Chapter 12
EEG and ERPs in the Study of Language and Social Knowledge

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Abstract Event-related potentials (ERPs) represent the ideal methodological approach for investigating the time course of language reading and comprehension processes. In this chapter, various ERP components reflecting orthographic, phonological, semantic, and syntactic processing of written and auditory language are examined. Furthermore, data are shown of how ERPs can reflect stereotypes, prejudices and world knowledge, including people's social traits and attributes. In particular, several recent neuroimaging and electrophysiological studies are presented investigating the neural underpinnings of ethnic and sex biases (both in male and female individuals).

Keywords EEG and ERPs · Electrophysiology of language · Orthographic analysis · Stereotypes and prejudices

Introduction: EEG and ERP Signals of the Brain

The electromagnetic activity of the brain essentially translates into (i) electric fields/potentials and oscillatory magnetic fields, which constitute the electroencephalogram and the magnetoencephalogram, and (ii) variations of the electric and magnetic fields caused by nerve impulses induced by external or mental stimuli/events, which result in event-related potentials (ERPs) and event-related fields (ERF), respectively (for details, see the handbook by Zani and Proverbio (2003)).

The rhythmic EEG oscillations originate in the cortex, but their pacemaker is subcortical and is located in the thalamic nuclei. The electrical potentials of the brain can be detected on the scalp surface through the application of metallic sensors named electrodes, while the magnetic fields are measured by sensitive MEG gradiometers. The potential changes recorded at the scalp derive from the sum of both excitatory and inhibitory postsynaptic potentials of neurons whose apical

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dendrites are oriented perpendicular to the cortical surface (e.g., pyramidal cells or hyper-columns of the visual cortex).

In general, the typical EEG rhythms of waking state in the adult person have a fairly rapid oscillation frequency, which varies between 8 and 25 Hz (alpha and beta rhythms), while in the sleepiness and sleep states, the EEG rhythm progressively decreases reaching 1 Hz of frequency in the *slow-wave sleep* (SWS), known as delta rhythm.

ERPs consist in electric potential oscillations that occur in the brain of an individual in response to a stimulus administered in one of the different sensory modalities ("exogenous" potentials) or in relation to higher cognitive functions such as attention, motivation, emotions, and expectations ("endogenous" potentials; see Zani and Proverbio (2003)). ERPs, in whatever modality they are recorded (visual, acoustic, or somatosensory), appear as waveforms characterized by a series of positive and negative deflections whose polarity is marked by P and N letters of the alphabet and accompanied by increasing numbers indicating the temporal progression of appearance (latency in ms). Each of the ERP components can be considered as the manifestation of neural activity associated with specific stages of information transmission and processing within the brain.

Electrophysiology of Language

Figure 12.1 shows the time course of linguistic information processing based on data derived from the event-related potentials (ERPs) recording technique. ERPs represent a unique tool in the study and analysis of different stages of linguistic information processing, since they are characterized, on the one hand, by the lack of invasiveness typical of electroencephalographic (EEG) recording and, on the other hand, by an optimal temporal resolution (which may be <1 ms).

The temporal latency of a given deflection or peak (positive or negative voltage shift), visible in the waveform of the ERPs, therefore represents the occurrence of brain processing activity time-locked to a cognitive event (Zani & Proverbio, 2003). For example, the occurrence of a voltage deflection at about 70–80 ms at the scalp sites over the primary visual cortex reflects the arrival of incoming information to the visual cortex and the corresponding activations of neural populations involved in visual information sensory processing. In the same way, the occurrence of a large negative deflection at about 400 ms in response to semantically incomprehensible stimuli reflects semantic meaning analysis processes for a given word. ERPs recording in the study of language comprehension mechanisms were applied for the first time at the end of the 1970s by researchers working in the field of what has since become known as cognitive neuroscience. In 1968, Sutton discovered that the human brain elicited a large positive response to those stimuli that were selectively attended at a particular moment (identical in terms of physical characteristics to those disregarded). This implied that it was possible to study mental processes by observing their neurophysiological manifestations.

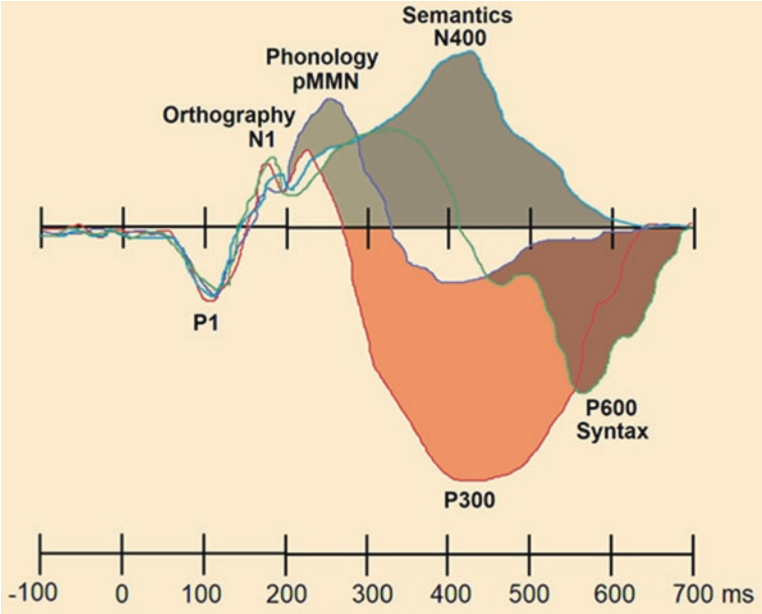

Fig. 12.1 Time course of cerebral activation during the processing of linguistic material as reflected by the latency of occurrence of various ERP components. Prelinguistic stimulus sensory processing occurs (P1 component) at about 100 ms poststimulus; orthographic analysis of written words (posterior N1 component) at 150–200 ms; phonologic/phonetic analysis at 200–300 ms, as revealed by phonological mismatch negativity (temporal and anterior pMMN) seen in response to phonologic incongruities (both visual and auditory); and a large centroparietal negativity at about 400 ms (N400), recorded in response to semantic incongruities and indexing lexical access mechanisms. The comprehension of meaningful sentences reaches consciousness between 300 and 500 ms (P300 component); finally, a second-order syntactic analysis is indexed by the appearance of a late positive deflection (P600) at about 600 ms poststimulus latency

To study language, Marta Kutas developed two different experimental paradigms. In the first, *rapid serial visual presentation* (RSVP), single words are consecutively presented in the center of a screen (Kutas, 1987) in order to simulate the process involved in the spontaneous reading of a sentence and to monitor the time course of semantic and syntactic comprehension processes while avoiding the horizontal ocular movements that normally go along with text reading. The second, quite popular, paradigm is called the *final word paradigm* (Kutas & Hillyard, 1980), and it is based on the presentation of a semantic or syntactic context of variable nature and complexity that is followed by a given terminal and critical word, to which brain potential is time-locked and which can be more or less congruent with the context or respectful of various word concatenation rules of a given language.

Orthographic Analysis

ERPs represent a quite useful tool for investigating reading mechanisms in that they provide several indices of what is occurring, millisecond by millisecond, in the brain, starting from stimulus onset: from the analysis of sensory visual characteristics (e.g., curved or straight lines, angles, circles, etc.) to orthographic analysis (letter recognition), to the analysis of complex patterns (words), and to their orthographic aspect (which, for example, greatly differs for the German, English, or Finnish languages) and their meaning.

Numerous ERPs and magnetoencephalography (MEG) studies (e.g., Bentin et al., 1999; Helenius et al., 1999; Proverbio et al., 2002, 2004) have provided clear evidence that the occipitotemporal N170 response (with a mean latency of 150–200 ms) specifically reflects stimulus orthographic analysis (Fig. 12.2). For example, Helenius et al. (1999) recorded MEG signals in dyslexic and control adult individuals engaged in the silent reading of words (either clearly visible or degraded with Gaussian noise) vs. symbolic strings. The results showed that while the first sensory response (100 ms of latency) associated with sensory processing did not differ in amplitude across groups, N170 component sensitive to orthographic factors, usually focused on the left inferior occipitotemporal cortex (i.e., over the *visual word form area*), was not lateralized and was considerably reduced in amplitude in dyslexic individuals.

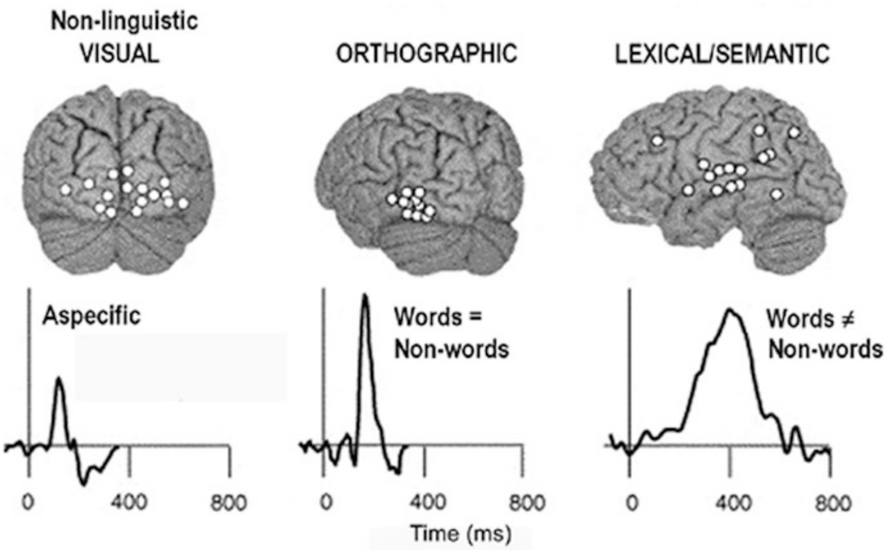

Fig. 12.2 Visual perception of words activates the left occipitotemporal cortex at about 170 ms poststimulus. This response is much larger to words than non-orthographic strings. Lexical processing reaches its peak at about 400 ms

In a recent study (Proverbio et al., 2007), we compared ERPs evoked by words and pseudo-words in their canonical orientation with those elicited by words and pseudo-words flipped horizontally. The aim was to assess whether the inversion of words deprived them of their linguistic properties, thus making them nonlinguistic stimuli. About 1300 Italian words and legal pseudo-words were presented to 18 right-handed Italian students engaged in a letter detection task. In order to identify the temporal latency of alphabetic letter processing and recognition, ERPs evoked by target and nontarget stimuli were compared. ERPs showed an early effect of word orientation at ~150 ms, with larger N1 amplitudes to rotated than to standard words. *Low-resolution brain electromagnetic tomography* (LORETA) localized this increase in N1 to flipped horizontally words primarily in the extrastriate cortex of the right occipital lobe (BA 18), which may indicate an effect of stimulus novelty. N1 was greater to target than to nontarget letters at left lateral occipital sites, thus reflecting the first stage of orthographic processing. LORETA revealed a strong focus of activation for this effect in the left fusiform gyrus (BA 37), which is consistent with the so-called visual word form area, corresponding to the left inferior occipitotemporal cortex.

Lexical Analysis

After accessing phonologic properties of words during reading, the brain is able to extract their semantic/lexical properties at about 300–400 ms of poststimulus latency (Federmeier et al., 2002), as indexed by N400 component. The amplitude of this component is generally greater over the right centroparietal areas at the scalp, but this does not correspond to the inner anatomical localization of semantic specialized areas. Intracranial recording studies have shown that N400 generators lie in the left temporal cortex, near the collateral sulcus and the anterior fusiform gyrus. In her original paper, Kutas (1980) used the *final word paradigm* to investigate the functional properties of N400 response and distinguished between the concepts of "semantic incongruence" and "subjective expectation" of sentence termination. Thus, Kutas postulated the existence of a *contextual constraint* generated by the overall semantic meaning of a sentence, which in itself would not be sufficient to explain the increased N400 effects. In order to illustrate this, let's take, for example, the following sentence: "She put sugar and lemon in her." The overall sentence meaning binds the terminal word to be a sort of drink and especially TEA. In the sentence "She put sugar and lemon in her BOOT," the final word elicits an N400 of noticeable magnitude because the contextual constraint has been macroscopically violated. However, in the sentence "She put sugar and lemon in her COFFEE," the final word still generates an N400 response but of lower amplitude as compared to the incongruent BOOT word. The negativity is generated because COFFE is semantically less related to sugar and lemon than the word TEA, but N400 to COFFEE is smaller than N400 to BOOT because the former belongs to the same semantic domain of TEA (drinks). This finding reflects the effect of the *contextual constraint*.

However, the contextual constraint alone cannot predict the whole process of semantic comprehension in reading.

Kutas also introduced the *cloze (closure) probability* factor, meant as the probability that a group of speakers might complete a certain sentence with a specific final word; this effect does not completely correspond to the contextual constraint, because it refers to subjective expectancy and not to semantic relatedness. For instance, in the sentence "He sent a letter without a STAMP," the final word is highly predictable, for many speakers, because it has a high cloze probability. Conversely, the final word of "There was anything wrong with the FREEZER" has a low cloze probability since, from a statistical point of view, not many speakers would complete this sentence in the same way. Therefore, while being not semantically incongruent with the context (therefore, not violating the semantic constraint), FREEZER would still elicit an N400 much larger than the word STAMP from the previous sentence, because it is completely unexpected and unpredictable for the speakers. In this vein, N400 paradigm might be advantageously used to investigate conceptual representation of social attributes in different groups of speakers, including stereotypes and prejudices (race-based, gender-based, etc.).

The N400 is a hallmark of the semantic integration mechanisms, and, as such, it is sensitive to the difficulty with which the reader/listener integrates the incoming sensory input with the previous context, based on the individual expectations. Although the maximum response peak to incompatible, unexpected, or low cloze probability words is reached around 400 ms, earlier ERP responses have also been reported to be sensitive to some lexical properties of words, such as their frequency of use. King and Kutas (1998) described an anterior negative component the *lexical processing negativity* (LPN), with a latency of about 280–340 ms, which seems very sensitive to the frequency of word occurrence.

In an ERP investigation (Proverbio et al., 2004) in which words, pseudo-words, and letter strings were presented during a phonetic decision task, the earliest effect of a lexical discrimination between words and pseudo-words was observed at about 200 ms poststimulus (Fig. 12.3). It would seem, then, that neural mechanisms of access to the lexical features of linguistic stimuli activate in parallel with the extraction of their orthographic and phonologic properties. Some studies also demonstrated a sensitivity to lexical properties of short, familiar words at latencies even earlier than 150 ms (e.g., Assadollahi & Pulvermüller, 2003; Pulvermüller et al., 2001). Finally, Proverbio et al. (2008) have shown that orthographic N170 response, generated within the left fusiform gyrus, manifested a sensitivity to sub-lexical properties (word frequency of use), being of greater amplitude in response to high- than low-frequency words.

Pragmatic Analysis

Just as the P300 represents an index at the scalp of neural mechanisms of *contextual updating*, that is, the updating of personal knowledge as a consequence of comparing the ongoing stimulus input with the information retained in long-term memory

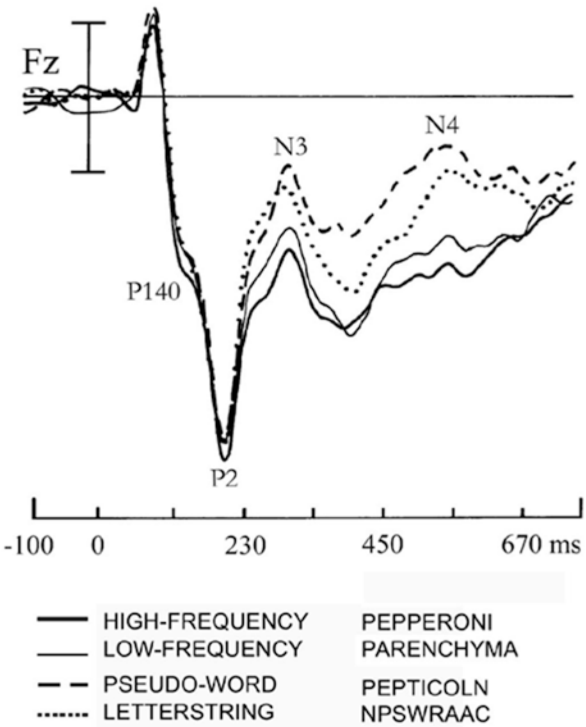

Fig. 12.3 ERP waveforms recorded in response to words, pseudo-words, and letter strings during a phonetic decision task (e.g., "Is phone/k/present in oranges?"). The first lexical effect was found at P2 level. (Adapted from Proverbio et al. (2004), with the permission of MIT Press)

(Donchin, 1987), conversely, an increased N400 represents a difficulty in integrating incoming inputs with previous knowledge, including world knowledge of pragmatic nature (scenarios, such as how to pay the bus ticket), and social knowledge (social conventions, cultural habits, rules about what is appropriate or not, etc.).

For example, let's first consider the classical case of a violation of the semantic constraint such as the one provided by the sentence "Jane told her brother that he was very...," followed by three possible terminal words:

A. FAST Congruent
B. SLOW Congruent
C. RAINY Incongruent

As extensively dealt with in the previous section, case C gives rise to N400 (depicted in Fig. 12.4, top) since "rainy-ness" is not a possible property of a person, which therefore makes it hard to integrate the meaning of the terminal word with the conceptual representation elicited by the aforementioned sentence. Since this incongruence is verifiable per se, independent of the context or the specific speakers, it is defined as a violation of the semantic constraint (which is to be distinguished by the cloze probability).

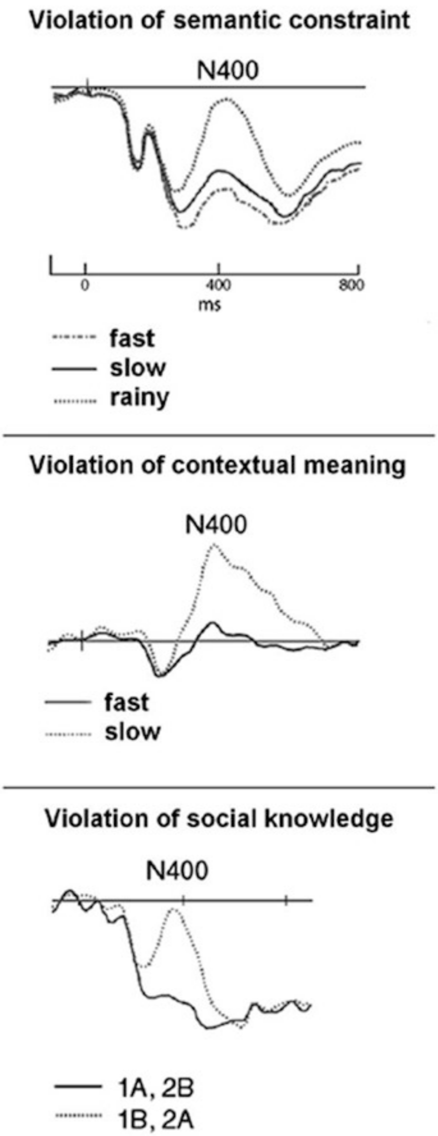

Fig. 12.4 ERPs recorded in response to terminal words completing a previous context (see the text for specific sentences) determining a violation of semantic constraint (case 1), contextual meaning (case 2), or pragmatic knowledge (case 3). Solid line, congruent word; dotted line, incongruent word. (Taken and adapted from studies of Hagoort and coauthors (Hagoorth et al., 2004; Van Berkum et al., 1999), with permission of authors)

However, Hagoorth and coworkers (e. g., Van Berkum et al., 1999) discovered that the N400 is also sensitive to violations of the sentence meaning mediated by the context or by social knowledge. Let's consider, for instance, the sentence "At 7:00 a.m., Jane's brother had already taken a shower and had dressed too," followed by "Jane told her brother that he was incredibly...," completed by the terminal words:

A. FAST Congruent
B. SLOW Incongruent

Case B would give rise to a large N400 (depicted in Fig. 12.4, middle) since the conceptual representation of a fast and early-rising brother induced by the previous context is in striking contrast with the way his sister defines him. The semantic incongruence can be extended to implicit or pragmatic knowledge, such as social knowledge. Let's take, for instance, the sentence "On Sunday, I usually go to the park with..." pronounced by the voice of (1) a child and (2) an adult man and followed by two possible terminal words:

A. MY DADDY
B. MY WIFE

Final words 1B and 2A would elicit a wide N400 deflection (Fig. 12.4, bottom) in the absence of any violation of the semantic constraint or of the contextual constraint, thus indexing a pure violation of pragmatic and/or social knowledge. Indeed the adult male voice would not predict a "daddy" final, so as the childish voice would not predict a "wife" final. These predictions are not based on semantics but on our social knowledge, according to which a child is not usually married and an adult male does not typically use a "sugary" language.

Another study by Hagoort et al. (2004) provided a very interesting parallelism between violation of the semantic constraint and violation of the world knowledge. A typical example of *world knowledge* could be the direction in which that doors open (almost always inward but outward in case of anti-panic doors), a knowledge that is implicitly learned by means of repeated experience with the external world. Hagoort comparatively presented three types of sentences:

A. Dutch trains are yellow and very crowded
B. Dutch trains are white and very crowded
C. Dutch trains are sour and very crowded

In their study sentences, B (i.e., a violation of the world knowledge) and C (i.e., a semantic violation) elicited N400s of similar amplitudes and topographic distributions in Dutch participants, although these violations were extremely different in type. Everyone knows that a train cannot be acidic (semantic knowledge). Similarly, a Dutch person who has traveled by subway or railway would definitely be aware of the fact that the trains of their town and country are not white.

The difficulty in integrating the incoming information provided by sentences B and C with previous knowledge would stimulate cognitive processes observable at about 400 ms after critical word onset, in the form of an enhanced N400 response.

ERP Indices of Stereotypes and Prejudices

The N400 has also been found to be affected by personal semantics (Coronel & Federmeier, 2016), that is, by violations relative to subjective knowledge (i.e., personal preferences such as likes and dislikes) across a wide range of topics (including foods, sport teams, music, films, etc.).

A few studies have used the N400 response to investigate the neural representation of stereotypes (Bartholow et al., 2001, 2003). Osterhout and coauthors (1997) showed participant sentences referring to stereotypically male or female occupations and pronouns that did or did not match the gender stereotypically implied by the job (e.g., “The beautician put herself through school” vs. “The beautician put himself through school”). They found increased N400 responses in association with the prejudice violation.

Recently, Proverbio and coauthors (2017) used ERPs to investigate the detection of a discrepancy between gender-based occupational stereotypes and written material presented to 15 Italian viewers in a completely implicit task. No awareness or judgment about stereotypes was involved, no decision had to be made on sentence acceptability or congruence, and no prime words related to gender were presented (which might reveal the matter of the investigation). EEG was recorded while participants were engaged in a task that consisted in quickly pressing a response key to animal words while ignoring the overall study’s purpose. Two hundred forty sentences that did or did not violate gender stereotypes were presented randomly mixed with 32 other sentences ending with an animal word. Final words violating gender stereotypes (such as “The notary is BREASTFEEDING” or “Here is the commissioner with HER HUSBAND”) elicited a greater anterior N400 response and left anterior negativity (LAN) than words conforming to the gender stereotype (e.g., “The chemist put on a nice TIE”) (see Fig. 12.5). LAN modulation suggests that gender stereotypes are processed automatically (as if they were morphosyntactic errors) and hints at how they are deeply rooted in our linguistic brain.

According to the inverse solution applied to incongruent minus congruent ERP difference waves recorded in the 350–450 time window, which corresponds to the N400 peak, the neural representation of gender-based stereotypes mostly involved the middle frontal gyrus (MFG), which is known to support the neural representation of stereotypes. The temporal/parietal junction (TPJ) supporting theory of mind (TOM) processes was also engaged, along with the superior and middle temporal gyri (STG and MTG) representing person information. The TPJ has been associated with the ability to attribute intentions and meanings to the behavior of others, which is part of TOM (Saxe, 2010; Young et al., 2010).

According to the neuroimaging literature, the medial frontal cortex (mdFC) represents social information that refers to others, particularly outgroup stereotyping and prejudice (Mitchell et al., 2006). In particular, sub-regions of the medial prefrontal cortex (mdPFC) would differentiate between thinking about the attributes and mental states of similar versus dissimilar others (Mahy et al., 2014). In a recent study on the neural bases of prejudice, it was found that the left cortical superior frontal gyrus (SFG, BA10) was particularly involved in representing negative prejudices related to others (Proverbio et al., 2016), which strongly fits with the current findings.

In that study, the neural bases and functional properties of social prejudices were investigated. During social interactions, we make inferences about people’s personal characteristics based on their appearance. These inferences form a potential prejudice that can positively or negatively bias our interaction with them. This

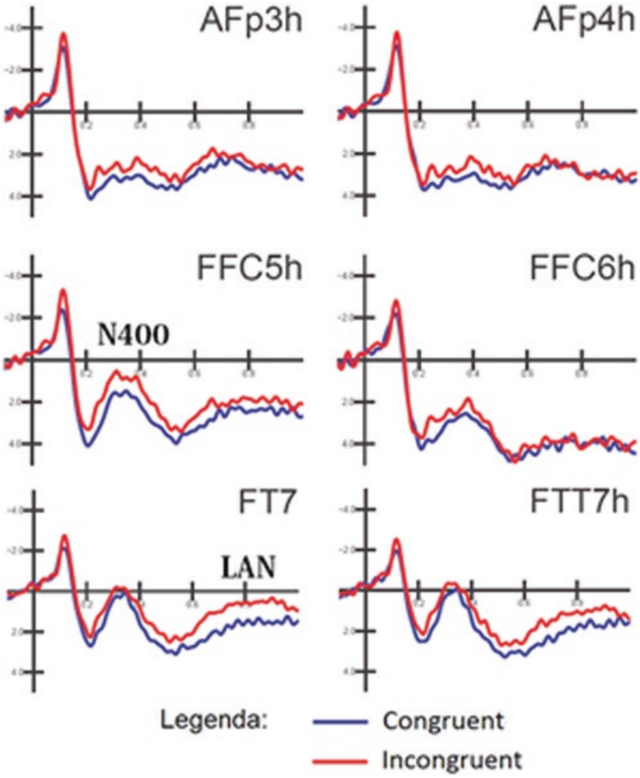

Fig. 12.5 N400 and LAN components elicited by incongruent (with respect to stereotypes) sentences over anterior scalp sites in Proverbio et al. (2017) study. (Courtesy of the authors)

ability was investigated by recording event-related potentials from 128 scalp sites in 16 volunteers. In the first session (encoding), they viewed 200 faces associated with a short fictional story that described anecdotal positive or negative characteristics about each person (see an example in Fig. 12.6).

In the second session (recognition), participants underwent an old/new memory test, in which they had to distinguish 100 new faces from the previously shown faces. ERP data relative to the encoding phase showed a larger anterior negativity in response to negatively (vs. positively) biased faces, indicating a deeper neural processing of faces with unpleasant social traits. In the recognition task, ERPs recorded in response to new faces elicited a larger FN400 than to old faces and to positive than negative faces. This piece of data indicates that negatively valenced faces were recognized as more familiar than positively valenced ones. Additionally, old faces elicited a larger old-new parietal response than new faces, in the form of an enlarged late positive component (LPC). An inverse solution swLORETA (applied to ERPs in the 450–550 ms poststimulus) indicated that remembering old faces was associated with the activation of right superior frontal gyrus (SFG), left middle temporal gyrus (mdTG), and right fusiform gyrus (FG). However, only negatively connoted

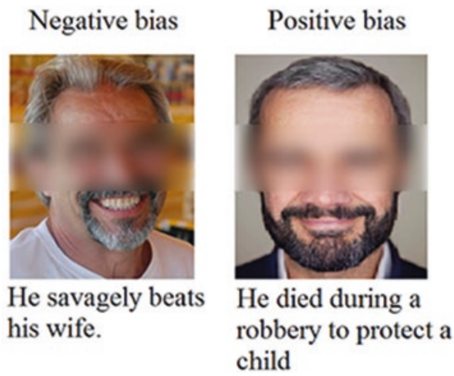

Fig. 12.6 Examples of how Proverbio et al. (2016) induced a positive or negative prejudice about previously unknown persons. In the encoding task, faces were presented in association with a short story that provided fictional information about the character, such as an anecdote or personal information. The biographic information could be positive, thereby inducing a positive prejudice toward the depicted character, or vice versa, a negative prejudice could induce a negative bias. (Courtesy of Proverbio and coauthors)

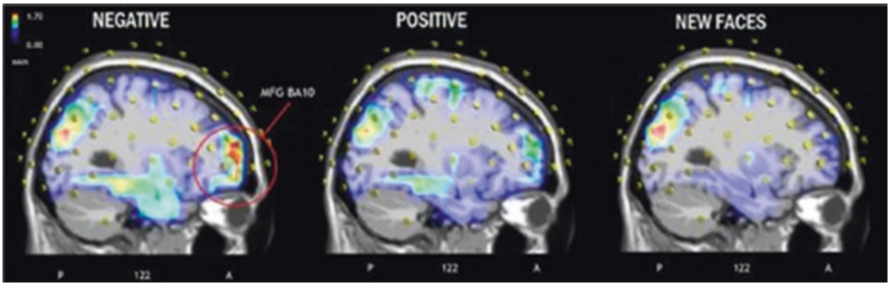

Fig. 12.7 Sagittal views of active sources during processing of negatively biased, positively biased, and new faces according to swLORETA analysis during the 450–550 ms time window. The images highlight the strong activation of the left middle frontal gyrus during memory recall of faces associated with a negative prejudice. (Taken from Proverbio et al. (2016) with permission from the authors. Creative Commons Public Domain picture)

faces strongly activated the limbic and parahippocampal areas and the left SFG (Fig. 12.7). Dissociation was found between familiarity (modulated by negative bias) and recollection (distinguishing old from new faces). Not only ERPs showed the existence of prejudices formed during the learning phase, but the latter were able to affect the recognition and memory recall of faces, with an advantage for negatively valenced social information.

Going back to gender-based prejudices, quite recently, Proverbio and coauthors (2018) showed that ERPs are so sensitive to social representations and constructs such as prejudices and stereotypes that it is possible to find differences within the population as a function of the different degree of prejudice possessed. In this study, the time course and the neural correlates involved in the representation of occupational gender bias were investigated by addressing two questions: first, if the bias 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 presented to participants. 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 (*final word paradigm*). 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 heterosexual Italian university students during the reading of hundreds of sentences depicting female and male characters and their professional attitudes (see Table 12.1 for some example of sentences carrying typical female or male stereotypes). The task consisted in responding as quickly and accurately as possible to animal words, that is, an implicit task designed in order to avoid social desirability processes. Brain responses of male and female participants totally unaware of study's purpose were compared as a function of whether the sentence was congruent or not with a gender stereotype.

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. ERPs were time-locked to critical words. Findings showed enhanced anterior N400 and occipitoparietal P600 responses to items that violated gender stereotypes, mostly in men (Fig. 12.8). The swLORETA analysis applied to N400 potentials in response to incongruent phrases showed that the most activated areas during stereotype processing were the right middle temporal (mdTG) and middle frontal gyri (mdFG), as well as the TPJ, as expected on the basis of previous literature (Fig. 12.9). The data hint at a gender difference in stereotyping, with men being more prejudicial especially when the depicted character was a male. One possible interpretation of these findings 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.

An asymmetry in gender bias, with a stronger prejudicial attitude in men, is not unknown in the literature. For example, an article summarizing data from more than 2.5 million completed IATs (Implicit Association Tests) and self-reports (Nosek & Smyth, 2007) showed that men are more prejudicial in terms of theories postulating that they have more social dominance (e.g., Sidanius & Pratto, 1999), attitudes toward gay vs. heterosexual people (e.g., Negy & Eisenman, 2005), and attitudes toward black vs. white people (e.g., Qualls et al., 1992). As for neuroscientific data, only in men it was shown that hostile sexism correlated with the activation of brain regions associated with mental state attributions (such as the medial prefrontal cortex (mdPFC), the posterior cingulate cortex (pCC), and the temporal poles) in Cikara et al.'s (2011) fMRI study.

Overall ERPs, and especially the amplitude of N400 component, proved to be extremely sensitive to violations of implicit stereotypes, thus allowing to tap at the representation of social attributes (such as stereotypes and prejudices) without the

Table 12.1 Example of sentence stimuli, relative to men or women, and violating or not current occupational gender stereotypes in which women engage more in care-related professions and men in strength−/power-related professions

Sentences incongruent with prejudices (men)
Prepared the tomato sauce and then shaved.
Gave up figure skating when he became father.
Hang the clothes out to dry and caught up with his wife.
We would be shopping all day if it was up to Johnny.
Lost his pipe leaving the ballet class.
That waiter wore a colorful skirt.
Sentences incongruent with prejudices (women)
After whitewashing, she was exhausted.
The notary is breastfeeding.
While changing the engine's oil, she stained herself.
The major's name is Josephine Nicolini.
The musical software engineer waxed her legs.
That boxer has just given birth.
Sentences congruent with prejudices (men)
The chemist put on a nice tie.
The motorist suffers from prostatitis.
The financial controller soiled his pants.
The lab technician ruined his scrubs.
Served with intelligence until he was cast out.
Once finished with the tile install, he was haggard.
Sentences congruent with prejudices (women)
Prepared a synchronized swimming choreography of which she is proud.
Works as a baby-sitter, and she is very maternal.
Fed the little girl and went to the lady hairdresser.
Laura enjoys working as a switchboard operator.
Loved kids so much that became an elementary school teacher.
She hurt herself doing needle work.

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 et al. 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). To determine whether the sentences actually represented (or violated) stereotypes for university students living in the Milan metropolitan area, the stimuli underwent validation, in which a group of Milan University students were asked to rate, by means of a 3-point Likert scale, how they reacted to reading the terminal word of the phrase. Scale units were as follows: 0 = Actually, I was a bit surprised. 1 = I do not know. 2 = I kind of saw that coming.

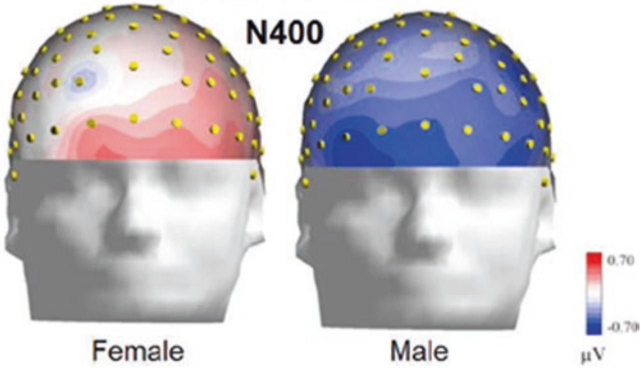

Fig. 12.8 Isocolor topographical maps (front view) of surface voltage measured in the 250–400 ms temporal window (N400 latency range) to incongruent stimuli as a function of participants' sex. It can be appreciated how N400 response to stereotypes violation was not found in female participants. This suggests that female participants were not surprised by final words that violated sex stereotypes. (Adapted from Proverbio et al., 2018)

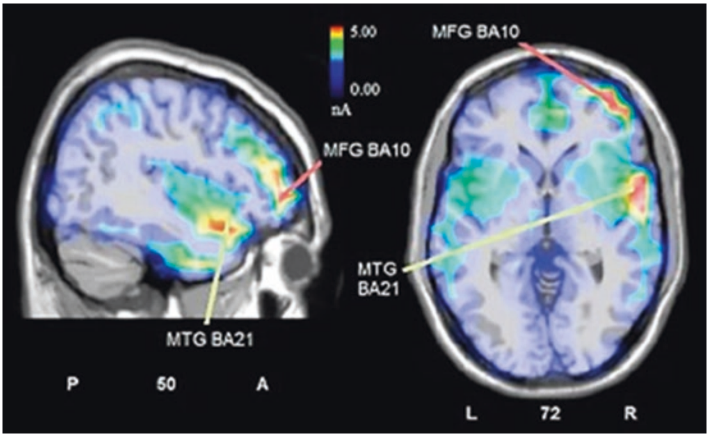

Fig. 12.9 Coronal and axial brain sections showing the location and strength of electromagnetic dipoles explaining the surface difference voltage obtained by subtracting ERPs to congruent from ERPs to incongruent stimuli in the 250–400 ms latency range, corresponding to the peak of N400. *L* left, *R*, right, *A* anterior, *P* posterior, *MTG* middle temporal gyrus, *MFG* middle frontal gyrus. (Taken for Proverbio et al., 2018)

problems related to social desirability processes and without participants being minimally aware of the study's purpose or experimental manipulation. For this reason, ERPs represent one core research technique for studying social cognition, including the representation of social attributes.

Indeed, N400 paradigm was also used for detecting implicit ethnic prejudices such as negative biases against rural migrant workers (Wang et al., 2011), unarmed Afro-Americans individuals (Correll et al., 2006), or non-Caucasian (other race

(OR)) professionals (Brusa et al., 2021). For example, Brusa et al. (2021) presented to Caucasian students 285 sentences that could either violate, non-violate, or be neutral with regard to stereotypical concepts concerning OR individuals (e.g., Asians, Africans, Arabs). No awareness or judgment about stereotypes was required. Participants passively read the sentences while engaged in a fictitious task, ignoring the overall study's purpose. Stimuli violating negative ethnic stereotypes elicited a large anterior N400 response, and participant's individual amplitude values of the N400-Difference Wave (Incongruent – Congruent) showed a direct correlation with the individual racism scores obtained at the *Subtle and Blatant Prejudice Scale*, administered at the end of the experimental session. The stronger the racial bias, the larger the N400 response.

These findings encourage the use of subjective, implicit, and explicit psychological scales to be correlated with physiological measures in the study of social stereotypes. Indeed, while the N400 paradigm allows to implicitly access the representation of racial or sexual stereotypes avoiding the activation of control processes guided by social desirability instances, the correlation between electrophysiological and behavioral measures can provide a wider and more complex view about psychological processes. Prejudices can exist (as demonstrated by electrophysiological signals) in the absence of conscious awareness and in contrast to a convinced voluntary progressive attitude of individuals.

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