba, 2007; Hill, Ott, & Weisbrod, 2005), a process that requires integrating the prime stored in working memory with the new semantic information provided by the target (Swaab et al., 1998; Van Petten, Kutas, Kluender, Mitchiner, & McIsaac, 1991).

In studies using homonyms in sentence contexts, the LPC is reportedly larger for targets related to both meanings of the homonyms, as compared to unrelated targets (e.g., Swaab et al., 1998; Van Petten & Kutas, 1987), with an absence of an effect of meaning frequency on LPC amplitude (e.g., Kotchoubey & El-Khoury, 2014). These findings raise at least two possibilities: The processes indexed by the LPC are insensitive to meaning frequency, or contextual effects may override the effect of frequency on LPC amplitude, as has been reported for the N400 (Kotchoubey & El-Khoury, 2014).

Although minimizing the effect of context could help to distinguish between these possibilities, to our knowledge, only one study using a word-pair priming paradigm has reported on an LPC effect for homonym processing. In this study with a long (950 ms) SOA, MacGregor et al. (2015) found that targets related to both meanings of biased homonym primes elicited larger LPCs than unrelated targets, similar to the pattern observed in sentential context studies. They interpreted the increased positivity as indexing difficulty “activating, processing and relating” (p. 136) the target and the prime, consistent with an interpretation of the LPC as an index of integration of the prime and target from sentential context studies (e.g., Swaab et al., 1998; Van Petten & Kutas, 1987). However, in contrast to studies using sentence stimuli, MacGregor et al. (2015) found that the LPC priming effect was stronger for subordinate than dominant homonym associates. This suggests that the processes involved in relating the prime and target words were affected by relative meaning frequency, an effect perhaps masked by contextual effects in the sentence studies. This is a somewhat surprising finding, as lexical effects of homonym primes might not be expected in such a late, post-lexical target time window (500–700 ms), particularly with a 950 ms SOA. Whether this pattern of LPC sensitivity to frequency is apparent in minimal context conditions with a short SOA, potentially more dependent on automatic spreading activation, remains to be investigated.

### 1.3. The present study

In this partial replication and extension of Klepousniotou et al. (2012), we used the minimal context of a word-pair paradigm in an ERP LDT in which biased homonym primes preceded targets that were either associated with the dominant meaning of the homonym, associated with the subordinate meaning, unrelated real words, or nonwords. With homonym primes presented as the first words in each word-pair trial, we could investigate the effects of biased homonym meaning frequency on subsequent target processing without the interactive and potentially overriding effects of sentential context. We used biased homonyms in order to investigate effects of relative meaning frequency and a short (250 ms) SOA in order to index the effects of automatic spreading activation (e.g., Collins & Loftus, 1975; Neely, 1991) in isolated homonym processing.

As in Klepousniotou et al. (2012), we predicted more localized N400 priming effects for targets associated with the subordinate meanings of the homonym primes, relative to targets associated with the dominant meanings of the homonym primes, as compared to unrelated targets. Further, we predicted a larger N400 priming effect for dominant associates than for subordinate associates, which would be consistent with the frequency predictions of the reordered access model (e.g., Duffy et al., 1988) and confirm an effect of meaning frequency on N400 amplitude despite Klepousniotou et al.’s (2012) findings of no effects of dominance on N400 amplitude at midline sites and no effects of balanced/biased homonym status on N400 amplitude. A similar pattern in the RT and accuracy results would also be consistent with the frequency predictions of the reordered access model (e.g., Duffy et al., 1988), and with previous behavioral findings suggesting automatic, but differential, activation of the dominant and subordinate meanings of homonyms at a short SOA (e.g., Nievas et al., 2005; Simpson & Burgess, 1985).

Although Klepousniotou et al. (2012) did not consider the LPC in their analyses, and visual analysis of a possible late effect is difficult as their plots extend only to 600 ms (p. 16), we predicted that the relational prime-target processing indexed by the LPC in sentential context (e.g., Swaab et al., 1998; Van Petten & Kutas, 1987) and long SOA word-pair (MacGregor et al., 2015) studies with homonyms would be evident in our short SOA word-pair study. Therefore, we expected a larger LPC for associated than unrelated targets, as reported in previous work (e.g., Kotchoubey & El-Khoury, 2014; MacGregor et al., 2015; Swaab et al., 1998; Van Petten & Kutas, 1987). Further, we reasoned that if frequency effects on LPC amplitude were related to a lack of preceding context, regardless of SOA, we would observe a larger LPC for subordinate as compared to dominant associates (e.g., MacGregor et al., 2015); however, we predicted that LPC amplitude, indexing a post-lexical relational process, would not be sensitive to meaning frequency here (e.g., Kotchoubey & El-Khoury, 2014). Finally, we hypothesized that, if the LPC indexes some sort of analysis of the relationship between prime and target that requires working memory, as has been
proposed previously (e.g., Swaab et al., 1998; Van Petten & Kutas, 1987), the size of the LPC priming effects might be related to working memory span. We explored this possibility in post-hoc correlation analyses.

2. Method

2.1. Participants

Participants were 36 fluent English speakers (18 female), average age 21.1 years (SD 1.6), who were students or recent alumni/ae of a selective college in the northeastern United States. All participants were right-handed (Edinburgh Handedness Inventory, Oldfield, 1971), had no history of neurological dysfunction or language or reading disorders, were not taking any medications that would affect brain function, and had normal or corrected-to-normal binocular vision (20/30 or better) as tested with a standard Snellen chart. They were volunteers compensated for their time.

2.2. ERP stimuli

Each trial of the ERP LDT consisted of a pair of words: a lowercase homonym prime (e.g., JELLY) followed by an uppercase target (e.g., JELLY).

2.2.1. Primes

One set of 39 homonym primes preceded word targets and another set of 39 homonym primes preceded nonword targets. The two sets were balanced for letter length, orthographic form frequency (CELEX frequency per million),

\[\text{orthographic neighborhood size (N), unconstrained bigram count, number of phonemes, and number of syllables (by } t\text{-test, all } p > 0.32,\]

based on metrics extracted from the MCWord (Medler & Binder, 2005) and MRC Psycholinguistic (Wilson, 1988) databases. Similarly, Klepousniotou et al. (2012, p. 15) controlled their ambiguous words for frequency of occurrence, syllable and letter length, and bigram and trigram frequency. Each of the homonyms preceding word targets (e.g., jam) had two noun meanings (although it is common in English that nouns also have verb meanings): dominant and subordinate noun meanings were determined based on meaning frequency. On average, the dominant meaning was provided by 77% of respondents (range 61–97%) and the subordinate meaning by 13% of respondents (range 1–31%) in the norming study from which the stimuli were drawn (Twilley, Dixon, Taylor, & Clark, 1994), comparable to Klepousniotou et al. (2012), with average 80% for dominant and 14% for subordinate meanings. Thus, dominant meanings were more frequent than subordinate meanings, \(F(1, 38) = 472.12, p = 0.001, \eta^2_p = 0.93,\) for the biased homonym primes preceding word targets. In contrast, the homonym primes preceding nonword targets were not controlled for grammatical category or meaning polarity.

2.2.2. Word targets

Over the course of the study, each of the 39 homonym primes preceding word targets (e.g., JELLY) was followed by three different types of words: an associate of the dominant meaning of the homonym (e.g., JELLY), an associate of the subordinate meaning (e.g., HIGHWAY), and an unrelated word (e.g., DISEASE). Dominant and subordinate associates included words taken from previous norming studies (Nelson, McEvoy, & Schreiber, 2004; Twilley et al., 1994) or morphological variants thereof (\(n = 54,\) as well as words culled from the dictionary (\(n = 24,\)). All targets were singular nouns and were balanced for letter length, orthographic form frequency.\(^3\) N, unconstrained bigram count, number of phonemes, and number of syllables (by \(t\)-test, all \(p > 0.29,\)) See Table 1 for a summary of target word stimulus characteristics. The stimulus set and presentation paradigm were thus similar to Klepousniotou and colleagues’ (2012).

2.2.3. Nonword targets

Nonword targets in the LDT (e.g., HELTWAY) were derived from each real word target using Wuggy software (Keuleers & Brysbaert, 2010). Up to four letters of each word were replaced while maintaining an acceptable syllabic and phonotactic structure. Nonword targets were divided into three lists that were balanced with each other (by \(t\)-test, all \(p > 0.43\)) and with the dominant associate, subordinate associate, and unrelated target real word lists (by \(t\)-test, all \(p > 0.05\)) for letter length, N, unconstrained bigram count, and number of phonemes. Each of the 39 homonym primes preceding nonword targets was

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1. Half the subjects were also fluent in Spanish, and participated in an additional Spanish version of the task. Order of presentation of language conditions was counterbalanced across the bilingual participants: half performed the English version of the task first, and half performed the Spanish version of the task first. Self-report data indicated that these participants were strongly English dominant for reading and writing. Although bilinguals scored more poorly than monolinguals on the English post-test, \(t(34) = 2.89, p < 0.01,\) analyses of the behavioral and electrophysiological priming effects for the English stimuli by subgroup (monolingual, bilingual) indicated no significant differences by subgroup, so results are reported here for all 36 participants as one group. All of the English stimuli were controlled for Spanish cognate status. Data from the Spanish condition are not reported.

2. The homonym primes that preceded word and nonword targets were also balanced using other measures of orthographic form frequency: Brysbaert and New (2009), \(t(76) = 1.07, p = 0.29,\) Gimenes and New (2016) blog frequency, \(t(76) = 0.29, p = 0.77,\) and Francis and Kučera (1982), the metric used by Klepousniotou et al. (2012), \(t(76) = 1.00, p = 0.32.\)

3. As with the homonym primes, orthographic form frequency was balanced in all pairwise comparisons of the three target word conditions across estimates from multiple lexical databases: Brysbaert and New (2009), all \(p > 0.57,\) Gimenes and New (2016) blog frequency, all \(p > 0.20,\) and Francis and Kučera (1982), all \(p > 0.58.\)
followed by one nonword in each of these three nonword lists; thus, homonym primes preceding nonword targets were also (as with homonym primes preceding word targets) repeated three times across the experiment.

2.2.4. Presentation order
In total, each participant viewed 117 homonym-word target pairs and 117 homonym-nonword target pairs. As in Klepousniotou et al. (2012), the pairs were divided into three blocks such that each prime was presented only once and target conditions were equally represented within each block (see Supplementary Materials Table 1 for the full stimulus list and blocks). Stimulus presentation order was counterbalanced by presenting each of the six possible permutations of these blocks (e.g., ABC, ACB, etc.) to six of the 36 participants. As a result, for any given homonym prime for word targets, one third of participants saw it paired with the dominant associate first, one third saw it paired with the subordinate associate first, and one third saw it paired with the unrelated target first; similarly for the three nonword target lists. Stimulus presentation order within blocks was pseudorandomized to avoid both more than three consecutive trials requiring the same response and orthographic similarity between a given target and the prime and target in the following trial.

2.3. Procedure

Upon arrival, the procedure was explained to participants and informed consent was obtained. Participants were then asked to fill out an information sheet, their vision was tested, and they completed the Digits Forward and Digits Backward subtests of the Test of Memory and Learning — Second Edition (TOMAL-2, Reynolds & Voress, 2007).

Subsequently, participants were prepared for the ERP portion of the study and were seated in a sound-attenuating and electrically shielded booth. Stimuli were presented at the center of a 19-inch LCD monitor approximately 66 inches in front of the participant using Presentation software (Neurobehavioral Systems). Stimuli were displayed in 31-point white Arial font within a white rectangle outline that subtended 2.7° of horizontal visual angle in order to discourage scanning eye movements. The sequence of events began with a white crosshair fixation that remained at the center of the black screen until participants pressed one of two buttons on a hand-held response device. The rectangle outline then appeared on the screen for 200 ms, the lowercase prime was displayed within the rectangle for 200 ms, and then the empty rectangle remained for 50 ms, comprising a 250 ms SOA. Subsequently, the uppercase target was displayed until participants pressed a button to indicate their word/nonword decision, or for a maximum of 3000 ms. At that time, the fixation reappeared and participants could pause or advance immediately to the next trial. Response hand for the LDT was counterbalanced. This immediate lexical decision contrasted with the delayed LDT used by Klepousniotou et al. (2012). The ERP task began with 12 practice trials, not including any items in the actual experiment.

Following the ERP task, a written post-test was administered to ascertain that participants were familiar with both meanings of the homonyms. Each of the homonym primes for word targets was presented in bold, followed by four words, including its dominant and subordinate associates. Participants were asked to circle all of the words that could be related to the bolded prompt word, being sure to consider all possible meanings of the prompt. Additional prompt and related words were used so that there could be one, two, or three related words per prompt word.

2.4. EEG recording

Participants were fitted with an elastic cap (Electro-Cap International) with active electrodes including FP1/2, F7/8, F3/4, FC5/6, C3/4, C5/6, T3/4, C7/8, T5/6, TO1/2, and O1/2; recordings from Fz, Cz, and Pz are not analyzed separately here, but data from these sites are included in the voltage maps. Mastoid electrodes were used for reference; online recordings were referenced to the right mastoid, and recordings were re-referenced to averaged mastoids in the final data averaging. Electrodes located below the right eye and at the outer canthi of both eyes were used to identify blinks, in conjunction with recordings from FP1/2, and horizontal eye movements, respectively. Impedances were maintained below 3 kΩ for mastoid electrodes, 5 kΩ for scalp electrodes, and 10 kΩ for eye electrodes. The electroencephalogram was amplified with SA Instrumentation bioamplifiers (bandpass 0.01–100 Hz) and digitized on-line (sampling rate 4 ms). ERPs were time-locked to the onset of the presentation of each target.
3. Results

Off-line, separate ERPs to dominant associates, subordinate associates, and unrelated word targets were averaged for each subject at each electrode site over a 1000-ms epoch, using a 200-ms pre-stimulus-onset baseline. Trials with incorrect responses and trials contaminated by eye blinks or movements, muscular activity, or electrical noise were not included in analyses. Standard artifact rejection parameters were initially employed, and data were subsequently analyzed on an individual basis for additional artifact rejection. Automated programs identified artifacts through a peak-to-peak amplitude function: Trials were rejected if the amplitude value between the maximum and minimum data points in the specified time window was larger or smaller than an established threshold. The average number of trials included in ERP analyses for the target bins of interest was: dominant associate 33.9 (SE 0.87) or 87%, subordinate associate 34.0 (SE 0.73) or 87%, and unrelated 33.5 (SE 0.72) or 86%. Pair-wise comparisons indicated no significant differences between bin totals for the three conditions, all ps > 0.41.

2.5. Data analysis: ERP LDT

Mean amplitude of the N400 was measured within the 300–500 ms epoch, and mean amplitude of the LPC was measured within the 500–800 ms epoch; time windows of analysis were based on visual inspection of both individual and grand average waveforms. Differences in N400 and LPC amplitude to word targets were investigated with separate repeated-measures ANOVAs with within-group factors condition (dominant associate, subordinate associate, unrelated), anterior/posterior [6 levels: frontal (F7/8, F3/4), fronto-temporal (FT7/8, FC5/6), temporal (T3/4, C5/6), central (CT5/6, C3/4), temporoparietal (T5/6, P3/4), and occipital (T01/2, O1/2)], lateral (F7/8, FT7/8, T3/4, CT5/6, T5/6, T01/2)/medial (F3/4, FC5/6, C5/6, C3/4, P3/4, O1/2), and hemisphere (left, right). Follow-up pair-wise planned comparisons (dominant/unrelated, subordinate/unrelated) with Bonferroni correction were used to further investigate priming effects.

In order to better characterize the priming effects, difference waves were created by subtracting the ERPs to the unrelated targets from the ERPs to the dominant (dominant effect) and subordinate (subordinate effect) targets. Additional ANOVAs using the mean amplitude data from the difference waves were conducted in order to directly compare the dominant and subordinate effects in both the N400 (300–500 ms) and LPC (500–800 ms) time windows; factors included effect, anterior/posterior, lateral/medial, and hemisphere. In addition, in order to visualize the distribution of the effects, topographical voltage maps based on the mean voltages measured in the difference waves at each electrode location within the two time windows were created using a spherical spline interpolation (Perrin, Pernier, Bertrand, & Echallier, 1989).

The Greenhouse-Geisser correction was applied to all within-subjects measures with more than one degree of freedom; epsilon (ε) values and corrected p-values are reported below. Partial eta squared (ηp²) values are reported as estimates of effect size. All results are significant at the 0.05 level unless otherwise noted.

3. Results

3.1. Behavioral measures

3.1.1. TOMAL-2 (Reynolds & Voress, 2007)

Average scaled score on the Digits Forward subtest measuring short-term memory was 10.19 (SE 0.40). Average scaled score on the Digits Backward subtest measuring working memory was also 10.19 (SE 0.48). Scores placed participants, on average, at the 53rd (SE 4%) percentile rank for short-term memory and the 51st (SE 5%) percentile rank for working memory.

3.1.2. Lexical decision task response times (correct trials only)

A repeated-measures ANOVA with three levels of Condition (dominant associate, subordinate associate, unrelated) yielded a significant effect of Condition, F(2, 68) = 9.26, p = 0.001, ε = 0.98, ηp² = 0.21 (see Fig. 1A). Follow-up comparisons with a Bonferroni-corrected p of 0.025 showed priming effects for both dominant associates (mean 697 ms, SE 21), t(35) = −4.31, p = 0.001, and subordinate associates (mean 705 ms, SE 21), t(35) = −2.86, p = 0.007, as compared to unrelated word targets (mean 727, SE 23). The size of the dominant (mean −29.21 ms, SE 6.77) and subordinate (mean −21.22, SE 7.42) priming effects did not differ significantly, p = 0.26.

Average response time for word targets (across all three categories of words) was 710 ms (SE 22.0), whereas average response time for nonword targets was 823 ms (SE 22.0). Participants were faster to respond to word than nonword targets, t(35) = 10.05, p < 0.001.

3.1.3. Lexical decision task accuracy

Similar to the response time analyses, a repeated-measures ANOVA with three levels of Condition yielded a significant effect of Condition, F(2, 68) = 5.10, p = 0.012, ε = 0.86, ηp² = 0.13 (see Fig. 1B). Follow-up comparisons with a Bonferroni-corrected p of 0.025 showed a priming effect for dominant associates (mean 37.97, SE 0.18, or 97.4% correct), as compared to unrelated word targets (mean 37.11, SE 0.27, or 95.2% correct), t(35) = 2.97, p = 0.005, but the effect for subordinate associates (mean 37.67, SE 0.18, or 96.6% correct), p = 0.08, was not significant.

Average accuracy for word targets (across all three categories of words) was 112.8 (SE 0.42) out of 117, or 96.4% correct, whereas average accuracy for nonword targets was 110.6 (SE 0.95) out of 117, or 94.6% correct. Participants were more accurate in identifying word than nonword targets, t(35) = 2.54, p = 0.016.
3.1.4. Post-test accuracy

An ANOVA indicated that more dominant (mean 35.75, SE 0.60) than subordinate (mean 26.67, SE 1.03) associates were identified overall, $F(1, 35) = 133.84, p = 0.001, \eta_p^2 = 0.98$. However, anecdotally, some participants did not appear particularly attentive during this task; false alarm rates ranging from 0 to 23 (mean 4.72, SE 0.89) confirmed this impression, and these data will not be considered further here.

3.2. Electrophysiological measures

3.2.1. N400 (mean amplitude, 300–500 ms)

Grand average ERPs are presented in Fig. 2. Omnibus ANOVA results indicated that the effect of Condition varied across the scalp, condition $\times$ anterior/posterior, $F(10, 350) = 6.21, p = 0.001, \varepsilon = 0.28, \eta_p^2 = 0.15$, condition $\times$ hemisphere $\times$ anterior/posterior, $F(10, 350) = 2.87, p = 0.01, \varepsilon = 0.60, \eta_p^2 = 0.08$, condition $\times$ hemisphere $\times$ anterior/posterior $\times$ lateral/medial, $F(10, 350) = 2.46, p = 0.027, \varepsilon = 0.59, \eta_p^2 = 0.07$. Mean amplitude of the N400 in the four-way interaction is illustrated in Supplementary Materials Fig. 1.

Follow-up planned comparisons with a Bonferroni-corrected $p$ of 0.025 showed an N400 priming effect for dominant associates as compared to unrelated word targets, condition $\times$ anterior/posterior, $F(5, 175) = 12.41, p = 0.001, \varepsilon = 0.30, \eta_p^2 = 0.26$, condition $\times$ hemisphere $\times$ anterior/posterior, $F(5, 175) = 4.56, p = 0.004, \varepsilon = 0.64, \eta_p^2 = 0.12$, such that dominant associates appeared to elicit smaller (i.e., less negative) N400s than unrelated targets particularly over right hemisphere, posterior sites. Follow-up analyses by hemisphere confirmed a priming effect at right hemisphere, posterior sites, condition $\times$ anterior/posterior, $F(5, 175) = 6.85, p = 0.006, \varepsilon = 0.29, \eta_p^2 = 0.16$, with a reverse effect at anterior sites, and a similar priming effect at posterior left hemisphere sites but a reverse effect at anterior, particularly lateral anterior, left hemisphere sites, condition $\times$ anterior/posterior, $F(5, 175) = 15.22, p = 0.001, \varepsilon = 0.37, \eta_p^2 = 0.30$, condition $\times$ anterior/posterior $\times$ lateral/medial, $F(5, 175) = 3.43, p = 0.017, \varepsilon = 0.64, \eta_p^2 = 0.09$.

In the planned comparison between subordinate associates and unrelated word targets, only the four-way interaction was significant, condition $\times$ hemisphere $\times$ anterior/posterior $\times$ lateral/medial, $F(5, 175) = 3.06, p = 0.022, \varepsilon = 0.73, \eta_p^2 = 0.08$. Compared to unrelated word targets, subordinate associates appeared to elicit less negative N400s over posterior, lateral, left hemisphere sites, but more negative N400s over anterior sites. However, follow-up analyses failed to confirm this pattern: An analysis at frontal and fronto-temporal sites (the two most anterior rows) yielded no significant results (all $p$s > 0.22), as did an analysis at the posterior, left hemisphere, lateral sites CT5, T5, and TO1 (all $p$s > 0.38). Thus, the subordinate priming effect appeared to be weak and variable across recording sites.

Analysis of the difference waves (see Fig. 3A) showed that the subordinate and dominant N400 priming effects were distributed differently across the scalp, effect $\times$ anterior/posterior, $F(5, 175) = 6.52, p = 0.007, \varepsilon = 0.28, \eta_p^2 = 0.16$, effect $\times$ hemisphere $\times$ anterior/posterior, $F(5, 175) = 3.79, p = 0.01, \varepsilon = 0.66, \eta_p^2 = 0.10$, effect $\times$ lateral/medial, $F(1, 35) = 4.54, p = 0.04, \eta_p^2 = 0.12$. The three-way interaction was followed up by separate analyses at left and right hemisphere sites. Over the left hemisphere, the priming effect for dominant associates was larger than the priming effect for subordinate associates at posterior, effect $\times$ anterior/posterior, $F(5, 175) = 9.00, p = 0.001, \varepsilon = 0.33, \eta_p^2 = 0.20$, and medial, effect $\times$ lateral/medial, $F(1,
35) = 5.73, $p = 0.022$, $\eta^2_p = 0.14$, sites, whereas there were no significant differences between the dominant and subordinate associate priming effects across right hemisphere sites (all $p$s > 0.06). The interaction involving laterality was followed up by separate analyses at lateral and medial sites. At lateral sites, the priming effect for dominant associates was larger than the priming effect for subordinate associates particularly at posterior sites, effect $\times$ anterior/posterior, $F(5, 175) = 6.40, p = 0.007$, $\epsilon = 0.29, \eta^2_p = 0.16$, a pattern that held at medial left hemisphere sites, but extended across both posterior and anterior medial right hemisphere sites, effect $\times$ anterior/posterior, $F(5, 175) = 5.55, p = 0.009$, $\epsilon = 0.33, \eta^2_p = 0.14$, and effect $\times$ hemisphere $\times$ anterior/posterior, $F(5, 175) = 4.41, p = 0.003$, $\epsilon = 0.74, \eta^2_p = 0.11$. Thus, dominant associates elicited a stronger priming effect in the expected direction (i.e., smaller amplitude N400 as compared to unrelated word targets) than subordinate associate word targets, but not consistently at all sites.

3.2.2. LPC (mean amplitude, 500–800 ms)

Analysis of the grand average waveforms (refer to Fig. 2) yielded a main effect of Condition, $F(2, 70) = 5.35, p = 0.008$, $\epsilon = 0.94, \eta^2_p = 0.13$, such that average LPC amplitude for dominant associates was 4.04 $\mu$V, for subordinate associates was 3.97 $\mu$V, and for unrelated word targets was 4.67 $\mu$V. However, Condition effects were distributed differently across lateral and medial sites, condition $\times$ lateral/medial, $F(2, 70) = 5.17, p = 0.011$, $\epsilon = 0.89, \eta^2_p = 0.13$. Mean amplitude of the LPC in this two-way interaction is illustrated in Fig. 4. No other interactions involving Condition were significant (all $p$s > 0.09).

Planned comparisons with a Bonferroni-corrected $p$ of 0.025 showed that dominant associates elicited a smaller amplitude LPC than unrelated word targets overall, $F(1, 35) = 7.26, p = 0.011, \eta^2_p = 0.17$; however, this effect appeared strongest over medial sites, condition $\times$ lateral/medial, $F(1, 35) = 5.66, p = 0.023, \eta^2_p = 0.14$. Follow-up analysis indicated an LPC priming effect for dominant associates at both medial, Condition, $F(1, 35) = 6.51, p = 0.015, \eta^2_p = 0.18$, and lateral, Condition, $F(1, 35) = 7.66, p = 0.009, \eta^2_p = 0.16$, sites.

Subordinate associates also elicited a smaller amplitude LPC than unrelated word targets overall, $F(1, 35) = 7.15, p = 0.011, \eta^2_p = 0.17$, which also appeared greater over medial sites, condition $\times$ lateral/medial, $F(1, 35) = 7.26, p = 0.011, \eta^2_p = 0.17$. Follow-up analysis indicated an LPC priming effect for subordinate associates at both medial, Condition, $F(1, 35) = 8.11, p = 0.007, \eta^2_p = 0.19$, and lateral, Condition, $F(1, 35) = 5.72, p = 0.022, \eta^2_p = 0.14$, sites.
A direct comparison of the dominant (average $-0.64 \mu$V) and subordinate (average $-0.71 \mu$V) LPC priming effects based on the difference waves yielded no significant results (all $p$s $> 0.15$), suggesting similarly sized and distributed LPC priming effects for subordinate and dominant associate targets (see Fig. 3B).

3.2.3. Correlations with working memory

In post-hoc exploratory analyses, there were no significant correlations between Digits Backward scaled scores (Reynolds & Voress, 2007) and the average size of the LPC priming effect measured across medial sites, for either dominant ($p = 0.941$) or subordinate ($p = 0.941$) associates.

4. Discussion

In contrast to unambiguous words, homonym processing involves one orthographic and phonological pattern of activation being mapped to two patterns of semantic activation (e.g., Rodd, Gaskell, & Marslen-Wilson, 2002). In order to investigate this processing in real time using ERPs, we presented isolated biased homonym primes followed 250 ms later by word targets that were related to the dominant or subordinate meanings of the primes or unrelated. Replicating Klepousniotou et al. (2012), we found a more widespread N400 priming effect for dominant than subordinate associates. In addition, for the first time in the ERP literature, to our knowledge, we documented a larger N400 priming effect for dominant than subordinate associates, showing that N400 amplitude is sensitive to biased homonym meaning frequency at a short SOA in minimal context. This pattern suggests stronger automatic activation of lexicosemantic nodes representing the dominant meaning and thereby stronger spreading of activation from those nodes to dominant associates, even without the influence of prior context. This appears consistent with the dominant advantage based on meaning frequency proposed in the reordered access model (e.g., Duffy et al., 1988). In contrast, LPC amplitude was not modulated by meaning frequency at this short SOA: Although both dominant and subordinate associates elicited a smaller amplitude LPC than unrelated targets, these priming effects were
similar in size and distribution. This is consistent with an interpretation of the LPC priming effect as an index of post-lexical relational processing between prime and target.

4.1. Meaning frequency and the N400

Targets associated with the dominant meanings of the biased homonym primes elicited substantially reduced N400s in comparison to unrelated targets, particularly at posterior sites, whereas targets associated with the subordinate meanings of the primes elicited a comparatively weak, topographically constrained N400 priming effect that did not survive follow-up analyses. Direct comparison of difference waves confirmed a more robust N400 priming effect for dominant than subordinate associates, particularly over the left hemisphere. Thus, by holding constant all other word-level factors (including basic visual input, linguistic factors such as word length, orthography, phonology, etc.) except meaning frequency in our isolated homonym primes, we were able to show that N400 amplitude is specifically sensitive to the lexical effect of meaning frequency without the influence of preceding sentential context.

In the only comparable ERP word-pair homonym priming study using a short SOA, the effect of meaning frequency on N400 amplitude was equivocal: Whereas the N400 elicited by dominant associates was more widespread than the N400 elicited by subordinate associates, similar to the pattern observed here, the sizes of the N400s elicited by dominant and subordinate associates were similar when compared directly at midline sites and there were no differences in N400 priming for biased and balanced homonyms (Klepousniotou et al., 2012). This latter finding is difficult to reconcile with ample evidence from behavioral (e.g., Miyake, Just, & Carpenter, 1994), eye-tracking (e.g., Duffy et al., 1988; Rayner & Frazier, 1989), and fMRI (e.g., Mason & Just, 2007) studies indicating that the two types of homonyms are processed differently. Thus, the lack of an effect of meaning frequency on N400 amplitude reported by Klepousniotou et al. (2012) appears anomalous, given both the inconsistency with existing literature and the present result of greater N400 priming for dominant as compared to subordinate associates. A factor that might have contributed to this differential finding between Klepousniotou et al. (2012) and the present study is the task difference: Whereas they used a delayed LDT, we required an immediate response in our LDT; there may have been something about keeping the information on-line for a later response that influenced the similarity of N400 priming for dominant and subordinate associates in their study that was absent in our study. Nonetheless, as predicted, by focusing exclusively on biased homonym processing (thus emphasizing any effects of meaning frequency) and requiring an immediate response, N400 amplitude here was revealed to be sensitive to meaning frequency at a short SOA in minimal context.

This confirmation of an effect of meaning frequency on N400 amplitude for isolated homonym processing supports the contention that the lack of such an effect in previous studies using biasing sentence contexts was due to stronger contextual effects overriding frequency effects (e.g., Kotchoubey & El-Khoury, 2014), consistent with the interaction between meaning frequency and sentence context.
frequency and preceding context proposed in the reordered access model (e.g., Duffy et al., 1988). It has been known for some time in the ERP word processing literature that N400 form frequency effects for unambiguous words are greater in less context (e.g., Kretzschmar, Schlesewsky, & Staub, 2015; Van Petten & Kutas, 1990); the pattern of context overriding meaning frequency effects in the homonym literature mirrors this. However, this overriding top-down influence of context seems particularly remarkable in the case of biased homonyms, as these words are differentiated only on the basis of meaning frequency. That is, meaning frequency is the defining characteristic that distinguishes one pattern of semantic activation from another (i.e., the dominant and subordinate meanings of a biased homonym), as elicited by the same orthographic and phonological input. This contrasts with form frequency effects, as form frequency alone does not distinguish one unambiguous word from another. Here, in isolation, our finding of N400 meaning frequency effects provides further evidence in support of separate lexical representations for each distinct meaning of a biased homonym, despite their association with the same lexical form (e.g., Eddington & Tokowicz, 2015; Klepousniotou et al., 2012).

Given the small but differential N400 priming effects related to dominance and the short SOA used in the present study, activation appears to spread automatically from these lexical representations, propagating more strongly (dominant meaning) or weakly (subordinate meaning) to separate associated lexicosemantic networks. Klepousniotou et al. (2012, p. 19) proposed that the small N400 priming effects that they observed were related to competition for activation between the meanings. Others have also proposed early competition between meanings related to the difference in meaning frequency (e.g., Rodd et al., 2002, p. 260), particularly at short SOAs. In this early competition, theoretical models including the effects of preceding context, such as the reordered access model, posit a processing advantage (in terms of strength of activation) for the meaning of biased homonyms based on frequency (e.g., Duffy et al., 1988; Paul, Kellas, Martin, & Clark, 1992; Rayner & Frazier, 1989); even without the influence of preceding context, a similar advantage is reflected here in the significantly larger N400 priming effect for dominant associates.

The very weak N400 priming effect for subordinate associates here, which appeared smaller than that in Klepousniotou et al. (2012), is likely related to this competition between meanings. Indeed, Klepousniotou et al. (2012, p. 19) posited that their more circumscribed N400 priming effect for subordinate associates was due to “only a subset of the semantic representation” for the subordinate meaning being activated at the short SOA. Speculatively, competition could be greater when balanced homonyms (with more equal meaning frequencies) are included in analyses, as in Klepousniotou et al., than when only biased homonyms are analyzed, as in the present study. The relatively greater frequency differential in the latter case may be reflected in the relatively smaller N400 subordinate associate priming effect observed here, confirming the utility of focusing exclusively on isolated biased homonyms to investigate the effects of meaning frequency on N400 amplitude.

4.2. **Beyond meaning frequency: the LPC**

In marked contrast to the N400 priming effects, in the 500–800 ms window in which we measured the LPC, we found that priming effects for dominant and subordinate associates were virtually indistinguishable. This is consistent with relatively early and brief lexically-based effects related to automatic spreading of activation in short SOA paradigms (e.g., Collins & Loftus, 1975; Neely, 1991). The lack of an effect of meaning frequency on LPC amplitude is also consistent with findings from previous homonym studies using a short SOA and sentential context (e.g., Kotchoubey & Ei-Khoury, 2014; Swaab et al., 1998; Van Petten & Kutas, 1987), and suggests that the absence of an effect in these studies was not indicative of contextual effects overriding frequency effects. Taken together, these findings indicate that the processes indexed by the LPC in studies with homonym stimuli are not sensitive to lexical meaning frequency at a short SOA, with or without preceding context. In turn, this pattern suggests that the LPC in short SOA studies does not provide an electrophysiological index of the interaction between meaning frequency and context in homonym processing posited by the reordered access model (e.g., Duffy et al., 1988).

Contrary to previous studies, we found that dominant and subordinate associate (i.e., related) targets elicited smaller LPCs than unrelated targets (cf. MacGregor et al., 2015; Meyer & Federmeier, 2007; Swaab et al., 1998, 2003). Despite the reversal of the effect in comparison to prior work, this finding is consistent with the core interpretation from previous studies of the LPC as an index of the prime–target relationship (e.g., MacGregor et al., 2015; Swaab et al., 1998). Similarly, in a recent review, Van Petten and Luka (2012, p. 187) posited that the late positivity reflected relational reprocessing in terms of the difficulty of semantic integration with what had come before. Having stripped away the effects of preceding sentential context (cf. Meyer & Federmeier, 2007; Swaab et al., 1998, 2003) and long processing time (cf. MacGregor et al., 2015) in terms of what has come before, it appears to be the semantic mismatch between unrelated word targets and homonym primes that is more difficult to reprocess (or utilizes more LPC processing resources) than the semantic match between related words in a homonym pair. This is consistent with the notion that readers attempt to relate words as they are reading, constructing an “integrated representation” (e.g., Brown, Hagoort, & Chwilla, 2000, p. 174) even when a single word target provides minimal subsequent context for a prime and the isolated prime word constitutes the only preceding context.

Whereas this interpretation of the LPC effects is internally consistent, the fact remains that the reverse pattern (a larger LPC for related than unrelated targets) has been observed both in other LDT studies of homonym processing (e.g., MacGregor et al., 2015) and in comparable short SOA, minimal context, word-pair studies using a LDT with unambiguous words (e.g., Bouaffre & Faita-Amsbea, 2007; Hill et al., 2005). This raises the possibility that the late positivity observed here may be a P3b, and might index an “oddball” effect for the one-third of target words that were unrelated (e.g., Coulson, King, & Kutas, 1998; Kok, 2001; Polich, 2007). However, the late positive effect was widely distributed across the scalp, rather than showing the
characteristic posterior distribution of the P3b. Moreover, in the only other homonym processing word-pair study to consider the LPC, with the same proportion of related and unrelated word targets (but additional conditions involving polysemy, using the same stimulus set as Klepousniotou et al. 2012), MacGregor et al. (2015) reported a larger LPC effect for subordinate than dominant and unrelated associates. It seems unlikely that the unrelated third in our study and the subordinate third in their study would each differentially be considered oddball. MacGregor et al. (2015) claimed that the LPC in their study indexed decay of both meanings of the homonym by the N400 time window and some sort of differential re-activation and reprocessing of both meanings in the P600 time window. This is difficult to interpret in the context of the present short-SOA study, and seems to indicate very late effects of lexical meaning frequency of the prime, especially considering both the long (950 ms) SOA and the lack of N400 effects related to dominance in their paradigm.

In contrast to MacGregor et al. (2015), the late positivity that we observed seems to index some sort of post-lexical reprocessing that involves the relatedness of the prime and target, rather than a lexical characteristic of the prime. Indeed, that relatedness in our paradigm appears to be binary: When the homonym prime and word target are related, regardless of dominance or level of activation within the N400 time window, the late positivity is reduced as compared to when the prime and target are not related. Whereas it could be argued that our design simply lacked the statistical power to find a greater LPC effect for subordinate associates, this seems unlikely as MacGregor et al. (2015) included 30 ambiguous biased homonym primes and 28 participants, compared to our 39 primes and 36 participants. Given that MacGregor et al. (2015) and the present study are the only two ERP investigations to have considered the late positivity in homonym processing in a word-pair paradigm, to our knowledge, these conflicting findings await further research for reconciliation.

Regardless, although the primary task was to make a lexical decision to the target, participants appear to have been performing a secondary task involving relatedness in the word-pair conditions. If this were the case, it might be predicted that this secondary task would make demands on working memory, which might be reflected in the amplitude of the late positivity. (Note that this does not address whether that positivity is a P3b or an LPC, as both have been associated with working memory processes, e.g., Polich, 2007; Swaab et al., 1998). However, there were no significant correlations between our working memory measure and the size of the late positive effects. Speculatively, the short SOA (250 ms) and minimal context (two words per trial) characterizing our paradigm — and no other ERP study that has investigated the late positivity in homonym processing to date — may have minimized the role of working memory and facilitated the relational reprocessing (whether oddball-based or otherwise) indexed by the late positivity here.

4.3. Behavioral measures: accuracy and RT

Overall, participants were faster and more accurate in responding to word targets than to nonword targets. This pattern is inconsistent with task-specific strategic predictability effects related to homonym prime repetition, but is consistent with a reflection of normal automatic processing. Focusing on accuracy for the different types of word targets, we found that participants tended to make more errors with unrelated than related targets: a 4.8% error rate for unrelated word targets, compared to 2.6% and 3.4% rates for dominant and subordinate associates, respectively. The accuracy priming effect was significant only for dominant associates; however, the subordinate effect was in the same direction and approached significance. In contrast, a similar main effect of target type for accuracy reported by Klepousniotou et al. (2012), such that participants made more errors for unrelated than related targets, did not appear to hold strongly in their unbalanced (biased) homonym condition, despite the lack of significant interactions: Their Table 1 reported error rates (expected to be comparatively lower due to the delayed nature of their LDT) of 0.74% for unrelated targets, 0.92% for dominant associates, and 1.66% for subordinate associates in this condition (p. 15). Overall, our findings suggest that LDT accuracy, when responses are immediate and word primes are exclusively biased homonyms, is sensitive to both the relationship between prime and target and effects of meaning frequency, similar to the pattern of N400 effects.

For our other behavioral measure, we found similar RT priming effects for dominant and subordinate associates: about 25 ms facilitation on average. [Given the delayed nature of their LDT, Klepousniotou et al. (2012) did not report response times.] Thus, the pattern of RT priming was mirrored in our priming effects for the late positivity. That neither of these measures was sensitive to meaning frequency and that the late positivity indexed a post-lexical, relational process suggests that RT in this paradigm provides a summative index of processing, perhaps subsuming both lexically-based automatic spreading of activation and post-lexical, relational processing. This could help to explain previous inconsistent behavioral findings of both similar (e.g., Frenck-Mestre & Prince, 1997; Nievas & Justicia, 2004) and different (e.g., Copland et al., 2003; Nievas et al., 2005; Simpson & Burgess, 1985) RT priming for dominant and subordinate associates at short SOAs, as the various contributing processes may have been more or less reflected in the RT measurements across these studies due to differences in design or stimuli. Regardless, the summative nature of behavioral measures like RT makes it all the more imperative to use on-line measures such as ERPs to investigate the course of biased homonym processing.

4.4. Summary and conclusion

Whereas current models posit complex interactions between the effects of preceding context and meaning frequency in homonym processing (e.g., Duffy et al., 1988), here, we attempted to isolate and investigate the potentially separable effect of meaning frequency in homonym processing and representation. Given one orthographic and phonological pattern of activation to be mapped to two patterns of semantic activation, and without preceding context to influence selection of one of
those patterns of activation, we found evidence of competition between biased homonym prime meanings in the N400 amplitude to subsequent targets. The less robust N400 priming effect for subordinate associates suggested relatively stronger early activation of the dominant meaning (e.g., Duffy et al., 1988; Simpson & Burgess, 1985) even without preceding context, an effect seemingly dependent on separate lexical representations for the two meanings (e.g., Eddington & Tokowicz, 2015). Shortly thereafter in the processing stream, the effect of meaning frequency disappeared: There was no effect of frequency on the late positivity. Instead, LPC amplitude indexed the relatedness of the homonym prime and the word target, a post-lexical effect indicating that readers integrate for meaning even in the minimal context of a word pair (e.g., Brown et al., 2000). In this paradigm, the relational processing indexed by the LPC appeared to occur regardless of the prior level of lexicosemantic activation observed during the N400 time window; a binary reprocessing that reflected the presence or absence of a semantic relationship between prime and target. Thus, in partially replicating and extending the ERP work of Klepousniotou et al. (2012), we have clarified the role of meaning frequency in biased homonym processing and representation, showing both the sensitivity of N400 amplitude to meaning frequency and the limits of the effects of automatic spreading activation in isolated biased homonym processing at a short SOA.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jneuroling.2016.09.002.

References


