Supplemental materials

Unpredicted findings during retrieval

As mentioned above, in addition to the predicted theta and alpha modulations, we also observed modulations in a continuous frequency band encompassing both alpha and beta as a function of our manipulations during retrieval, which are indicated by dashed lines in Figures 3 and 4. Importantly, because these effects were not defined in the a priori predictions, some exploratory follow-up analyses were conducted in order to characterize them. We note that these results should be interpreted with caution due to the exploratory nature of the associated analyses.

Alpha/beta modulations as a function of Pronominal Ambiguity during retrieval

As shown in Figure 3 (dashed lines on the left panel, third row), younger, but not older adults showed greater alpha/beta (8-24Hz) power for ambiguous relative to unambiguous pronouns in the 150ms-600ms time window. As reported in Table 5, we observed no main effects of Age or Pronominal Ambiguity. But there was a trend towards a 2-way interaction between Age and Pronominal Ambiguity. Simple analyses revealed that although younger adults exhibited greater alpha/beta power for ambiguous than unambiguous pronouns, older adults showed the flipped pattern, namely, smaller alpha/beta power for ambiguous than unambiguous pronouns. Moreover, the 2-way interaction between Pronominal Ambiguity and Scalp Region was significant. Simple effect analyses revealed that alpha/beta power was greater for ambiguous than unambiguous pronouns only at the frontal regions, whereas this effect was flipped at the parietal regions (albeit no simple effects reached statistical significance).

Table 5. Mean alpha/beta power and ANOVA results for the effect of Pronominal Ambiguity during retrieval. *"*" indicates statistically significant effects at p < .05.*

Time window & Frequency	***Predictor***	***Mean Power***	***Results***
150ms-600ms Alpha (8-24Hz)	Age	YAs: -.03 OAs: -.07	$F(1,39) = .35, p = .55$
	Pronominal Ambiguity	Amb: -.04 Unamb: -.06	$F(1,39) = .13, p = .71$
	Age × Pronominal Ambiguity		$F(1,78) = 3.41, p = .06$
	Pronominal Ambiguity effect-YA	Amb: .03	$F(1,39) = 1.84, p = .18$

		Unamb: -.09	
	Pronominal Ambiguity effect-OA	Amb: -.11 Unamb: -.03	*F*(1,39) = 1.63, *p* = .20
	*Pronominal Ambiguity × Scalp Region		*F*(2,156) = 5.45, *p* =.01
	Pronominal Ambiguity effect-Frontal	Amb: .04 Unamb: -.06	*F*(1,79) = 2.49, *p* =.11
	Pronominal Ambiguity effect-Central	Amb: -.11 Unamb: -.13	*F*(1,79) = .13, *p* =.71
	Pronominal Ambiguity effect-Parietal	Amb: -.06 Unamb: .008	*F*(1,79) = 1.32, *p* =.25

Alpha/beta modulations as a function of Lexical Form Similarity during retrieval

As shown in Figure 4 (dashed lines on the left panel, third row), younger but not older adults showed increased alpha/beta power (8-24Hz) for similar relative to dissimilar pronouns in the 50ms-300ms and the 1250ms-1450ms time windows. The results are reported in Table 6. As can be seen in this table, with regards to alpha/beta power (8-24Hz) in the 50ms-300ms window, we observed a main effect of Age, with younger adults exhibiting *smaller* alpha/beta power than older adults[1]. Although the main effect of Lexical Form Similarity was not significant, the 2-way interaction between Lexical Form Similarity and Scalp Region was significant. Simple analyses revealed that the effect of Lexical Form Similarity was significant at the parietal regions, but not at the frontal or central regions. With regards to alpha/beta power (8-24Hz) in the 1250ms-1450ms window, we observed a main effect of Age, with younger adults exhibiting greater alpha/beta power than older adults. The main effect of Lexical Form Similarity was not significant. But there was a trend towards a 3-way interaction between Age, Lexical Form Similarity and Scalp Region. Simple analyses revealed that the lexical form similarity effect was significant only for younger adults and only at the central and parietal (but not frontal) regions.

Table 6. Mean alpha/beta power and ANOVA results for the effect of Lexical Form Similarity during retrieval. *"*"indicates statistically significant effects at p < .05.*

Time window & Frequency	***Predictor***	***Mean power***	***Results***
50ms-300ms	*Age	YAs: .11 OAs: .32	*F*(1,78) = 6.68, *p* =.04
Alpha/beta	Lexical Form Similarity	Sim: .23	*F*(1,78) = .48, *p* =.48

[1] Note that the similarity *effect* (similar – dissimilar) is numerically *greater* for younger adults (see third row of Figure 4 in the manuscript).

8-24Hz		Dissim: .19	
	Age × Lexical Form Similarity		$F(1,78) = 2.36$, p =.12
	*Lexical Form Similarity × Scalp Region		$F(2,156)$ =7.70, p =.001
	Lexical Form Similarity Effect-Frontal	Sim: .23 Dissim: .30	$F(1,78) = 1.24$, p =.26
	Lexical Form Similarity Effect-Central	Sim: .14 Dissim: .11	$F(1,78)$ =.14, p =.70
	Lexical Form Similarity Effect-Parietal	Sim: .33 Dissim: .18	$F(1,78)$ =6.99, p =.009
1250-1450ms Alpha/beta 8-20Hz	*Age	YAs: -.45 OAs: -.64	$F(1,78) = 5.51$, p =.02
	Lexical Form Similarity	Sim: -.50 Dissim: -.60	$F(1,78) = 2.47$, p =.12
	Age × Lexical Form Similarity		$F(1,78) = 1.33$, p =.25
	Age × Lexical Form Similarity × Scalp Region		$F(2,156) = 3.71$, p =.06
	Lexical Form Similarity Effect-YAs-Frontal	Sim: -.31 Dissim: -.36	$F(1,39)$ = .31, p =.58
	* Lexical Form Similarity Effect-YAs-Central	Sim: -.34 Dissim: -.58	$F(1,39) = 6.28$, p =.01
	* Lexical Form Similarity Effect-YAs-Parietal	Sim: -.44 Dissim: -.67	$F(1,39) = 5.54$, p =.02
	Lexical Form Similarity Effect-OAs-Frontal	Sim: -.42 Dissim: -.51	$F(1,39)$ = .65, p =.42
	Lexical Form Similarity Effect-OAs-Central	Sim: -.73 Dissim: -.75	$F(1,39)$ = .01, p =.90
	Lexical Form Similarity Effect-OAs-Parietal	Sim: -.73 Dissim: -.71	$F(1,39)$ = .04, p =.83

Discussion of unpredicted findings

As mentioned above, we did not predict these results based on the time-frequency literature on referential processing. However, an exploratory post-hoc search in the literature provided some valuable insights as to what these effects might reflect. Nonetheless, we note that because these effects were not predicted, the following interpretations should be taken with care.

First, we observed greater alpha/beta power on ambiguous relative to unambiguous pronouns at the frontal scalp regions (see Figure 3 and Table 5). Interestingly, alpha/beta power has been linked with syntactic binding during language processing (e.g., Bastiaansen & Hagoort, 2015; Haarmann & Cameron, 2005; Segaert et al., 2017). For example, Segaert et al. (2017) presented participants with pronoun-nonword pairs that required syntactic binding (e.g., *she dotches*), or nonword-nonword pairs for which syntactic binding could not take place (e.g., *pob dotches*). They observed an increase in alpha/beta power shortly after the onset of the second nonword, suggesting that increases in alpha/beta power may reflect syntactic unification. Critically, because pronoun resolution is a form of syntactic binding where the pronoun is unified with its antecedent, this observed alpha/beta power may reflect more difficult syntactic binding for ambiguous relative to unambiguous pronouns.

Consistent with this interpretation, we also observed greater alpha/beta power for perceptually similar relative to dissimilar NPs almost immediately after the critical pronouns (see Figure 4 and Table 6), suggesting that lexical form similarity renders syntactic binding/referential resolution more difficult. Interestingly, this effect turns into an alpha/beta modulation at a late time window of 1250ms-1450ms, with significantly greater alpha/beta power for younger than older adults for pronouns following similar than dissimilar NPs, suggesting an apparent ease of syntactic binding/pronoun resolution for similar than dissimilar NPs for older adults. Note that this effect is fully consistent with the theta activity as a function of lexical form similarity as well as the good-enough interpretation of older adults' referential processing.

The effect of working memory on pronominal ambiguity resolution

Working memory scores differed significantly between the younger (mean = .51) and older group (mean = .41, $t(70) = 2.19$, $p = .03$)[2]. We investigated the potential effect of working memory span on pronominal ambiguity resolution by dividing the participants into Low- and High-Span groups (regardless of age) using a median split. The working memory scores for all participants as well as the associated analyses are provided in the supplementary materials. Figure 5 shows time-frequency plots at the frontal electrodes for each condition (first two rows), and for the difference between critical conditions (third row) across the two memory span groups in the 800ms-1400ms time window. As shown in the contrast plots, only the high-span group exhibited sensitivity to pronominal ambiguity in the form of greater delta power for ambiguous relative to unambiguous pronouns.

[2] The working memory score for one of the participants was missing, which resulted in a sample size of 39 (instead of 40) for the High-Span group.

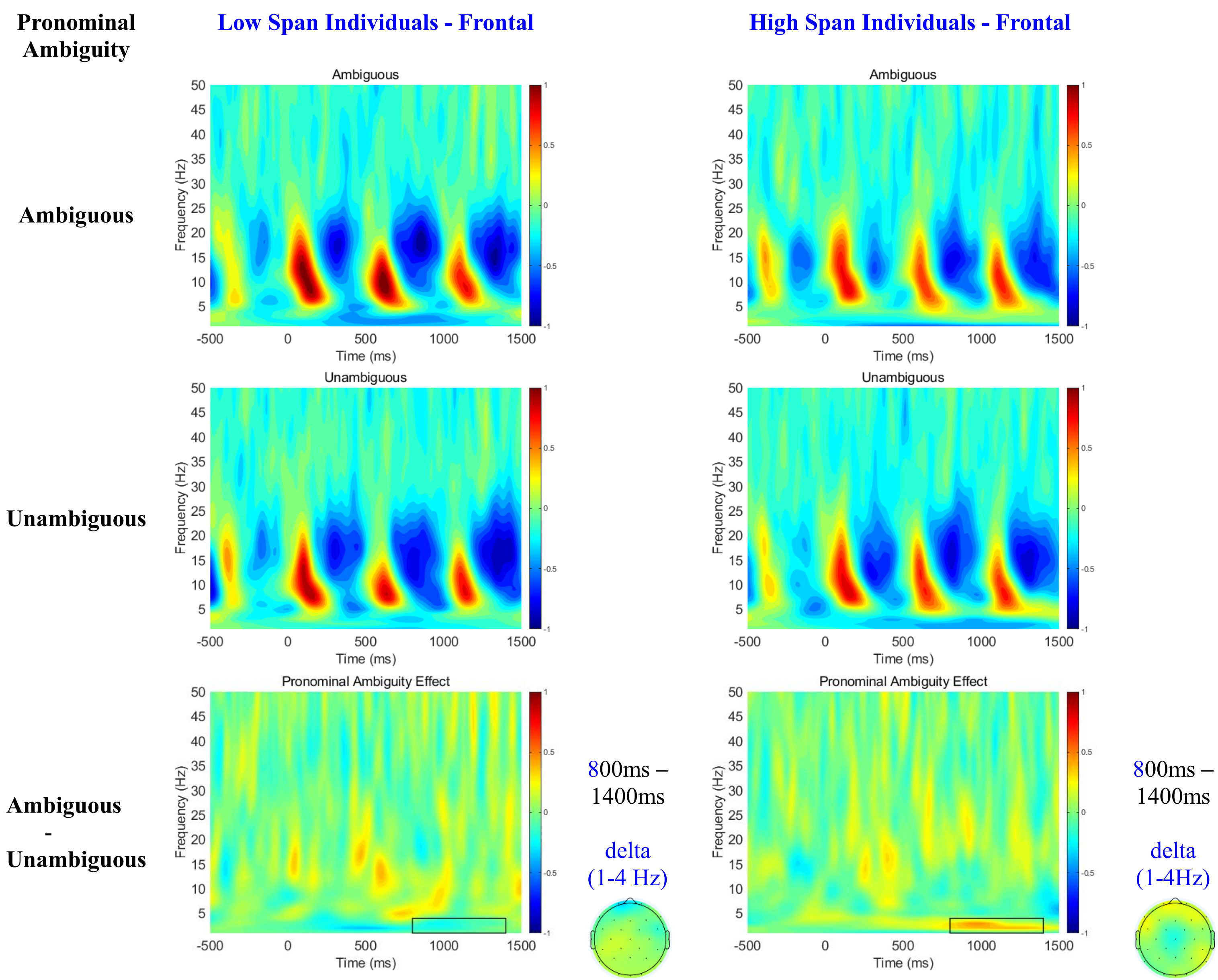

Table 7 reports mean delta power as well as the results of the statistical analyses for the effect of working memory span on referential ambiguity resolution (800ms-1400ms). As can be seen in this table, although the effects of Memory Span Group, Pronominal Ambiguity and their interaction was not statistically significant, the 3-way interaction between Memory Span Group, Pronominal Ambiguity and Scalp region reached statistical significance. Follow-up simple analyses revealed that although high-span individuals exhibited greater delta power for ambiguous than unambiguous pronouns at the frontal scalp regions, low-span individuals showed the opposite pattern at the same regions (although no simple effects were significant). See manuscript for a discussion of these results.

Table 7. Mean delta power and ANOVA results for the effect of Working Memory Span during retrieval. "" indicates statistically significant effects at p < .05.*

Time window & Frequency	***Predictor***	***Mean Power***	***Results***
800ms-1400ms Delta (1-4Hz)	Memory Span Group	Low Span: -.14 High Span: -.11	$F(1,77) = .14, p = .69$
	Pronominal Ambiguity	Amb: -.10 Unamb: -.14	$F(1,77) = .29, p = .58$
	Memory Span Group × Pronominal Ambiguity		$F(1,77) = .08, p = .76$
	*Memory Span Group × Pronominal Ambiguity × Scalp Region		$F(2,154) = 3.46, p = .04$
	Pronominal Ambiguity effect-Low Span-Frontal	Amb: -.21 Unamb: -.13	$F(1,39) = .43, p = .51$
	Pronominal Ambiguity effect-Low Span -Central	Amb: -.10 Unamb: -.14	$F(1,39) = .20, p = .65$
	Pronominal Ambiguity effect-Low Span -Parietal	Amb: -.08 Unamb: -.17	$F(1,39) = .91, p = .34$
	Pronominal Ambiguity effect-High Span -Frontal	Amb: -.06 Unamb: -.21	$F(1,39) = 1.72, p = .19$
	Pronominal Ambiguity effect-High Span -Central	Amb: -.07 Unamb: -.06	$F(1,39) = .00, p = .95$
	Pronominal Ambiguity effect-High Span -Parietal	Amb: -.11 Unamb: -.14	$F(1,39) = .11, p = .73$