Topographic analysis

Although some studies suggest that electrophysiological activity shifts from posterior to anterior with increasing age (e.g., Davis, Dennis, Daselaar, Fleck, & Cabeza, 2008), studies specifically investigating the N400 component in older populations do not show such a general age-related shift in the distribution of the effect (e.g., Federmeier & Kutas, 2005; Federmeier et al., 2003; Grieder et al., 2012; Payne & Federmeier, 2018). Therefore, we do not expect to find a significant effect of age on the distribution of the N400. However, electrode location may interact with Target word, as larger amplitude of the N400 in response to the target word may be associated with a wider spread of the effect across the scalp. As a result, unrelated target words are expected to elicit the effect with the widest spread, followed by literal and correct target words, respectively.

We analyzed how the topographic distribution of the brain responses to correct, literal, and unrelated target words presented in SOV and SVO sentences changes with age. To this aim, we computed the mean amplitude per participant per condition for each electrode in the 300-400 ms time window following the onset of the target word. To investigate the scalp distribution of the difference between the correct, literal, and unrelated conditions, we fitted a GAM model in which the topographic location of each electrode was included as a predictor. Consistent with the time course analysis, separate GAM models were fitted to mean voltages in the SOV and SVO sentences.

We first fitted a full model including all factors. Table A1 summarizes the model's statistics. The summary statistics indicate that the topographic distribution of mean voltages in response to the three target word conditions is not significantly affected by Age in general (i.e., no main effect of Age). Model comparison confirmed that the smooth over Age did not

significantly contribute to model fit in both SOV ($\chi^2(6)=0.200$, $p > .10$; Δ AIC = 4.99) and SVO sentences ($\chi^2(6)=0.029$, $p > .10$; Δ AIC = 5.90) and was therefore removed from both models.

The difference in topographic distribution of effects between the target word conditions was evaluated by using *binary predictors* that directly model potential differences between conditions in a difference smooth (see Boll-Avetisyan et al., 2018). In contrast to the ordered factors that were used in the time course analysis, binary predictors model constant (intercept) and nonlinear differences in one curve.

Summary statistics

For SOV sentences, the topographic analysis indicates a significantly different topographic distribution of brain responses elicited by unrelated versus correct target words (F(17.700, 10293.490) = 9.89, $p < .001$), by literal versus correct target words (F(3.000, 10293.490) = 19.20, $p < .001$), and by unrelated versus literal target words (F(17.703, 10286.022) = 6.51, $p < .001$). We also found a significant interaction effect between Age and the topographic distribution of the electrodes, meaning that the distribution of effects changes with age in general (F(32.761, 10293.490) = 9.24, $p < .001$). In addition, this interaction effect was significantly different for unrelated versus correct target words (F(15.569, 10293.490) = 3.09, $p < .001$), for literal versus correct target words (F(10.105, 10293.490) = 2.75, $p < .001$), and for unrelated versus literal target words (F(24.358, 10286.022) = 2.13, $p < .001$). This means that the topographic distribution of the differences between the three target words conditions significantly changes with age in SOV sentences.

Similar to SOV sentences, the topographic analysis on the SVO sentences reveals a significantly different topographic distribution of brain responses elicited by unrelated versus

correct target words ($F(16.141, 10316.153) = 12.47$, $p < .001$), by literal versus correct target words ($F(10.766, 10316.153) = 5.35$, $p < .001$), and by unrelated versus literal target words ($F(10.453, 10321.733) = 5.41$, $p < .001$). Furthermore, we found a significant interaction effect between Age and the topographic distribution of the electrodes in SVO sentences, indicating a general age-related change in the distribution of effects ($F(39.983, 10316.153) = 8.86$, $p < .001$). Moreover, summary statistics indicate that age significantly influences the difference in topographic distribution of effects between unrelated and correct target words ($F(14.537, 10316.153) = 4.46$, $p < .001$), between literal and correct target words ($F(7.662, 10316.153) = 8.58$, $p < .001$), and between unrelated and literal target words ($F(6.096, 10321.733) = 5.20$, $p < .001$).

To interpret the significant differences in topographic distribution of brain responses elicited by the three target conditions, and the modulating effect of age on these topographic differences, we visualized the model predictions in scalp plots. To gain insight in the general differences in topographic distribution between target word conditions, we first plotted the scalp distribution of these differences averaged over all participants. Subsequently, we created separate scalp plots for participants of different ages to gain insight in the way in which the topographic distribution of effects changes with age.

Visual inspection

Figure A1 shows the topographic distribution of the difference in the predicted voltages in the 300-400 ms time window elicited by unrelated versus correct target words (panel A), unrelated versus literal target words (panel B), and literal versus correct target words (panel C) in SOV sentences. Here, predicted voltages are averaged over participants of all ages. The difference

between unrelated versus correct target words and between unrelated versus literal target words shows a negativity that is maximal in centroparietal electrodes, consistent with the typical topographic distribution of the N400 (e.g., Kutas & Federmeier, 2011; Kutas & Hillyard, 1980; Rommers, Dijkstra, & Bastiaansen, 2013). However, the distribution of the difference between literal and correct target words shows a negativity that is maximal in posterior electrodes.

Table A1. Summary statistics of topographic analysis: full models fitted on mean voltages in response to target words in SOV and SVO sentences. Significant effects are indicated in bold.

	SOV sentences				**SVO sentences**			
A. Parametric coefficients	**Estimate**	***SE***	***t*-value**	**Pr (> |t|)**	**Estimate**	***SE***	***t*-value**	**Pr (> |t|)**
(Intercept)	0.003	0.016	0.210	0.833	0.000	0.017	0.024	0.981
Targetword (literal)	-0.005	0.020	-0.257	0.797	0.006	0.022	0.275	0.783
Targetword (unrelated)	-0.004	0.020	-0.220	0.826	-0.001	0.022	-0.030	0.976
B. Smooth terms	**Edf**	**Ref. edf**	***F***	***p*-value**	**Edf**	**Ref. edf**	***F***	***p*-value**
s(x, y):Targetword (correct)	**13.28**	**17.35**	**6.876**	**< .001**	**15.33**	**19.68**	**5.487**	**< .001**
s(x, y):Targetword (literal)	**14.08**	**18.27**	**6.370**	**< .001**	**14.92**	**19.23**	**15.235**	**< .001**
s(x, y):Targetword (unrelated)	**19.19**	**23.59**	**14.375**	**< .001**	**15.64**	**20.02**	**29.676**	**< .001**
s(Age):Targetword (correct)	1.00	1.00	0.108	0.743	1.00	1.00	0.041	0.83983
s(Age):Targetword (literal)	1.00	1.00	0.190	0.663	1.00	1.00	0.013	0.91102
s(Age):Targetword (unrelated)	1.00	1.00	0.287	0.592	1.00	1.00	0.007	0.93329
ti(x, y, Age):Targetword (correct)	**21.41**	**29.25**	**8.537**	**< .001**	**25.96**	**36.13**	**11.061**	**< .001**
ti(x, y, Age):Targetword (literal)	**22.71**	**31.31**	**5.992**	**< .001**	**27.93**	**39.46**	**6.601**	**< .001**
ti(x, y, Age):Targetword (unrelated)	**33.34**	**46.15**	**4.174**	**< .001**	**26.27**	**37.76**	**10.142**	**< .001**
S(Age, Electrode)	**66.29**	**555.00**	**0.185**	**< .001**	**16.38**	**555.00**	**0.044**	**.002**

[a] Explained variance model SOV sentences: 14.9 %
[b] Explained variance model SVO sentences: 18.9 %

The relative magnitude of the differences between target word conditions in SOV sentences is largely consistent with a graded N400 effect, with the largest differences in predicted voltages for unrelated versus correct target words, followed by the difference between unrelated versus literal target words, and the smallest difference between literal and correct target words. Therefore, the scalp distributions in Figure A1 support the pattern in the amplitude change over time in the target word conditions that was presented in Figure 3, including the negative peak between 300-400 ms following target word onset.

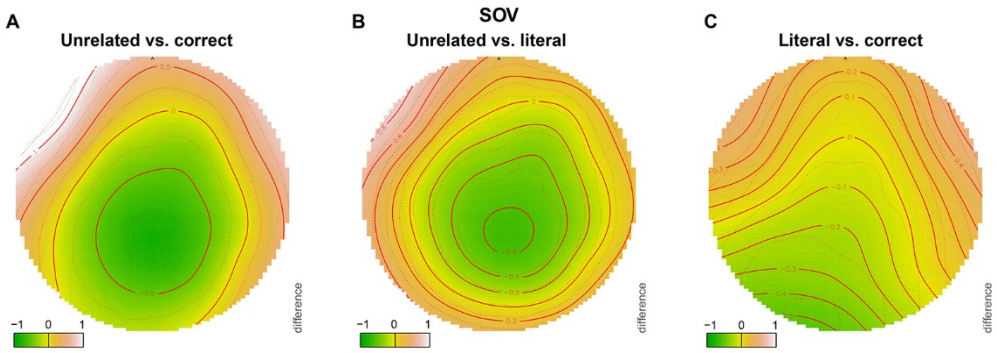

Figure A1. Difference in topographic distribution of effects in unrelated versus correct target words (panel A), unrelated versus literal target words (panel B), and literal versus correct target words (panel C) in SOV sentences. Green colors indicate a negative difference, red colors indicate a positive difference. White areas indicate values that exceed the limits of the z-axis (-1 μV for negative values and 1 μV for positive values).

Figure A2 shows the topographic distribution of the difference in the predicted voltages elicited by unrelated versus correct target words (panel A), unrelated versus literal target words (panel B), and literal versus correct target words (panel C) in SVO sentences. Similar to the topographic distribution of predicted voltages in SOV sentences, in SVO sentences the difference between

unrelated versus correct target words (panel A) and between unrelated versus literal target words (panel B) shows a negativity that is maximal in centroparietal electrodes. However, whereas in SOV sentences the negative difference between predicted voltages in response to literal versus correct target words was maximal in posterior electrodes, in SVO sentences the distribution of this difference (panel C) has the same centroparietal distribution of differences as those between the unrelated versus correct (panel A) and unrelated versus literal target words (panel B). In addition to revealing a difference in topographic distribution of voltages between SOV and SVO sentences, Figure A2 also indicates a different pattern in the strength of the differences between conditions. In SVO sentences, like in SOV sentences, the strongest difference is found between unrelated versus correct target words. However, in contrast to SOV sentences, in SVO sentences the difference between literal versus correct target words is larger than the difference between unrelated and literal target words. This pattern of effects is consistent with the time course results in Table 3 in the paper, in which the difference in mean amplitude change over time between literal and correct target words was present in none of the participants for SOV sentences, but in participants up to middle age in SVO sentences.

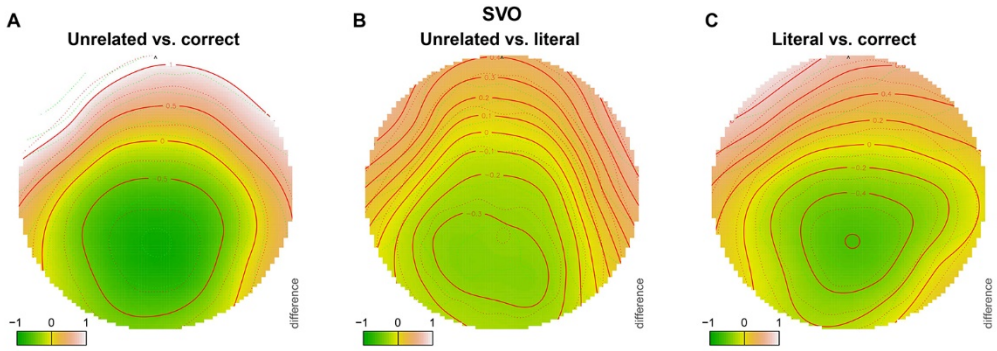

Figure A2. Difference in topographic distribution of effects in unrelated versus correct target words (panel A), unrelated versus literal target words (panel B), and literal versus correct target words (panel C) in SVO sentences. Green colors indicate a negative difference, red colors indicate a positive difference. White areas indicate values that exceed the limits of the z-axis (-1 μV for negative values and 1 μV for positive values).

To gain insight in the effect of age on the topographic distribution of differences between target words, Figures A3 and A4 present the estimated summed effects for all predictors on mean voltages in SOV and SVO sentences for (virtual) participants of different ages. Figure A3 shows that in SOV sentences the difference between unrelated versus correct and between unrelated versus literal target words is maximal in centroparietal electrodes and shows a gradual decline (i.e., becomes less negative) from younger adults to participants up to the age of 70. This pattern matches the effect of age on the amplitude change over time presented in Figure 4 in the paper. For the oldest participants, the distribution of the difference between unrelated compared with correct target words and unrelated compared with literal target words shifts to posterior electrodes. In addition, for literal versus correct target words in SOV sentences, this shift in topographic distribution from centroparietal to posterior electrodes already starts in middle-aged participants.

The topographic distribution of differences in SVO sentences (Figure A4) differs from the distribution of differences in SOV sentences (Figure A3) in two ways. First, in contrast to SOV sentences, in SVO sentences the gradual age-related decline in the strength of differences between target word conditions is also present for literal versus correct target words. Second, relative to the difference between literal versus correct target words, the difference between unrelated versus literal target words in SVO sentences seems to be weaker and decline more rapidly. This is consistent with the pattern of findings summarized in Table A1.

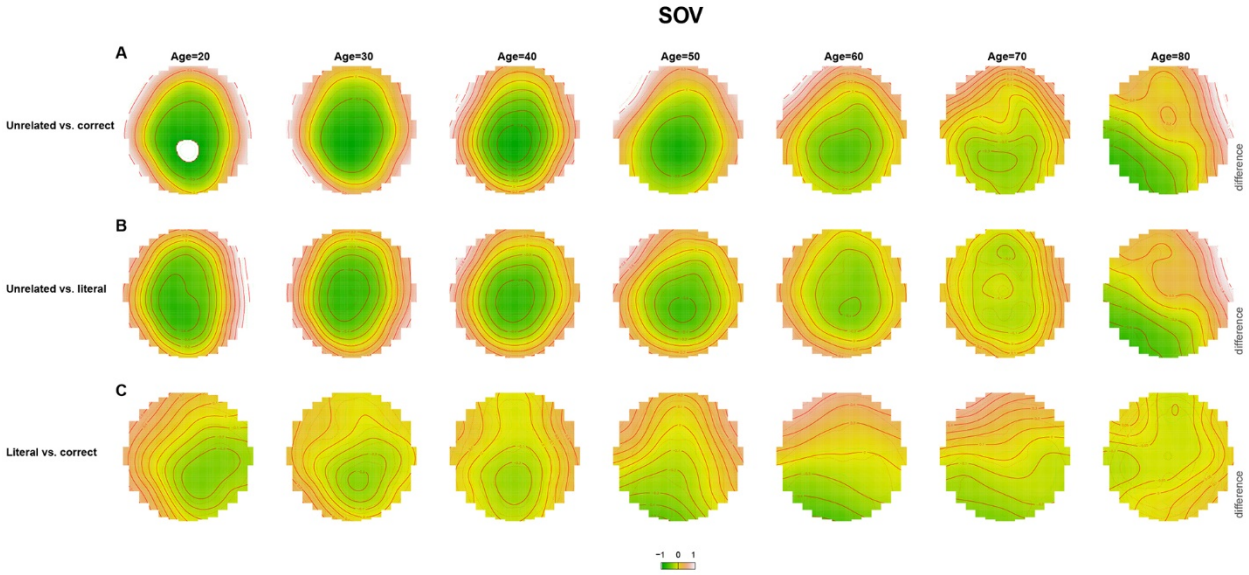

Figure A3. Topographic differences across age between unrelated versus correct target words (panel A), unrelated versus literal target words (panel B), and literal versus correct target words (panel C) in SOV sentences. Green colors indicate a negative difference, red colors indicate a positive difference. White areas indicate values that exceed the limits of the z-axis (-1 μV for negative values and 1 μV for positive values).

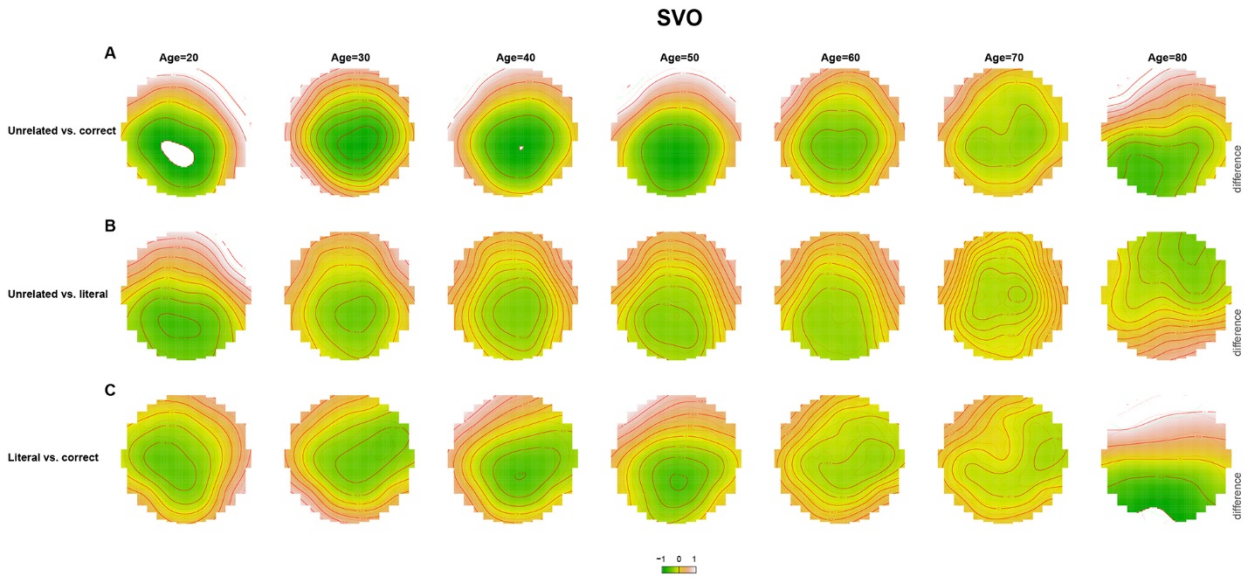

Figure A4. Topographic differences across age between unrelated versus correct target words (panel A), unrelated versus literal target words (panel B), and literal versus correct target words (panel C) in SVO sentences. Green colors indicate a negative difference, red colors indicate a positive difference. White areas indicate values that exceed the limits of the z-axis (-1 μV for negative values and 1 μV for positive values).

Summary results topographic analysis

The topographic analysis revealed that the difference between voltages elicited by the different target word conditions was generally maximal in centroparietal electrodes, consistent with the typical distribution of the N400 effect (e.g, Kutas & Federmeier, 2011; Kutas & Hillyard, 1980; Rommers et al., 2013). Furthermore, with increasing age, the strength of differences gradually declined and differences shifted from a centroparietal to a posterior distribution in the oldest participants.