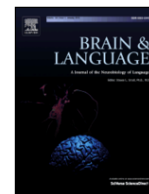




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Brain and Language

journal homepage: www.elsevier.com

Neural correlates of automatic beliefs about gender stereotypes: Males are more prejudicial

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ARTICLE INFO

Keywords:

N400
P600
Stereotype
Social cognition
TOM
ERPs
Gender differences

ABSTRACT

Aim of this study was to investigate the neural bases of stereotype representation, including the presence of gender bias. EEG was recorded from 128 sites in 38 Italian participants. While looking for rare animal words, participants read 240 sentences, half of which expressed notions congruent with gender stereotypes, and the other half did not (e.g., “Prepared the tomato sauce and then SHAVED”, “The engineer stained HER SKIRT”). Event-related potentials (ERPs) were time-locked to critical words. Findings showed enhanced anterior N400 and occipito-parietal P600 responses to items that violated gender stereotypes, mostly in men. The swLORETA analysis applied to N400 potentials in response to incongruent phrases showed that the most activated areas during stereotype processing were the right medial temporal and medial frontal gyri, as well as the TPJ. The data hint at a gender difference in stereotyping, with men being more prejudicial especially when the depicted character is a male.

1. Introduction

The aim of this study was to investigate the neural correlates of the representation of social information, and, in particular, the occupational gender stereotypes in which women engage more in care-related professions and men in strength/power related professions. The time course and the neural correlates involved in the representation of occupational gender biases were investigated by addressing two questions: first, if the biases varied as a function of participant's sex; and second, if there was a difference based on the gender of the character depicted in the phrases. An implicit paradigm was chosen to trigger the automatic activation of any mental function involved in the processing of gender stereotypes. This was carried out by recording electrophysiological responses in young heterosexual Italian university students during the reading of hundreds of sentences depicting female and male characters and their professional attitudes. The task consisted of responding to animal words, in order to avoid explicit social desirability processes, and the brain responses of male and female participants totally unaware of study's purpose were compared. The implicit nature of the task provides a significant benefit in comparison to explicit tasks commonly used in the previous literature on gender stereotypes (e.g., see

the nice and updated collection of papers in Garnham, Oakhill, Szesny, & Von Stockhausen, 2016, as well as Molinaro, Su, & Carreiras, 2016; Fabre, Causse, Pesciarelli, & Cacciari, 2015; Osterout et al., 1997; White, Crites, Taylor, & Corral, 2009). Indeed, moral instances, for example the believe that “women should be engineers too!” may interfere with decisional processes, thus masking semantic or pragmatic effects in task requiring to establish sentence correctness. A clear example is provided by Canal, Garnham, & Oakhill's (2015) investigation in which they recorded Event-Related Potentials (ERPs) to investigate differences in the use of gender information during the processing of reflexive pronouns. Pronouns (e.g. him, her) either matched or not the gender provided by role nouns (such as “king” or “engineer”) and participants were explicitly asked to judge their acceptability in terms of grammar and meaning. The explicit nature of the task requirements likely engaged voluntary control and moral decisions; indeed the authors of the study themselves report that “participants were instructed to base their ratings on how the world is and not how it ought to be”, corresponding to a request of suppressing possibly moral instances. Again, in White et al.'s (2009) study participants were primed with either the gender category ‘Women’ or ‘Men’, followed by a word which was either consistent with gender stereotypes (e.g.

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Women: Nurturing) or inconsistent (e.g. Women: Aggressive). They were explicitly asked to indicate whether the words matched or did not match, according to gender stereotypes. Both response times and event-related brain potentials (ERPs) were recorded during performance of the task. As predicted, stereotype incongruent word pairs were associated with larger N400 ERP amplitudes and slower response times, relative to congruent word pairs. Both studies did not show a sex bias in stereotype representation.

An implicit task was instead used in a previous electrophysiological investigation (Proverbio, Orlandi & Bianchi, 2017), in which however the sex of participants was not considered. The data showed that a violation of the current stereotype in a terminal word paradigm, as in the sentence “Prepared the tomato sauce and then SHAVED” as compared to a congruent sentence such as “Fed the little girl and went to the LADY-HAIRDRESSER”, elicited a N400-like anterior negativity in the 350–450-ms temporal window followed by a later anterior negativity (LAN). These findings suggest that gender stereotypes are processed automatically (as if they were morpho-syntactic errors) and hints at how they are deeply rooted in our linguistic brain. According to the source reconstruction performed on the N400 responses, the neural representations of gender-based stereotypes mostly involved the middle frontal gyrus, which is compatible with available literature (e.g., Fourie, Thomas, Amodio, Warton, & Meintjes, 2014; Knutson, Mah, Manly, & Grafman, 2007; Proverbio, La Mastra, & Zani, 2016; Mitchell, Macrae, & Banaji, 2006; Mahy, Moses, & Pfeifer, 2014); the temporo/parietal junction (supposedly supporting theory of mind (TOM) processes according to Saxe, Moran, Scholz, & Gabrieli, 2006; Saxe, 2010); and the superior and middle temporal gyri, representing person information (e.g., Freeman, Schiller, Rule, & Ambady, 2010; Ibañez & Manes, 2012; Quadflieg et al., 2009).

Because these stereotypes are a part of everybody’s cultural heritage and learned early in life, people form implicit gender stereotypes, which automatically associate men and women with stereotypical traits, abilities, and roles, even when they disavow these traditional beliefs (e.g., Nosek, Banaji, & Greenwald, 2002). For instance, women are typically stereotyped as being nicer (Eagly & Mladinic, 1989) and are more likely to enact subordinate roles that require communal traits. The presence of gender stereotyping has been demonstrated for an extensive list of role nouns in Czech, English, French, German, Italian, Norwegian, and Slovak by Misersky et al. (2014). With the help of a reaction-time-based measure of implicit cognition that is the Implicit Association Test (Greenwald, McGhee, & Schwartz, 1998), gender stereotypes that consist of associating agency to men and communality to women have been demonstrated at the implicit level (e.g., Rudman & Glick, 2001). Strong gender implicit stereotypes have also been observed among the Italian population at all age ranges, including elderly individuals and children as young as 8 years old (Cacciari & Padovani, 2007; Siyanova-Chanturia, Warren, Pesciarelli, & Cacciari, 2015). These stereotypes have also been translated into a gender-career implicit stereotypes, with men more strongly associated with careers and women more strongly associated with family (Nosek et al., 2002). In an interesting neuropsychological study (Milne & Grafman, 2001), patients with prefrontal cortex lesions and controls were administered an IAT that measured the degree of implicit associations between male and female names and attributes of strength and weakness. The results showed that while controls manifested strong stereotypical associations (i.e., stronger associations between male names and strength attributes and between female names and weakness attributes than those between males and weakness and females and strength), patients with ventromedial prefrontal cortex lesions showed significantly lower associations, thus suggesting a role for this region in representing social knowledge. A similar finding was described by Gozzi, Raymont, Solomon, Koenigs, and Grafman (2009) in patients with a lesion in the ventrolateral prefrontal cortex (vIPFC), showing a reduction of the gen-

der stereotype in which female names (e.g., Mary) are usually more associated with “fragile” and “delicate” than with “dominant” and “powerful” attributes (and vice versa). Accordingly, Cattaneo, Mattavelli, Platania, and Papagno (2011) using the same strength/weakness IAT paradigm and found that applying TMS over the left dorsolateral PFC and the right anterior dorsomedial prefrontal cortex (aDMPFC) increased the gender-stereotypical bias in male participants compared to when TMS was applied to a control site (vertex).

Interestingly, in that study, women did not show a significant gender bias on the IAT, and, correspondingly, their responses were unaffected by TMS. A gender stereotype confined to males only was also reported by Cikara et al.’s fMRI study (2011) in which male (but not female) participants with higher hostile sexism scores more quickly associated sexualized women with objectifying verbs such as “handle” (and clothed women with third-person action verbs such as “handles”) than the inverse, compared to their less sexist peers. Furthermore, hostile sexism correlated with activation of regions associated with mental state attributions, such as the medial prefrontal cortex, posterior cingulate and temporal poles.

Whether social attributes are more gender-biased in male than female participants has seldom been investigated with electrophysiological techniques. For example, the ERP study by Leynes, Crawford, Radebaugh, and Taranto (2013) provided evidence that gender stereotypes affected a late ERP memory component by enhancing recollection, but no sex analysis was performed. Again, in the ERP study by White et al. (2009), participants made quicker judgments for stereotypically congruent prime–target word pairs (Women: Nurturing) than to incongruent word pairs (Men: Nurturing). This incongruence effect led to larger N400 amplitudes in response to incongruent word pairs vs. congruent word pairs, but no gender effect was investigated.

Other studies on gender stereotypes (e.g., Canal et al., 2015) have found a modulation of the later positive P600 complex or SPS (Syntactic Positive Shift), which is supposed to reflect the costs of repair and reinterpretation of phrase structural mismatches and/or higher order integration processes (Martin-Loeches, Nigbur, Casado, Hohlfeld, & Sommer, 2006; Friederici, 2002). In detail, in Osterhout et al.’s study (1997), ERPs were recorded while 14 males and 14 females read sentences containing a reflexive pronoun that referred to a definitionally or stereotypically male or female antecedent noun. Pronouns that disagreed with the gender definition or gender stereotype of the antecedent elicited a large-amplitude P600. In sentences such as “The doctor prepared herself for the operation”, the pronoun herself was perceived as anomalous due to the stereotype that the medical profession is purely male. Instead, in the sentence “The nurse prepares herself for the operation” the pronoun agreed with the shared stereotypes that the nurse is a more feminine profession. Pronouns violating stereotypes triggered a large positive wave that corresponded to the P600. It is interesting to note that female participants showed larger P600 components than males, but this effect was independent of the inconsistency condition.

In a behavioral study, Cacciari and Padovani (2007) found that when the gender stereotype conveyed by a role noun acting as a prime stereotypically female-oriented, an inhibition effect emerged in the response times to a gender- incongruent pronoun (e.g., teacher – he). In contrast, compared to the control condition, no inhibition emerged when participants were presented with a masculine role noun followed by an incongruent pronoun (e.g., engineer – she). In Siyanova-Chanturia, Pesciarelli, & Cacciari (2012) gender stereotypes affected the brain response to masculine and feminine pronouns differently: participants were more accepting of female drivers than male teachers suggesting that gender stereotypes – conveyed by occupation nouns or personal traits – might be more restrictive for females than males. They found a larger N400 in response to masculine pronouns preceded by incongruent definitional or stereotypical primes (e.g., “he” preceded by

either (female) *passenger* or *teacher*) or in response to feminine pronouns preceded by incongruent definitional primes (e.g., “she” preceded by (masculine) *retired*) but, interestingly, not by incongruent stereotypical primes (e.g., “she” preceded by *driver*).

In conclusion, the effect of gender on occupational stereotypes has failed to show a uniform pattern of results across different studies, probably also because of the use of explicit tasks requiring to openly judge the correct associations between genders and gender-biased professions. For example, Osterhout, Bersick, and McLaughlin (1997) found that gender violations elicited larger P600 responses for female subjects than for male subjects while Canal et al. (2015), Cacciari and Padovani (2007), Siyanova-Chanturia et al. (2012) did not find any clear sex difference during the processing of reflexive pronouns.

Conversely, Cattaneo et al. (2011) using the Implicit Association Test (IAT) found that a TMS application over the prefrontal cortex (compared to a sham condition) increased a gender-stereotypical bias only in male participants and not in females. Interestingly, in that study, women did not show a significant gender bias on the “delicate/powerful” IAT, and, correspondingly, their responses were unaffected by TMS.

In the present investigation, we wished to shed some light on this matter, by analyzing the specific effects of the gender of participants and the gender of the characters depicted (associated with typical or atypical masculine or feminine professions) on the amplitude of N400 and P600 responses to stereotype violations, which were expected to be greater in incongruent conditions on the basis of the available literature.

On the basis of some of the previous literature (Nosek & Smyth, 2007; Cikara, Eberhardt, & Fiske, 2011; Cattaneo et al., 2011) we hypothesized that prejudice violations would affect mostly male individuals, therefore we expected to find much smaller or null N400 and P600 responses to stereotype violations in female participants. However we did not have specific predictions about the stereotype violation effects in relation to the characters’ gender, because of the too many inconsistencies in the literatures, and of the explicit (instead of implicit) nature of most previous experimental designs.

2. Methods

2.1. Participants

Thirty-eight university students (19 men and 19 women) ranging in age from 18 to 35 years took part in the study. All of them had heterosexual preferences as ascertained by a written questionnaire. All participants had normal or corrected-to-normal vision. They were strictly right-handed as assessed by the Oldfield Inventory and reported no history of neurological or mental disorders. Experiments were conducted with the understanding and written consent of each participant according to the Declaration of Helsinki (BMJ 1991; 302: 1194), with approval from the Ethical Committee of the University of Milano-Bicocca. The data from 2 women and 3 men were subsequently discarded for excessive EEG artifacts. The final sample of 17 females and 16 males had a mean age of 23.48 years (SD = 3.053).

2.2. Stimuli

Stimuli were the same as those used in Proverbio et al. (2017) and consisted of 240 sentences in Italian, half of which expressed notions congruent with the prevalent gender stereotype, thereafter named congruent phrases, and the other half expressed notions incongruent with gender stereotypes, thereafter named incongruent phrases (see Table 1 for some examples). It should be noted that the gender sensitive words such as adjectives were always located at the end of phrases, which is

Table 1

Some examples of sentences used as experimental stimuli, as a function of stimulus type. On the left column are the original sentences, with their translation on the right.

Sentences violating the prejudices (male character)	
<i>Preparò il sugo e si fece la BARBA</i>	Prepared the tomato sauce and then shaved
<i>Lasciò il pattinaggio artistico quando divenne PADRE</i>	Gave up figure skating when he became father
<i>Stese i panni e raggiunse la MOGLIE</i>	Hang the clothes out to dry and caught up with his wife
Sentences violating the prejudices (female character)	
<i>Il notaio sta ALLATTANDO</i>	The notary is breastfeeding
<i>Cadendo dal tetto, l'antennista si è quasi AMMAZZATA</i>	Falling from the roof, the cable guy almost killed herself.
<i>Ecco l'assessore con suo MARITO</i>	Here is the commissioner with her husband
Congruent sentences (male character)	
<i>Il chimico si mise una bella CRAVATTA</i>	The chemist put on a nice tie
<i>Operò nell'intelligence finché non fu SCACCIATO</i>	Served with intelligence until he was cast out
<i>Finito di mettere le piastrelle, era STREMATO</i>	Once finished with the tile install, he was haggard
Congruent sentences (female character)	
<i>Ha preparato una coreografia in piscina di cui va FIERA</i>	Prepared a synchronized swimming choreography of which she is proud
<i>Lavora come baby-sitter ed è molto MATERNA</i>	Works as a baby-sitter, and she is very maternal
<i>Fece mangiare la bambina e andò dalla PARRUCCHIERA</i>	Fed the little girl and went to the lady hairdresser
Target sentences	
<i>Luca ha l'abitudine di andare al parco con il CANE</i>	He is used to go to the park with his dog
<i>E' sicuramente daltonico perché colora di rosa le PECORE</i>	He surely is color-blind in that he is coloring the sheep pink
<i>Luana ha voluto comprare un PESCE</i>	Luana wanted to buy a fish

correct in Italian (e.g., Nel posteggiare è molto ESPERTO; Stendendo i vestiti è SCIVOLATA; Sostituì la gomma e sorrise ORGOGLIOSA).

Sentences were created in a way that the gender of the character engaging in a given professional activity or behavior was made explicit only at the very end of the sentence (terminal word paradigm) through a pronoun or a declination. The stereotype violation involved males in half of the cases and females in the other half. Examples of sentences concerning female characters are the following: “(She) did the laundry and went out with HER friends”, which is congruent with the stereotype of a woman engaging in housework; or “Replaced the tire and smiled, proud of HERSELF”, which is instead incongruent with that stereotype. An example of sentences concerning male characters is the following (translated in English): “To become a body-builder HE trained staunchly”, which is congruent with the stereotype that bodybuilding is mostly a male “sport discipline” (please see Table 1 for further examples). Phrases concerning men and women (both congruent and incongruent) were balanced for semantic domains (childcare, jobs, hobbies, housework, clothes, physical strength, and hairstyle).

For ERP averaging, EEG epochs were synchronized with the onset of the terminal words. The latter were balanced across categories in length and frequency of use, as determined on the basis of the CoLFIS database (Bertinetto et al., 2006). Terminal words were also balanced for grammatical category (# of proper names, adjectives, verbs, nouns, professions, and adjectives used as nouns) and for concreteness and imagery value. Sentences including female and male characters were also matched for all the above dimensions. To determine whether the sentences actually represented (or violated) stereotypes for university students living in the Milan metropolitan area, the stimuli underwent validation, as described in Proverbio et al. (2017). Two hundred fifty-two

phrases were randomly mixed and presented in a written questionnaire to a group of 20 university students (10 men and 10 women) ranging in age between 18 and 35 years old. All participants were Italian citizens and heterosexual. They were asked to rate, by means of a 3-point Likert scale, how they reacted to reading the terminal word of the phrase (0 = Actually, I was a bit surprised, 1 = I do not know, and 2 = I kind of saw that coming). On the basis of the validation, a corpus of 120 incongruent phrases (violating stereotypes) and 120 congruent phrases (supporting gender stereotypes) were obtained.

Thirty-two other sentences (sharing the same linguistic structure and characteristics as the previous ones) were created with an animal as the terminal word (e.g., rabbit, woodpecker, horse, kangaroo). Some examples are provided in Table 1. The task consisted of responding to animal words as accurately and quickly as possible. ERPs to animal sentences were not processed.

All sentences were presented randomly mixed in 8 different experimental runs. Sentences flashed for 1 sec and were arranged in two or three short rows centered circularly around the fixation point. The terminal words followed after an ISI of 700 ms and were typed in uppercase. Their size was $5.89\text{ cm} \times 1.1\text{ cm}$, which was $10^{\circ}18' \times 1^{\circ}54'$ of the visual angle (minimum length = 1.8 cm, maximum length = 12.2 cm). Their duration was 1 sec, and they were followed by an ITI of 1.2 sec. The text was printed in yellow on a black background. Terminal words were equiluminant across experimental categories as determined by means of a Minolta CS-100 luminance meter. The mean luminance values of the terminal words in the congruent (3.78 fL, SE = 0.04) vs. incongruent (3.81 fL, SE = 0.04) classes were subjected to an ANOVA which showed that they did not differ statistically [$F(1, 112) = 0.24$, $p = 0.62$].

2.3. Procedure

Participants sat comfortably in a faradized and acoustically shielded cubicle in front of a PC monitor placed 100 cm from their eyes. The PC was located outside the cubicle and was visible through a mirror. Participants were asked to fixate on the center of the screen where a red dot served as a fixation point. They were instructed to sit relaxed but still while avoiding any head or body movements or ocular saccades. The task consisted of responding as quickly and accurately as possible to the terminal word when it represented an animal by pressing a key with the index finger of the right or left hand. The response hand was alternated across trials and announced at the beginning of each trial. The run order and response hand order were randomized across subjects. A brief training using novel sentences preceded the beginning of the actual EEG recordings. Each experimental run lasted 2 min and 40 s and was followed by a 30-second pause. A longer pause was allowed at a point about halfway through the recording time. Each experimental sequence started with the presentation of 3 warning signals that lasted 700 ms ("Ready, Set, Go!") and ended with "thank you" on the screen. Both the warnings and thanks were typed in uppercase characters. The whole experimental session lasted about 1 h.

The task was implicit in that the potential congruence or incongruence with gender career stereotypes was not made explicit or suggested to participants, who were focused on looking for an animal terminal word. Behavioral data for targets were recorded.

2.4. EEG recording and analysis

EEG signals were continuously recorded by using an *EEProbe* system (*ANT Software*, Enschede, The Netherlands) from 128 scalp sites located according to the 10–5 International System at a sampling rate of 512 Hz. Vertical (vEOG) and horizontal (hEOG) eye movements were also recorded. Linked mastoids served as the reference lead. The EEG and EOG were filtered with a half-amplitude bandpass of 0.016–70 Hz.

Electrode impedance was maintained below 5 KOhm. EEG epochs were synchronized with the onset of the stimulus presentation. Computerized artifact rejection was performed prior to averaging. The artifact rejection criterion was a peak-to-peak amplitude exceeding 50 μV . This procedure resulted in a rejection rate of approximately 5%. Event-related potentials (ERPs) from 100 ms before to 1000 ms after stimulus onset were averaged off-line. ERP components were identified and measured where they reached their maximum amplitude with respect to the average baseline voltage. The mean area amplitude of the N400 response was recorded from anterior-frontal (AF3, AF4, AF7, AF8), inferior-frontal (F7, F8) and fronto-central sites (FFC5h, FFC6h) in the 250–400-ms temporal window. The mean area amplitude of the P600 response was recorded at P1/P2 and PPO1/PPO2 sites in the 600–800-ms temporal window. Tukey's test was used for post hoc comparisons between means. Partial eta squared values were provided to estimate effect sizes.

For each ERP component, the mean amplitude values were subjected to repeated-measures ANOVAs whose factors of variability were 1 between-groups: sex of participants (males, females), and 4 within-groups: congruence to stereotype (congruent, incongruent), gender of character (male, female), electrode (depending on the component of interest), and hemisphere (left, right). Response times were analyzed by means of a repeated-measures ANOVA whose factors of variability included the gender of participants (male, female) and hand (left, right). Low-resolution electromagnetic tomography (LORETA; Pascual-Marqui, Michel, & Lehmann, 1994) was performed on the ERP waveforms relative to the N400 potential using *ASA4 Software*. LORETA is a discrete linear solution to the inverse problem, which corresponds to the 3D distribution of neural electrical activity that maximizes similarities (that is, maximizes synchronization) in terms of orientation and strength between neighboring neural populations (represented by adjacent voxels). Here, an improved version called the standardized weighted low-resolution brain electromagnetic tomography (i.e., swLORETA; Palmero-Soler, Dolan, Hadamschek, & Tass, 2007) was used. The data were automatically re-referenced to the average reference as part of the LORETA analysis.

3. Results

3.1. Behavioral data

No statistical significant differences were found. On average, RT were 665 ms (SE = 21.9) for men and 618 ms (SE = 19.87) for women. Left-hand responses were approximately 639 ms (SE = 24.6) and right-hand responses, 645.2 ms (SE = 19.2).

3.2. Electrophysiological results

Fig. 1 shows grand-average ERP data recorded in response to congruent and incongruent stimuli as a function of the participants' sex. Some sex-related differences can be observed, such as earlier and larger P300 responses (possibly correlated with RTs) in women. For the experimental manipulation, as can be appreciated, only in men it was found a response to stereotype violations in the form of an enhanced N400 and P600 response to incongruent stimuli.

3.2.1. N400 response

The ANOVA carried out on the N400 mean area values measured between 250 and 400 ms at anterior-frontal, inferior-frontal and fronto-central (AF3, AF4, AF7, AF8, F7, F8, FFC5h, FFC6h) sites showed the significance of the electrode factor [$F(3,93) = 5.6674$, $p < 0.01$; $\eta_p^2 = 0.154$]. Relative post hoc comparisons indicated greater amplitudes of N400 at F7/F8 sites (1.10 μV , SE = 0.47) compared to other sites (FFC5h/FFC6h = 1.25 μV , SE = 0.56; AF7/AF8 = 1.59 μV ; SE = 0.5;

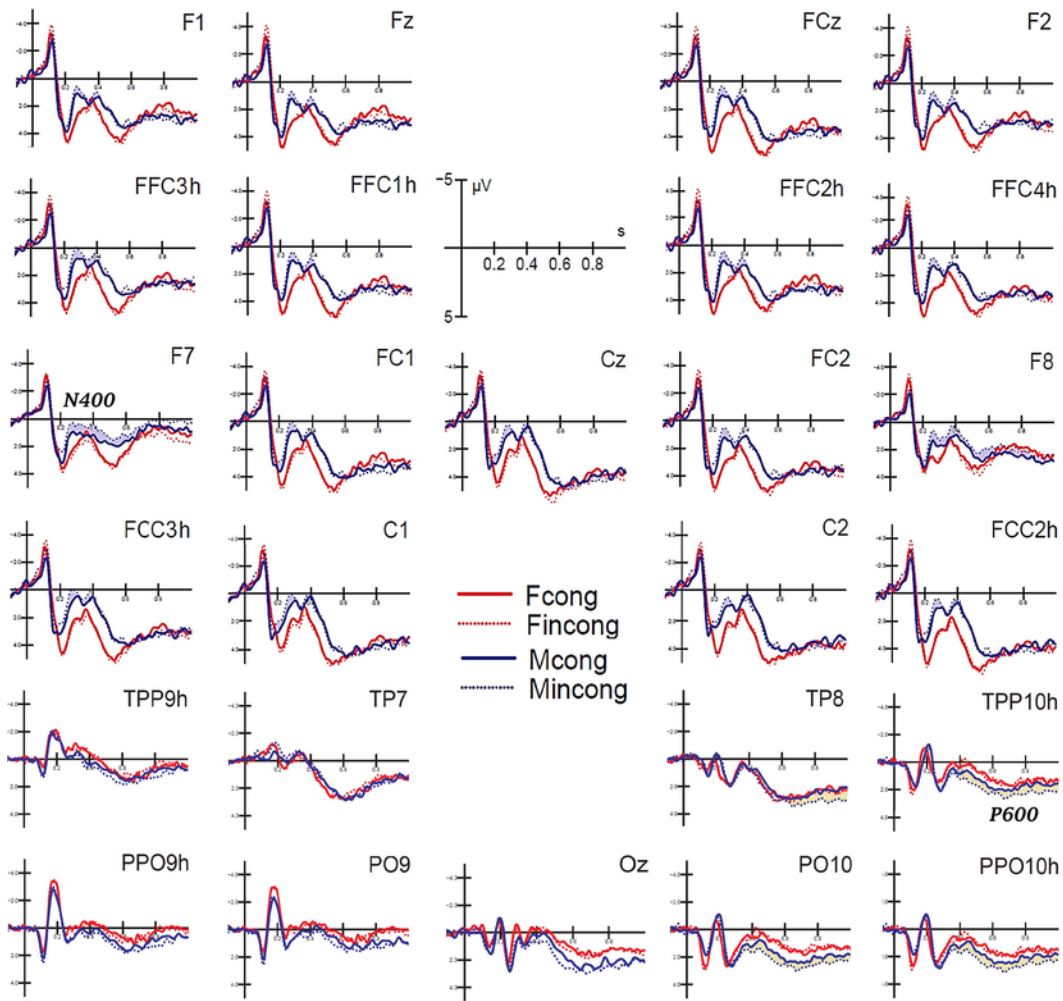


Fig. 1. Grand-average ERPs recorded at left and right frontal, central and posterior sites, in women and men, as a function of stimulus congruence.

AF3/AF4 = 1.70 μV; SE = 0.56). A significant interaction between group x congruence [$F(1,31) = 6.2629, p < 0.018; \eta_p^2 = 0.17$] was also found. Post hoc comparisons showed that only in men, the N400 was larger in response to incongruent (0.36 μV, SE = 0.77) than congruent (1 μV, SE = 0.74) sentences ($p < 0.01$), but this was not seen in women (Incongruent = 2.18 μV, SE = 0.75; Congruent = 2.10; SE = 0.72). Therefore a LORETA source reconstruction was applied to the incongruent minus congruent difference (within the N400 latency range) only in men.

The additional interaction between congruence x character gender [$F(1, 31) = 5.06, p < 0.03; \eta_p^2 = 0.16$] showed a significant effect of congruence only for male characters (prejudice violation), with larger N400 ($p < 0.01$) responses to incongruent (1.02 μV, SE = 0.55) than congruent (1.67 μV, SE = 0.54) stimuli when a man was the depicted character and not when the statements concerned a woman (incongruent = 1.52 μV, SE = 0.55; congruent = 1.43 μV, SE = 0.51). Fig. 2 shows the ERPs recorded in women and men at inferior frontal sites in response to both types of stimuli (congruent and incongruent) as a function of the character gender (male vs. female character). As can be appreciated, the violation of stereotype relative to male attitude or occupations generated a larger N400 response. This sex difference is also highlighted in Fig. 3, showing the topographical distribution of surface voltages recorded between 250 and 400 ms (N400 latency range) to incongruent stimuli as a function of the sex of the participants (male or female) or of the gender of the character within the sentence (in men).

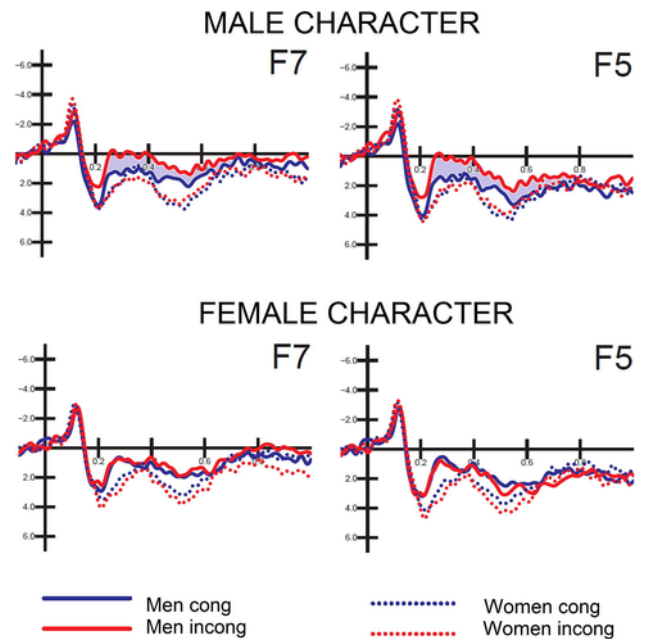


Fig. 2. Grand-average ERPs recorded at left and right inferior frontal sites, in women and men, as a function of stimulus congruence and characters' gender.

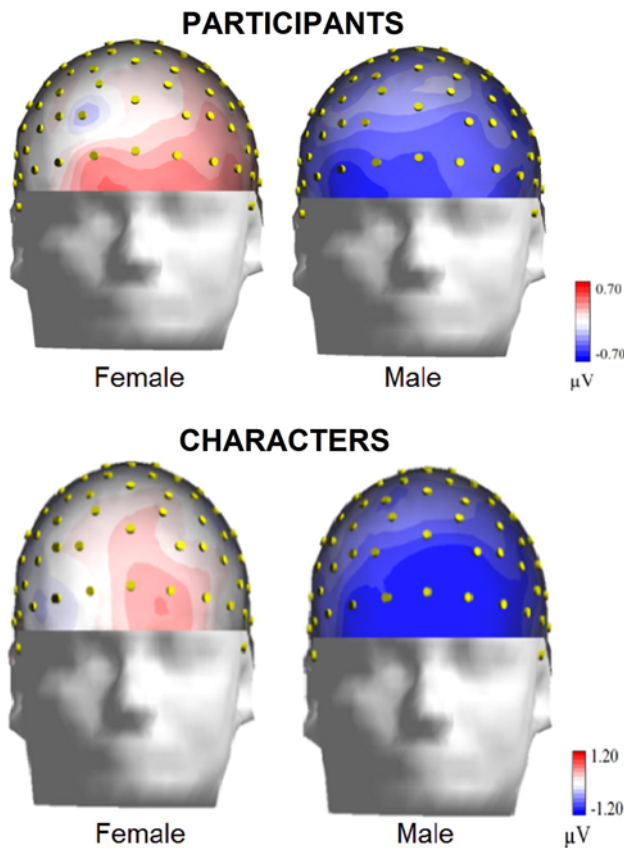


Fig. 3. Isocolour topographical maps (front view) of surface voltage measured in the 250–400 ms temporal window (N400 latency range) to incongruent stimuli as a function of participants' sex (top) or characters' gender (bottom), in male participants.

To identify the neural generators subtending the N400 surface activity, a difference wave was obtained by subtracting ERPs in response to congruent stimuli from those in response to incongruent stimuli (in male participants), and a *swLORETA* (*standardized weighted Low Resolution Electromagnetic Tomography*, Pascual-Marqui et al., 1994) was applied to the differential activity recorded between 250 and 400 ms. Table 2 shows a list of active electro-magnetic dipoles, while Fig. 4 shows the results of the source reconstruction. The most active areas during the processing of stereotype violations were the right medial temporal gyrus (BA21) and the right medial frontal gyrus (BA10).

3.2.2. P600 response

The ANOVA performed on the amplitude of the P600 responses recorded at P1/P2 and PPO1/PPO2 sites between 600 and 800 ms

Table 2

Talairach coordinates corresponding to the intracortical generators explaining the different surface voltage incongruent – congruent recorded during the 250–400 ms time window. Magnitude in nAm; T-x, T-y, T-z = Talairach coordinates (in mm); Hem. = hemisphere; BA = Brodmann area.

N400 (250–400 ms) MEN								
Magn.	T-x (mm)	T-y (mm)	T-z (mm)	Hem.	Lobe	Gyrus	BA	General function
6.29	60.6	2.8	-5.9	R	T	Middle temporal	21	Person information, Gender stereotype (Quadflieg et al., 2009)
4.18	-68.5	-25.5	-8.1	L	T	Middle temporal	21	
5.70	40.9	44.4	15	R	F	Middle frontal	10	Prejudice: Proverbio et al. (2016) Mitchell et al., (2006), Mahy et al., (2014)
4.12	1.5	38.2	-17.9	R	F	Medial frontal	11	
5.66	-38.5	21.4	40	L	F	Precentral	9	
5.19	11.3	-91.3	29.7	R	O	Cuneus	19	
4.38	60.6	-49.7	24.2	R	T	Supramarginal	40	Temporo/parietal junction (Saxe, 2010) TOM
4.15	1.5	40.5	50.7	R	F	Superior frontal	8	TOM
4.00	-48.5	-0.6	-28.2	L	T	Inferior temporal	20	

showed the significance of the gender of the character ($[F(1, 31) = 7.7189, p < 0.009; \eta_p^2 = 0.25]$, with greater P600 responses to sentences containing female characters ($3.86 \mu\text{V}$, $\text{SE} = 0.53$) than sentences containing male characters ($3.43 \mu\text{V}$, $\text{SE} = 0.48$). The further interaction between character gender x sex of participants [$F(1, 31) = 4.7039, p < 0.038; \eta_p^2 = 0.15$], and relative post hoc comparisons showed that only in men, the P600 varied as a function of the gender of the character, being larger ($p < 0.008$) in response to female ($4.24 \mu\text{V}$, $\text{SE} = 0.75$) than male characters ($3.44 \mu\text{V}$, $\text{SE} = 0.69$), while no difference was observed in women (female character = $3.51 \mu\text{V}$, $\text{SE} = 0.73$; male character = $3.41 \mu\text{V}$, 0.67). This effect is clearly visible in the waveforms shown in Fig. 5.

The interaction between Congruence x electrode was significant [$F(1, 31) = 7.3448, p < 0.01; \eta_p^2 = 0.24$], and relative post hoc comparisons showed that the P600 was larger in response to incongruent sentences, especially at PPO1/PPO2 sites (Congruent = 3.5 , $\text{SE} = 0.53$; Incongruent = 3.75 , $\text{SE} = 0.49$; $p < 0.0001$).

The ANOVA also showed a significance interaction between Congruence x character gender x electrode [$F(1, 31) = 4.4032, p < 0.044; \eta_p^2 = 0.111$]. Post hoc comparisons for the multiple-factor interaction revealed that the P600 was larger in response to incongruent than congruent stimuli at both hemisphere and electrode sites when the character was a woman, while the effect was smaller (not significant at the PPO1 site) when the character was a male.

4. Discussion

Here, the timing and the neural correlates involved in the representation of occupational gender biases were investigated by addressing two questions: first, if the biases varied as a function of participant's sex; and second, if there was a difference based on the gender of the character depicted in the phrases. An implicit paradigm was chosen to trigger the automatic activation of any mental function involved in the processing of gender stereotypes. Consistent with a previous study carried out on a smaller sample of participants (Proverbio et al., 2017) sentences violating gender stereotypes elicited a larger anterior N400 response, but the analysis of the sex factor showed that this was true only in men who also showed a P600 modulation as a function of sentence incongruence. It is worth mentioning that, compared to the present one, the effect of stereotype on the N400 appeared smaller in Proverbio et al.'s (2017) study, possibly because there was a lack of modulation in the female sample.

An asymmetry in gender bias, with a stronger prejudicial attitude in men, it is not unknown in the literature. For example, an article summarizing data from more than 2.5 million completed IATs and self-reports (Nosek & Smyth, 2007) showed that men are more prejudicial in terms of theories postulating that men have more social dominance (e.g., Sidanius & Pratto, 1999), attitudes towards gay vs. heterosexual

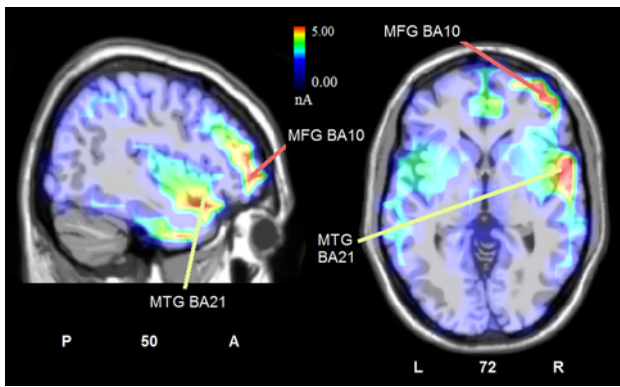


Fig. 4. Coronal and axial brain sections showing the location and strength of electromagnetic dipoles explaining the surface difference-voltage obtained by subtracting ERPs to congruent from ERPs to incongruent stimuli in the 250–400 ms latency range, corresponding to the peak of N400. L = left, R = Right, A = anterior, P = posterior. MTG = Medial temporal gyrus; MFG = medial frontal gyrus.

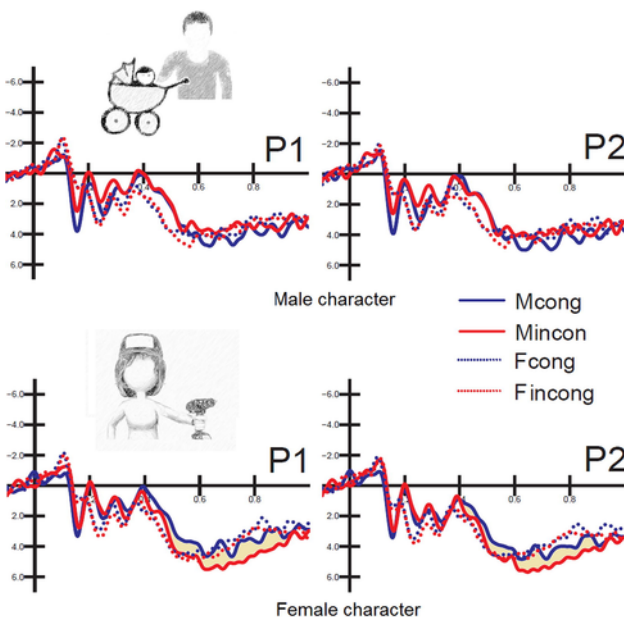


Fig. 5. Grand-average ERPs recorded at left and right mesial parietal sites, in women and men, as a function of stimulus congruence and characters' gender.

people (e.g., Negy & Eisenman, 2005), and attitudes toward black vs. white people (e.g., Qualls, Cox, & Schehr, 1992). For neuroscientific data, only in men was it shown that hostile sexism correlated with the activation of regions associated with mental state attributions (such as the medial prefrontal cortex, posterior cingulate, temporal poles) in the Cikara et al. (2011) fMRI study.

Our data suggest that there might be a gender difference in stereotyping, with men being more prejudicial than woman, beginning with the former being quicker to react to stereotypes involving a male character (at the N400 level) and, later on, a female character (at the P600 level). It can be speculated that the difference in latency between the two violation detections (more than 200 ms) in the male brain might be due to the degree of self-identification with male and female characters that characterizes own-sex individuals. Indeed, Proverbio, Vanutelli, & Viganò (2017) found that emotional memory improved the ability to recall own-sex faces but no other-sex faces, showing a clear self-referential effect. Previous research on empathic resonance or mimicry, i.e., an intersubjective induction process by which the observation of an emotion elicits the activation of an analogous representation in the observer (Decety & Meyer, 2008), showed that perceived

similarities (such as the same sex) can facilitate emotional mirroring and self-identification. This can influence empathic responding through a tendency to identify more closely with others who appear to be more similar in features (Gruen & Mendelsohn, 1986) or appearance (Bufalari, Porciello, Sperduti, & Minio-Paluello, 2015).

The lack of a N400 effect relative to women is somewhat similar to what was found by Siyanova-Chanturia et al. (2012), who reported larger N400 responses to masculine pronouns preceded by incongruent stereotypical primes (e.g., “he” preceded by “(female) teacher”) but, interestingly, not to feminine pronouns preceded by incongruent stereotypical primes (e.g., “she” preceded by driver), which suggests a lack of stereotypes for female professions.

As a well-known response, the N400 is thought to reflect semantic and conceptual integration processes, enhanced by the presence of an incongruity between incoming information and available knowledge (Kutas & Hillyard, 1984; Hagoort, Hald, Bastiaansen, & Petersson, 2004).

The present results are consistent with previous ERP investigations on sexual stereotypes carried out with explicit paradigms (White et al., 2009; Osterhout et al., 1997). The analysis of the intracranial generators that explained the differences in voltage obtained by subtracting ERPs to congruent stimuli from those to incongruent stimuli (in male participants) performed via a swLORETA in the N400 temporal window (250–400 ms) showed a complex neural circuit devoted to stereotype representations, listed in Table 1. Some of the regions (especially BA40, inferior parietal) fits with functional anatomic models (Lau et al., 2008) predicting inferior frontal, anterior temporal or inferior parietal generators for N40 effects in cases N400 reflected semantic integration difficulty. However our source reconstruction did not reflect N400 effect per se, but the brain areas challenged by the prejudice violation, therefore hardwiring social cognition, and particularly person knowledge. Indeed, most of these regions are also involved in a more general processing of social conventions, regularities and prejudices, not just gender stereotypes. One of the most active area was the right middle frontal gyrus, which the literature has described as being a main neural basis for stereotype representation (e.g., Fourie et al., 2014; Knutson et al., 2007; Proverbio et al., 2016; Mitchell et al., 2006; Mahy et al., 2014). This finding strongly agrees with previous fMRI data showing the role of the medial frontal cortex in representing social information that references others, particularly outgroup stereotyping (Mitchell et al., 2006). Also involved in our study was the medial temporal gyrus, bilaterally, but with a right hemispheric asymmetry. This region has been shown to be involved in the representation of person information (e.g., Freeman et al., 2010; Ibañez & Manes, 2012); most notably, an fMRI study by Quadflieg et al. (2009) showed how the representation of gender bias was linked to the activity of the medial temporal gyrus (BA21), the superior frontal gyrus and the STG. Consistently, both neuropsychological (Semenza, 2009) and electrophysiological evidence support the role of the medial temporal gyrus in representing information concerning persons and proper names (Proverbio, Lilli, Semenza, & Zani, 2001, 2009). Last but not least, the right supramarginal gyrus (BA40), i.e., the temporo-parietal junction (TPJ), contributed to generation of the N400; this area has been shown to support theory of mind (TOM) processes, especially self-reflection, according to Saxe and coworkers (e.g., 2006, 2010).

The fact that the stereotype violations elicited enhanced grammar-related ERP components such as the N400 and P600 might suggest that gender stereotypes are so deeply rooted in our memory that their violation is treated such as a linguistic error. The electrophysiological data gathered represent an important contribution for understanding how gender stereotypes are differentially represented in men and women. The findings agree with previous data in the literature but for the first time highlight the notion that stereotypes are massively represented in the male brain, and sparsely observed in the female brain. One possible

interpretation of this finding relies on the asymmetrical nature of occupational stereotypes, mostly rooted in the principle that females could not perform male professions because of a lack of strength or powerful attitude. Therefore, it is conceivable that women participants might disagree more easily with the stereotype being themselves women (thus knowing that directly). This hypothesis is supported by the nature of the ERP waves that reflected the stereotype violations in the male brain, which showed an N400 response for own-sex characters and a P600 response for other-sex characters. While the first is generated automatically, reflecting unintentional access to implicit knowledge, the second reflects conscious higher-order integration processes (Martin-Loeches et al., 2006; Friederici, 2002). In this regard, Rohaut and Naccache (2017) have clearly shown a dissociation between unconscious and conscious cognitive processing as disentangled by the N400 and P600 responses, but this interpretation certainly needs further research. Interestingly other studies showed a similar P600 modulation for stereotype violations involving female characters, in an implicit task in which subjects' attention was directed to control questions that had to be answered with "yes" or "no" (Irmen, Holt, & Weisbrod, 2010). In that study, participants read general statements about occupational groups denoted by a role name (e.g., florists, pilots) followed by person nouns with masculine, feminine or neutral gender (e.g., men/women/people) that could either semantically match, mismatch or be neutral to the role name's gender typicality. The responses to feminine nouns were systematically more positive at P600 latency range when the noun was incongruent to the antecedent's gender typicality than when it was congruent. On the other hand, between 300 and 400 ms (N400) responses to all anaphors were more negative after typically male than after typically female antecedents, which resembles the present pattern of data.

5. Conclusions

The aim of this study was to investigate the neural and temporal correlates of the mechanisms underlying gender-biased presentations. Three sets of evidences were found. First, a greater response to items that violated occupational stereotypes was demonstrated in the male population, as suggested by both N400 and P600 data.

Second, the first stereotype-related ERP modulation was found with regard to male characters in the 250–400-ms time window (N400), while the response to violations was observed for female characters later, in the 600–800-ms time window (P600), in the male brain only.

Finally, according to the swLORETA inverse solution analysis, the main neural areas involved in stereotype representations were the right middle temporal and frontal gyri, as well as the TPJ.

In conclusion, our data suggest that there might be a gender difference in stereotyping, with men being more prejudicial than woman as for occupational stereotypes.

One possible limit of the present investigation is that it is relative to the Italian population, and there might be cultural differences across nations and age ranges, but this is true for any other study in the field.

6. Uncited references

Greenwald et al. (2003), Oakhill and Garnham (2005).

Acknowledgements

We are very grateful to all participants and to Andrea Orlandi for his technical help. The study was supported by the 2016-ATE-0058 15296 grant from the University of Milano-Bicocca to AMP.

Conflict of interest statement

The authors declare no competing financial interests.

Statement of significance to the neurobiology of language

The present findings provide strong empirical data that enhance our understanding of how stereotypes (gender social attributes) are represented in the brain. Linguistic ERPs and the observation of N400 and P600 responses revealed that stereotypes were present even when IAT implicit measures failed to show any stereotypical bias.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.bandl.2018.08.006>.

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