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Potato not Pope: human brain potentials to gender expectation and agreement in Spanish spoken sentences

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Abstract

Event-related potentials were used to examine the role of grammatical gender in auditory sentence comprehension. Native Spanish speakers listened to sentence pairs in which a drawing depicting a noun was either congruent or incongruent with sentence meaning, and agreed or disagreed in gender with the immediately preceding spoken article. Semantically incongruent drawings elicited an N400 regardless of gender agreement. A similar negativity to prior articles of gender opposite to that of the contextually expected noun suggests that listeners predict specific words during comprehension. Gender disagreements at the drawing also elicited an increased negativity with a later onset and distribution distinct from the canonical N400, indicating that comprehenders attend to gender agreement, even when one of the words is only implicitly represented by a drawing.

Keywords

Grammatical gender; Semantic congruity; Auditory-sentence comprehension; Line drawings; Event-related potentials; N400; P600; Prediction

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To an English speaker learning a second language, it may be disconcerting to realize that knowing the word for say, potato, is not enough; in most languages it is also necessary to know the word's gender. The seemingly small difference between words like '*la papa*' and '*el Papa*' in Spanish is the difference between the potato and the Pope, respectively. While gender markings alone do not typically make such a drastic difference in a word's meaning, a noun's gender class does determine the behavior of other words (e.g. articles, adjectives, pronouns) related to it in an utterance or text [2]. In Spanish, for example, 99.9% of nouns ending in '-o' are masculine while 96.3% of those ending in '-a' are feminine [20]. These endings are also overtly marked on the articles and adjectives associated with that noun (e.g. a red basket, *una canasta roja*). In this study, we capitalize on the gender-agreement system in Spanish and individuals' sensitivity to *overt* gender agreement [1,16] to determine, via event-related potentials (ERP), if the brain is similarly sensitive to *covert* gender violations, as between an article and a line drawing, where noticing gender agreement requires more than matching the final vowels of related words. We also examined ERPs to gender-marked articles to test the controversial hypothesis that listeners anticipate items during natural language processing. To the extent that sentence context leads a listener to expect a noun of specific gender, in a gender-marked language such as Spanish, its violation would be evident

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in the ERP to the immediately preceding article. Differential brain activity at the expected versus unexpected article thus would provide evidence for an anticipatory-based [1,12] rather than the prevailing strictly post-lexical integration view of sentence comprehension [8,9].

Native Spanish speakers listened to sentence pairs like '*Caperucita Roja cargaba la comida para su abuela en* **una** *… muy bonita. Pero el lobo llegó antes que ella.*' (Red Riding Hood carried the food for her grandmother in a … [very pretty]. But the wolf arrived before she did.). One of the sentences in each pair had an embedded line drawing replacing a noun that was either the expected continuation ('*canasta*'; basket) or a semantically incongruous continuation of the same gender ('*corona*'; crown). In half the sentences an article of the wrong gender preceded the drawing (e.g. **un** *canasta/corona*), creating a gender-agreement violation at the noun (drawing). Semantic violations, whether words or drawings, typically elicit a broadly-distributed negativity at the human scalp between 200 and 500 ms post-stimulus called the N400 [10,15,17]. N400 amplitude is inversely correlated with an item's predictability and positively correlated with the difficulty of integrating it into context. Accordingly, we expected semantically incongruous drawings to elicit larger N400s relative to semantically congruous ones. As our sentence contexts were moderate-to-highly constraining (mean noun cloze: 0.67; range: 0.40–1), if context leads to an expectation for a particular noun, we might also observe an N400 to the preceding *article* when its gender violates that expectation, suggesting that articles not only play a role in syntactic parsing operations, but also in semantic analysis. In English, for example, articles can contribute to discourse-level processing by rendering subsequent mention of their associated nouns more 'accessible' (see Ref. [11] for cataphoric use of indefinite determiners). Here we assess whether an article's gender can contribute to sentence meaning by indicating agreement with contextually-expected nouns.

Previous studies would lead us to expect gender mismatches, at least between two *words*, to elicit a late posteriorly distributed positivity, variously called the P600 [18] or syntactic positive shift (SPS) [15], sometimes accompanied by a left anterior negativity [5,6,13,14]. Such positivities have been taken to index syntactic reprocessing [9,18] or recognition of a task-related anomaly [3,19]. If line drawings embedded in sentences are treated like words, those whose referents (names) mismatch in gender with the preceding article would elicit a P600. Alternatively, if gender markings are irrelevant when concepts appear as pictures, then there would be no effect of gender disagreement.

Here we present evidence for grammatical gender contributing to emerging sentence meaning, as well as maintaining agreement between words in a sentence, even when one of them is only covertly represented by a line drawing.

Thirty-one healthy, right-handed, native Spanish-speaking adults (18 women, mean age 28 years, range 21–35 years) listened for meaning (with no additional task) to naturally spoken sentence pairs such as the examples below. One of either sentence in each pair had an embedded black-on-white line drawing replacing a noun that was either the expected continuation ('*canasta*'; basket) or a semantically incongruous continuation with the same gender ('*corona*'; crown). The drawing could appear at any point in either sentence but was never sentence final. In half the sentences an article of the wrong gender preceded the drawing (e.g. **un** *canasta/corona*), creating a gender-agreement violation at the drawing. The amount of context preceding the drawing and its prior article varied in length (mean 16.3 words, range 6–30) as it did in number of articles (mean 1.7, range 0–5), thus making the target's sentence position relatively unpredictable. Sentences were recorded with a blank after the target article by a male, native Spanish speaker using natural prosody, and were presented in an insulated booth over loud speakers adjusted 55 dB above each listener's

estimated hearing threshold. The drawings appeared for 500 ms on a CRT (3 inch^2 at 300 dpi^2) immediately upon target article offset and 500 ms before the sentence continued. The 110 experimental sentence pairs and drawings appeared in all four conditions across five lists; drawings were counter-balanced across two sentence pairs to create the semantically congruous and incongruous versions for each. Each drawing also appeared in a sentence with no preceding article or semantic constraint (e.g. 'Armando took a test in which he had to name ___ 5 times.') as fillers. Each list contained 22 items per condition, 22 neutral fillers and 22 additional lower constraint (mean 0.41) gender-matching congruous fillers similar to the experimental sentence pairs, for a total of 132 items. Participants listened to one list wherein each experimental sentence pair and drawing appeared once. Examples of the sentences in the four experimental conditions are given in Fig. 1.

The electroencephalogram (EEG) was recorded from 26 tin electrodes in a electro-cap, each referenced on-line to the left mastoid. Blinks and eye movements were monitored via electrodes placed on the outer canthi of each eye and under each eye (referenced to the left mastoid). Electrode impedances were maintained below 5 kΩ. The EEG was amplified with Grass amplifiers (band pass 0.01–100 Hz), and sampled at 250 Hz. Trials with artifacts due to eye movements, excessive muscle activity or amplifier blocking were eliminated off-line before averaging, ~3.3% and 4.2% of the data time locked to the article and drawing, respectively. Data with excessive blinks were corrected using a spatial filter algorithm [4]; a digital band-pass filter of 0.1–20 Hz was applied to all the data prior to statistical analyses to reduce high frequency noise. Data were re-referenced off-line to the algebraic sum of the left and right mastoids, and averaged for each experimental condition time-locked to the onsets of the critical article (mean duration 346 ms; range 198–485 ms) and line drawing.

Mean amplitude of ERPs to the line drawings were subjected to ANOVAs with two levels of semantic congruence, two levels of gender, and 26 levels of electrode between 300 and 500 ms (N400 region) and between 500 and 700 ms (P600 region). Criterion for significance was set at $P < 0.01$ for all comparisons; effects for repeated measures with greater than one degree of freedom are reported after Huynh-Feldt correction.

Line drawings that were semantically incongruous in their sentences elicited a larger negativity between 300 and 500 ms than congruous drawings, especially over frontal, medial sites on the right hemisphere, a typical distribution for the N400 to drawings [7,10] [main effect of congruence, $F(1, 30) = 34.78$, $P < 0.00001$; congruence by electrode interaction, $F(25, 750) = 10.78$, $P < 0.00001$]. This effect of semantic congruence lasted from 200 to 800 ms and was unaffected by grammatical gender [main effect of gender, 300–500 ms, $F(1, 30) = 0.01$, $P < 0.94$], and thus is shown collapsed across gender (Fig. 2 left-half). The earliest effect of a gender mismatch on the drawing was around 500 ms post-drawing onset (Fig. 2 right-half). In contrast to previous studies where gender-agreement violations between two words elicited an increased late positivity (P600), gender mismatches between the line drawing's referent and preceding article were associated with a slightly greater *negativity* over medial, posterior sites than gender matches on the ERPs to the drawings [main effect of gender, 500–700 ms, $F(1, 30) = 3.15$, $P < 0.086$; gender by electrode, $F(25, 750) = 4.68$, $P < 0.002$]. At no time did gender (dis)agreement interact with semantic congruence (300–500 ms, $P < 0.72$; 500–700 ms, $P < 0.85$).

Thus, listeners do attempt to integrate a drawing with the ongoing auditory context and are sensitive to gender-agreement information during sentence comprehension, even when the agreement mismatch is implicit (i.e. a drawing's referent). Listeners could have ignored the gender mismatch between the line drawing's name and the preceding article and still have made perfect sense of the sentence; they did not. Alternatively listeners could have treated the gender mismatch as if the drawing's *name* had been presented; again, they did not.

Rather, we saw a response of the opposite polarity – perhaps due to the lack of overt physical (phonemic) information on drawings that is highly correlated with a word's gender in Spanish (e.g. -a, -o) (see Ref. [6]), suggesting that gender is not always processed in exactly the same way in sentences.

The more remarkable finding was the presence of an apparent 'semantic' mismatch in the ERPs to the article itself (Fig. 3), which is perhaps partially why the effect of gender mismatches at the drawing was so small. Note that this mismatch is between the article's gender and the gender of the item *expected* on the basis of the preceding context (but not yet presented). There is no *overt* mismatch, because articles of either gender are possible and grammatically correct continuations. Red Riding Hood could just as well have been carrying the food in a sack (**un costal**) or a basket (**una canasta**), though the latter continuation was more expected (according to off-line cloze ratings collected from a different group of participants supplying the missing article and noun given the preceding sentence context). The ERPs to articles with gender markings different than that of the expected nouns' were characterized by a greater negativity between 300 and 500 ms compared to articles of the expected gender, especially over central medial sites [$F(1, 30) = 12.59$, $P < 0.001$; gender expectation by electrode, $F(25, 750) = 4.74$, $P < 0.001$]. Prior studies of gender mismatches did not report this effect probably because they were aimed at elaborating the matching process, which takes place at the second of two gender-marked items, and generally did not include enough prior context to generate specific expectations [6,13,14]. Although the unexpected-gender effect at the article peaks somewhat later (450 ms) than the semantic congruency effect at the drawing (350 ms), the effects are similar in their scalp topography (Fig. 4), suggesting that they may reflect functionally similar neural events (i.e. the N400), indexing the difficulty of integrating the unexpected item with the current semantic representation. Thus, although the gender system is often viewed as a purely formal device [2,9], it does play a role in semantic interpretation, at least in utterances with moderate to high constraint. Articles are clearly more than syntactic placeholders devoid of semantic content [11].

In sum, listeners do attend to the gender information carried by articles during sentence comprehension, both for agreement matching, even for implicit agreement with the gender of a drawing's referent, and as an integral part of the message-level representation built from the ongoing context. Some differences in the brain's response to gender-agreement violations between two words or a word and a drawing indicate that gender agreement can be processed in different ways (e.g. physical matching versus higher level agreement). Moreover, counter to the prevailing view, the human brain does use sentence context in natural speech to generate fairly specific expectations about upcoming items, including information about a word's gender, presumably to help us make sense of utterances with the breakneck speed with which they come.

Acknowledgments

References

1. Bates E, Devescovi A, Pizzamiglio L, Damico S, Hernandez A. Gender and lexical access in Italian. Percept Psychophys. 1995; 57:847–862. [PubMed: 7651809]

2. Corbett, GG. Gender. Cambridge University Press; Cambridge: 1991.

3. Coulson S, King JW, Kutas M. Expect the unexpected: event-related brain response to morphosyntactic violations. Lang Cogn Process. 1998; 13:21–58.

4. Dale, AM. Source Localization and Spatial Discriminant Analysis of Event-Related Potentials: Linear Approaches, Department of Cognitive Science. University of California; San Diego, La Jolla, CA: 1994. p. 175

5. Demestre J, Meltzer S, Garcia-Albea JE, Vigil A. Identifying the null subject: evidence from event-related brain potentials. J Psycholing Res. 1999; 28:293–312.

6. Deutsch A, Bentin S. Syntactic and semantic factors in processing gender agreement in Hebrew: evidence from ERPs and eye movements. J Mem Lang. 2001; 45:200–224.

7. Federmeier KD, Kutas M. Meaning and modality: influences of context, semantic memory organization, and perceptual predictability on picture processing. J Exp Psychol Learn Mem Cogn. 2001; 27:202–224. [PubMed: 11204098]

8. Frazier L. Getting there (slowly). Special Issue: Celebrating a quarter century of (the Journal of) Psycholinguistic Research. J Psycholing Res. 1998; 27:123–146.

9. Friederici AD. Towards a neural basis of auditory sentence processing. Trends Cogn Sci. 2002; 6:78–84. [PubMed: 15866191]

10. Ganis G, Kutas M, Sereno MI. The search for "common sense": an electrophysiological study of the comprehension of words and pictures in reading. J Cogn Neurosci. 1996; 8:89–106.

11. Gernsbacher MA. Mechanisms that improve referential access. Cognition. 1989; 32:99–156. [PubMed: 2752708]

12. Gernsbacher MA, Shroyer S. The cataphoric use of the indefinite this in spoken narratives. Mem Cognit. 1989; 17:536–540.

13. Gunter TC, Friederici AD, Schriefers H. Syntactic gender and semantic expectancy: ERPs reveal early autonomy and late interaction. J Cogn Neurosci. 2000; 12:556–568. [PubMed: 10936910]

14. Hagoort P, Brown CM. Gender electrified: ERP evidence on the syntactic nature of gender processing. J Psycholing Res. 1999; 28:715–728.

15. Holcomb PJ, Neville HJ. Natural speech processing: an analysis using event-related brain potentials. Psychobiology. 1991; 19:286–300.

16. Jakubowicz C, Faussart C. Gender agreement in the processing of spoken French. J Psycholing Res. 1998; 27:597–617.

17. Kutas M, Hillyard SA. Reading senseless sentences: brain potentials reflect semantic incongruity. Science. 1980; 207:203–205. [PubMed: 7350657]

18. Osterhout L, Mobley LA. Event-related brain potentials elicited by failure to agree. J Mem Lang. 1995; 34:739–773.

19. Patel AD, Gibson E, Ratner J, Besson M, Holcomb PJ. Processing syntactic relations in language and music: an event-related potential study. J Cogn Neurosci. 1998; 10:717–733. [PubMed: 9831740]

20. Teschner RV, Russell WM. The gender patterns of Spanish nouns: an inverse dictionary-based analysis. Hisp Ling. 1984; 1:115–132.

Gender Match – Semantically Congruous

Caperucita Roja cargaba la comida para su abuela en **una** *muy bonita.*

Pero el lobo llegó antes que ella.

Little Red Riding Hood carried the food for her grandmother in a [fem] BASKET[fem] [very pretty].

But the wolf arrived before she did.

Gender Match – Semantically Incongruous

Caperucita Roja cargaba la comida para su abuela en **una** ...

Little Red Riding Hood carried the food for her grandmother in a [fem] CROWN[fem] ...

Gender Mismatch – Semantically Congruous

Caperucita Roja cargaba la comida para su abuela en **un** ...

Little Red Riding Hood carried the food for her grandmother in a [masc] BASKET[fem] ...

Gender Mismatch – Semantically Incongruous

Caperucita Roja cargaba la comida para su abuela en **un** ...

Little Red Riding Hood carried the food for her grandmother in a [masc] CROWN[fem] ...

Fig. 1.
Examples of the sentences in the four experimental conditions.
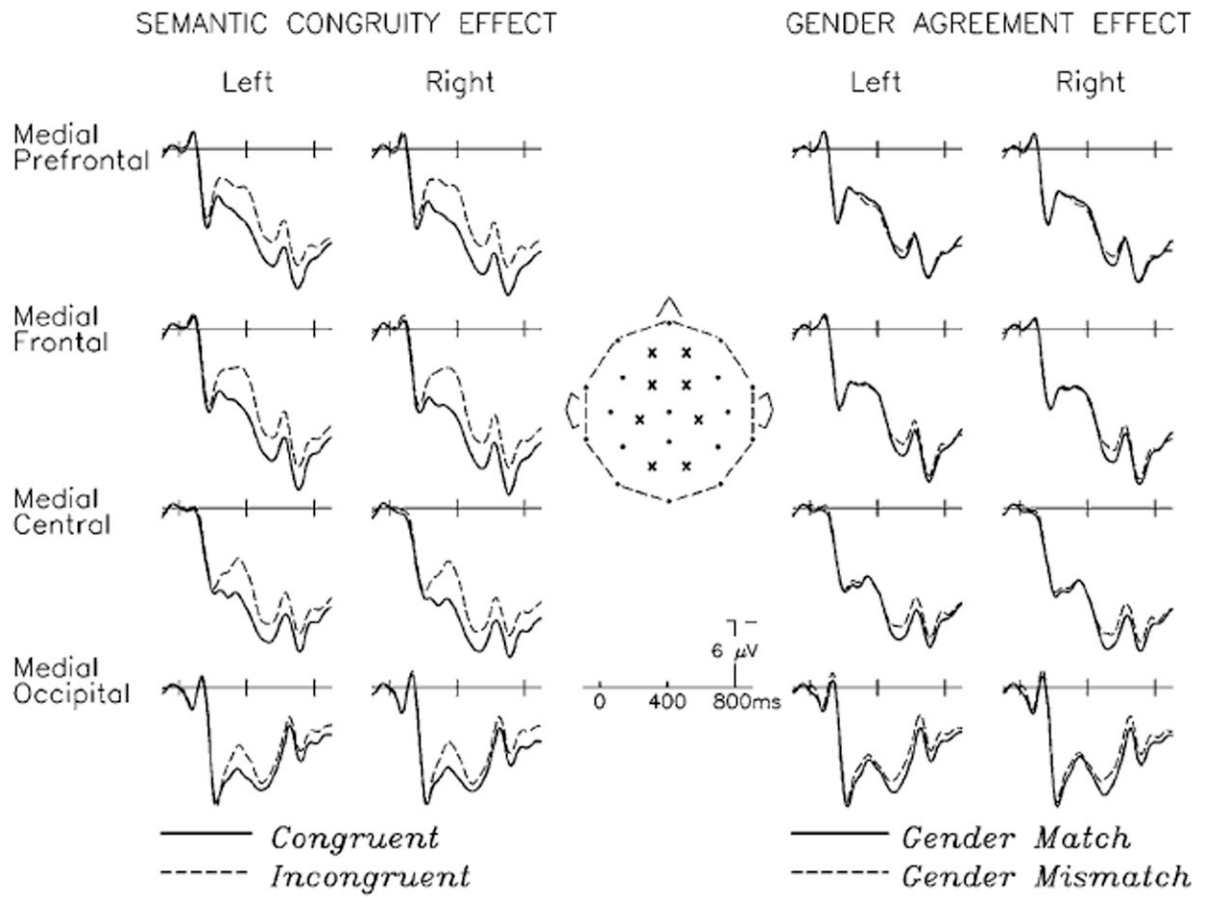
Fig. 2.
Grand average ERPs from eight representative sites (Xs on schematic head) to drawings showing the semantic-congruity effect across gender agreement and the gender-agreement effect across semantic congruity. *Y*-axis: amplitude in microvolts, negative polarity plotted up; *X*-axis: time with drawing onset at 0 ms.

GENDER EXPECTATION EFFECT
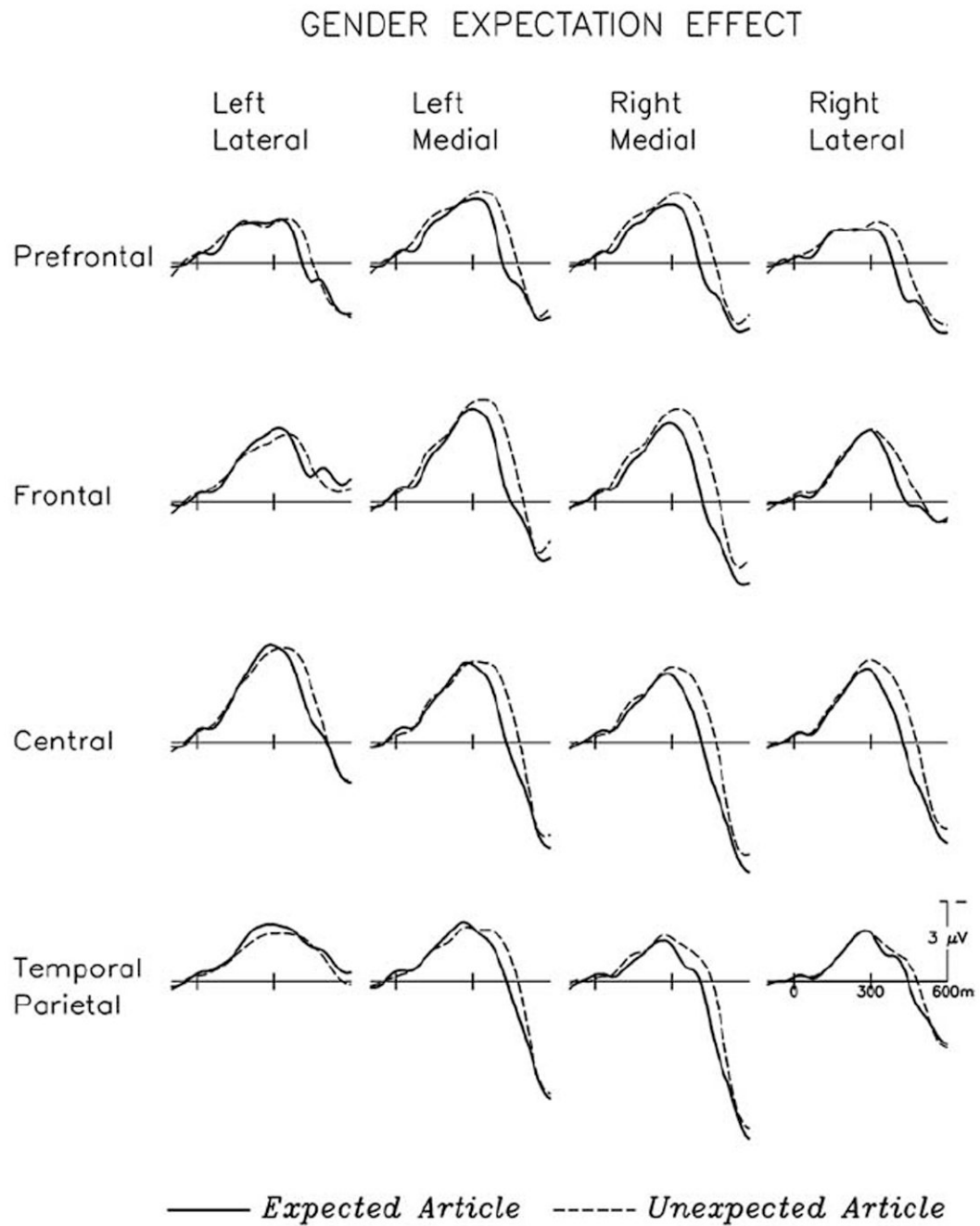
Fig. 3.
Grand average ERPs elicited by naturally spoken articles preceding the drawings from 16 representative electrodes, showing the gender expectation effect.
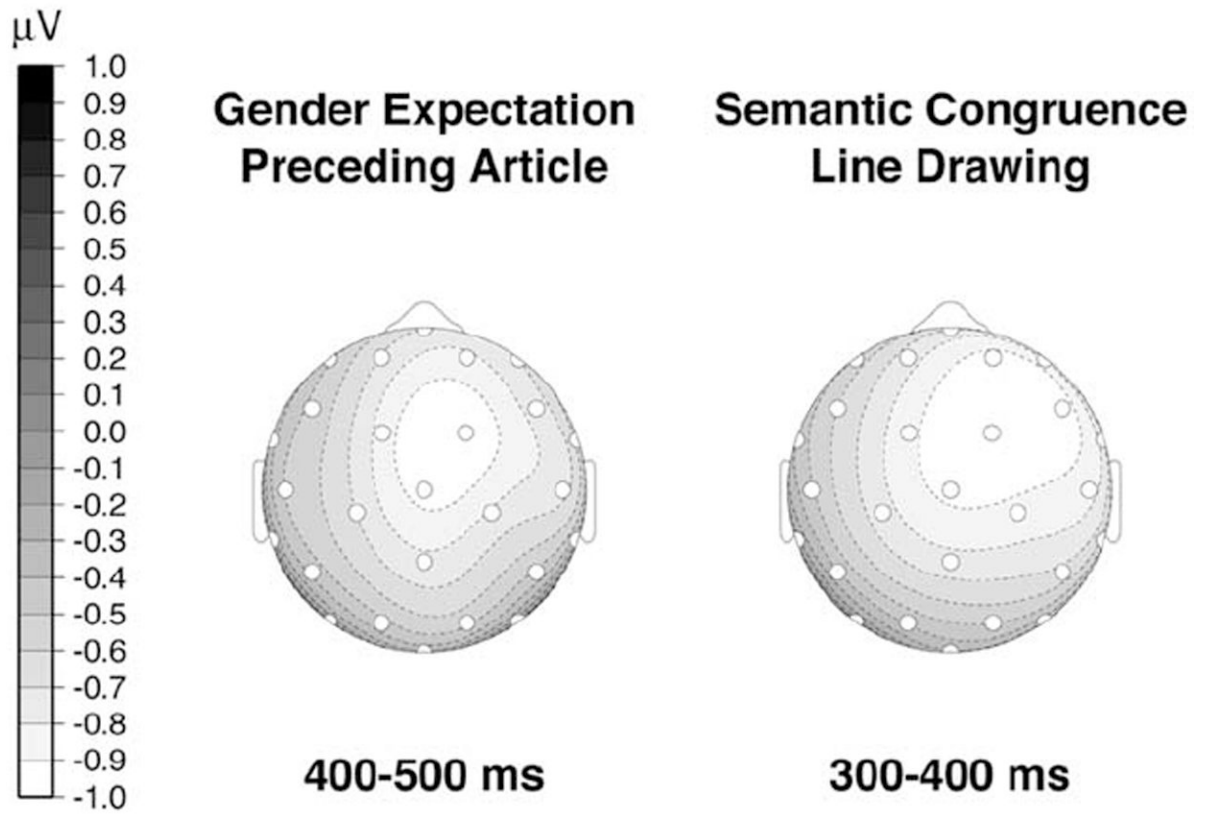
Fig. 4.
Voltage maps (100 ms window) of the gender expectation effect (unexpected minus expected-gender ERP) at the article and semantic-congruity effect (semantically incongruent minus congruent ERP) at line drawing. Lighter to darker coloration indicates more negativity to more positivity, respectively.