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**Impact of social knowledge about the speaker on irony understanding: Evidence from neural oscillations.**

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**Abstract**

The aim of the present study was to explore neuronal oscillatory activity during a task of irony understanding. In this task, we manipulated implicit information about the speaker such as occupation stereotypes (i.e., sarcastic versus non-sarcastic). These stereotypes are social knowledge that influence the extent to which the speaker's ironic intent is understood. Time-frequency analyses revealed an early effect of speaker occupation stereotypes, as evidenced by greater synchronization in the upper gamma band (in the 150-250 ms time window) when the speaker had a sarcastic occupation, by greater desynchronization for ironic context compared to literal context in the alpha1 band and by a greater synchronization in the theta band when the speaker had a non-sarcastic occupation. When the speaker occupation did not constrain the ironic interpretation, the interpretation of the sentence as ironic was revealed as resource-demanding and requiring pragmatic reanalysis, as shown mainly by the synchronization in the theta band and the desynchronization in the alpha1 band (in the 500-800 ms time window). These results support predictions of the constraint satisfaction model suggesting that during irony understanding, extra-linguistic information such as information on the speaker is used as soon as it is available, in the early stage of processing.

**Keywords** : Non-literal language ; irony; social knowledge; stereotypes; constraint satisfaction model; time-frequency analyses

## Introduction

In everyday life, the understanding of non-literal language (e.g. irony) requires the listener to integrate linguistic information and extra-linguistic information (e.g., contextual information, encyclopedic knowledge of the world) to identify what the speaker means. Such extra-linguistic information may concern the speaker. It has been shown in psycholinguistics that amongst different contextual factors (e.g. the level of incongruity between context and speaker's utterance, prosody), knowledge of the speaker (e.g. his/her social status or his/her occupation) influences the extent to which utterances are interpreted as ironic (Pexman & Olineck, 2002; Ivanko & Pexman, 2003; Rivière et al., 2018; Rivière & Champagne-Lavau, 2020). Irony is the general term used to refer to a common form of non-literal language in which what is uttered is different from or, in some cases, the opposite to what the speaker means (Gibbs, 1994). For example, a speaker can say "*you are a wonderful cook*" meaning "*you are a terrible cook*" if the meal is burnt. It has been demonstrated that speaker occupation stereotypes carry social knowledge which cues speaker ironic intent (Katz & Pexman, 1997; Pexman & Olineck, 2002). Stereotypes refer "to membership in social categories such as sex, race, age, or profession that are believed to be associated with certain traits and behaviors." (Kunda & Thagard, 1996, p. 284). Speaker occupation stereotypes contribute to what Utsumi (2000) called the ironic environment. For instance, people are more prone to interpret a statement as ironic and mocking if it is spoken by an actor rather than a clergyman (Katz & Pexman, 1997; Pexman & Olineck, 2002; Champagne-Lavau & Charest, 2015). In other words, members of certain occupations (e.g. actor) are perceived to be likely to use irony while members of other occupations (e.g. clergyman) are perceived to be unlikely to use irony. To simplify, we called the first occupations *sarcastic* occupations while the second ones were called *non-sarcastic* occupations. Pexman & Olineck (2002) pointed out that these stereotypes were associated with speaker characteristics, members of sarcastic occupations being perceived as funnier, more critical, less sincere and having a lower level of education compared to members of non-sarcastic occupations. The effect of these speaker occupation stereotypes has been shown to be preserved in schizophrenia (Champagne-Lavau & Charest, 2015). While individuals with schizophrenia were shown to have difficulty integrating contextual information (i.e., contextual incongruity tapping into the incongruity between the utterance and the contextual situation in which the utterance is produced) leading them to an incorrect interpretation of ironic utterances, they were helped by the presence of the speaker occupation in the stimuli. In other words, they were able to use speaker occupation stereotypes to understand the speaker's ironic intent correctly. Such results suggest that different types of extra-linguistic information are integrated in different ways during

irony comprehension. According to the constraint satisfaction model, information from various sources (e.g., context, utterance, knowledge about the speaker) is integrated rapidly and in parallel leading to the activation of an ironic interpretation that better fits the available information than an alternative literal interpretation would have done (Katz, 2005; Pexman, 2008)<sup>1</sup>. Activation of the ironic interpretation is considered as soon as there are sufficient cues supporting it (Pexman, 2008). Some of this information called *constraints* would be used during the early stage of the comprehension process as soon as it is available while other would play a role later (Pexman et al., 2000). The present article focuses on how and when extra-linguistic information such as speaker occupation stereotype is integrated during irony understanding.

Event-related brain potentials (ERPs) studies have revealed that knowledge about the speakers affects sentence interpretation (Osterhout et al., 1997; Lattner & Friederici, 2003; Van Berkum et al., 2008; Regel et al., 2010). Lattner & Friederici (2003) manipulated implicit speaker information such as gender stereotypes conveyed by the speaker's voice through congruent (e.g., a man saying "I like to play soccer") and incongruent conditions (e.g., a woman saying "I like to play soccer"). Compared to the congruent one, this last condition elicited a larger P600 which the authors interpreted as a re-integration of semantic meaning with extra-linguistic information (speaker information conveyed by his/her voice and stereotypical knowledge). This result confirmed the findings of Osterhout et al. (1997) showing that violations of gender-based occupational stereotypes (e.g., "*The doctor prepared herself for the operation*") lead to a late positivity (P600). Van Berkum et al. (2008) showed that participants who listened to sentences uttered by different speakers integrated both the message and the speaker identity (i.e., gender, age, social-economic status of the speaker inferred from his/her voice) in the early stages of meaning interpretation. They reported an N400 effect starting between 200–300 ms after the acoustic onset of a relevant word for sentences contrasting with the speaker gender (e.g., "*If only I looked like Britney Spears*" uttered with a male voice). While these results demonstrated that knowledge on the speaker such as his/her age or gender during meaning interpretation is taken into account by the listeners, less is known about the extent to which irony comprehension is influenced by extra-linguistic information about the speaker and when such information is processed in the brain.

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<sup>1</sup> "There are four defining characteristic of constraint-based approaches. First, as an utterance unfolds, listeners rapidly integrate multiple probabilistic sources of information in a weighted manner. Second, listeners generate expectations of multiple types about the future, including the acoustic/phonetic properties of utterances, syntactic structures, referential domains, and possible speaker meanings. Third, speakers and listeners can rapidly adjust expectations to different speakers and different situations, etc. Fourth, explanations that depend upon architectural constraints (e.g., information-encapsulated modules, discrete sequential processing stages) are only considered as a last resort." (Degen & Tanenhaus (2019), page 22)

Several ERP studies have investigated the time course of irony understanding (Cornejo et al., 2007; Regel et al., 2010; 2011; 2014; Spotorno et al., 2013; Filik et al., 2014; Regel & Gunter 2017; Caillies et al., 2019; Caffarra et al., 2019; Mauchand et al., 2021), the study by Regel et al. (2010) being the only one to assess the impact of speaker communicative style on irony understanding. Most of these studies found that irony processing, compared to literal sentence processing, elicits an enhancement of the P600 component (i.e., a late positivity, typically distributed over centroparietal electrodes and emerging around 500 ms post-stimulus onset) in absence of an N400 effect (Regel et al., 2010; Regel et al. 2011; Spotorno et al., 2013; Filik et al., 2014; Regel & Gunter 2017; Caillies et al., 2019; Caffarra et al., 2019). Regel et al. (2010) also reported an increase of the P200 amplitude when speaker communicative style (ironic versus non ironic) was congruent with the sentence meaning (respectively ironic versus literal). A P200-P600 irony-related ERP pattern has been described by Regel and colleagues (Regel et al., 2010; 2011; 2014; Regel & Gunter, 2017). The authors concluded that irony processing entails initial semantic analysis processes indexed by a P200 (i.e., a component that peaks at about 200 milliseconds after the onset) followed by a later pragmatic reanalysis process indexed by the P600.

In addition to the classic ERP analyses, the oscillatory neural activity can be analyzed by time-frequency analysis (TFA) that capture meaningful EEG features not visible with ERPs. Regarding language comprehension, studies performing time-frequency analyses have focused on semantic processing and syntactic processing (see Bastiaansen et al., 2012 and Meyer, 2018 for a review). As an overview, gamma band activity may reflect unification processes in the semantic domain (Hagoort et al., 2004; Bastiaansen & Hagoort, 2015; see Lewis et al., 2015 for a review). It has also been associated with language predictions about the lexical content of the upcoming word during sentence processing (Lewis, Wang & Bastiaansen, 2015; Lam et al., 2016; Wang et al., 2018). Theta activity has been shown to reflect working memory retrieval, long-term memory retrieval, and retrieval of lexical-semantic information (Klimesch et al., 1999; Bastiaansen et al., 2005; Lam et al., 2016; Meyer, 2018). More precisely, frontal theta oscillations have been related to verbal working memory retrieval during sentence comprehension (Hald et al., 2006; Meyer et al., 2015). Alpha band activity has been shown to be involved in syntactic processing (Bastiaansen et al., 2010; Kiellar et al., 2015), in verbal working memory storage (Meyer et al., 2013), and in increased attentional demands during sentence comprehension (Lam et al., 2016). In addition, research has demonstrated that different processes underlie alpha1 (8-10Hz) and alpha2 (11-13Hz) sub-bands (Klimesch et al., 1992; Krause et al., 1997). Krause and colleagues (1997) investigated auditorily-elicited event-related

synchronizations and desynchronizations and showed that the alpha2 sub-band exhibited reactivity to linguistic content, while the alpha1 band activity appeared to be related to more general processes linked to attention. An alpha2 desynchronization has been found to be positively correlated with search and retrieval processes in long-term semantic memory (Klimesch, 1999).

To our knowledge, only four studies used TFA to explore the oscillatory activity supporting irony comprehension. Spotorno et al. (2013) reported a frontal synchronization in the gamma band, in the 280-400 ms window, for the ironic compared to the literal condition, suggesting that an activity of integration of different information could start earlier than revealed by the ERP analyses. The authors also suggested that this synchronization could reveal the involvement of social cognition processes (e.g., attributing intention to the speaker). Comparing ironic and literal conditions, Spotorno et al. (2013) also reported a synchronization in the theta band in the 500-700 ms window and in the alpha band in the 400-700 ms window over the right frontal regions. They also found a desynchronization in the alpha band in the 550-700 ms window over the left parietal regions. According to the authors, these results respectively suggested a recovery of information in memory and a greater allocation of cognitive resources for understanding ironic statements compared to literal statements. Regel et al. (2014) found different patterns of oscillatory activity in the theta frequency band, in the time window of the P600 (500-900 ms) for syntactic processing and pragmatic processing, giving support to the claim that different neural networks are involved in the emergence of a syntax-related P600 versus a P600 related to irony. In a magnetoencephalography (MEG) study, Akimoto et al. (2017) found desynchronization in the alpha band occurring 600-900 ms after the onset of the critical sentence. This desynchronization in the right anterior temporal lobe was greater in the ironic than in the literal condition. Recently, Rothermich et al. (2022) used TFA to investigate the perception of social appropriateness for non-literal statements (i.e., sarcasm, teasing) compared to literal statements (i.e., literal, blunt) during audio-only and audio-visual interactions. Their results mainly revealed activities in the alpha and theta bands occurring in 500-1000 ms and 1000-1500 ms time windows when participants had to judge the appropriateness of blunt compared to sarcastic and teasing statements presented in the audio-only condition. However, these studies explored irony processing without considering extra-linguistic information processing (Spotorno et al., 2013; Regel et al., 2014; Akimoto et al., 2017; Rothermich et al., 2022). Therefore, characterizing the oscillatory dynamics during irony understanding has still to be achieved and would yield additional knowledge on the neural mechanisms involved in how and when linguistic and extra-linguistic information, such as knowledge about the speaker, are integrated.

The purpose of the present study was to investigate the neurocognitive processes involved in understanding ironic versus literal statements. More specifically, we examined how and when linguistic and extra-linguistic information concerning knowledge about the speaker (i.e., speaker occupation stereotypes) was integrated when understanding ironic statements. To this aim, we studied the neural oscillatory activity with TFA. Given that the EEG activity in different frequencies can be related to differing processes, by considering the activity in different frequency bands over time we can better access the complexity of processing and to track it over time. This, in addition to ERP analysis, allowed us to better characterize the processes of integration involved in irony understanding. We used an irony-understanding task manipulating implicit information on the speaker such as occupation stereotypes (i.e., sarcastic versus non-sarcastic), which has been demonstrated to be social knowledge which cues the speaker's ironic intent (Katz & Pexman, 1997; Pexman & Olineck, 2002; Champagne-Lavau & Charest, 2015). Specifically, we explored whether synchronization and desynchronization patterns differ between the ironic and literal conditions and between the different speaker occupation conditions. Based on the literature exploring neural oscillatory activities during irony comprehension (Spotorno et al., 2013; Regel et al., 2014; Akimoto et al., 2017), we expected to find alpha activity and theta activity in the P600 time window, and gamma activity in an earlier time window (P200 time window) for the ironic condition compared to the literal condition. We expected a modulation of these results according to the speaker occupation condition, given that speaker sarcastic occupations (e.g., actor) cue irony interpretation, in contrast to speaker non-sarcastic occupations (e.g., clergyman). Nevertheless, as this is the first study to explore the neural oscillatory activity during the processing of stereotypes about the speaker occupation, we had no specific a priori hypothesis regarding the effect of the speaker occupation conditions on the neural oscillatory activity.

## **Methods**

### ***Participants***

Twenty-four native French speakers from Aix-Marseille University (10 females; mean age = 22 years,  $SD = 3.79$ ; mean education in years = 14.06,  $SD = 2.16$ ) participated in this study. They were all right-handed and reported normal or corrected-to-normal vision. None of them reported any neurological impairment. All participants signed a written consent form before participating in the study. The study was approved by the ethics committee of Aix-Marseille University. Data of one participant was excluded from the analysis because of a noise-contaminated EEG signal,

while another participant was excluded from the analysis because of an accuracy rate of 55.6%. Thus, the final data included 22 participants.

### ***Materials***

The stimuli were composed of 180 target sentences (e.g., Melanie is a graceful dancer, *Mélanie est une danseuse gracieuse*) preceded by a context (cf. Table 1). There were two types of context intended to trigger either a literal meaning or an ironic meaning of the target sentence. Each context comprised two sentences. The first sentence presented the two characters and the situation while the second sentence was manipulated to bias either the literal or the ironic target sentence meaning. The target sentence was exactly the same in the ironic and literal context conditions and the final word in French (e.g., *gracieuse*) was critical for the respective interpretations. To assess how the speaker communicative features, conveyed by occupation stereotypes, may influence the interpretation of ironic sentences, the context was manipulated according to the presence of an occupation cueing or not ironic meaning (cf. Table 1). Thus, the materials for the experiment included 180 stories involving a 2 context (ironic, literal) by 3 occupation (occupation that cues ironic intent, occupation that does not cue ironic intent, no occupation) combination of conditions. For the sake of clarity, we named these conditions sarcastic occupation and non-sarcastic occupation conditions in the rest of the article. The no occupation condition, in which the speakers were identified by their first name, was added to create filler stimuli. Following Pexman & Olineck (2002) in English and Champagne-Lavau & Charest (2015) in French, this no occupation condition was included to prevent the participants from developing a strategy that would help them foresee profession information. The speaker occupations used in the stimuli were selected in a pretest (see below).

(Table 1 about here)

### ***Pretests of materials***

Ninety-two stimuli among the 180 stimuli used in the present study came from Champagne-Lavau & Charest (2015) and Champagne-Lavau et al. (2012) and had already been validated. The other 88 stimuli were created for the present research. A first pretest was performed to ensure that target utterances following contexts were perceived as correctly reflecting the intended meaning (ironic, literal). The 88 new stimuli, including 44 stories in the ironic context condition and 44 stories in the literal context condition, were tested in this pretest. For this

pretest, the two characters were always designated by their first name. Forty undergraduate students from Aix-Marseille University, not involved in the main experiment, were recruited. They had to rate to what extent each target sentence was ironic on a 5-point Likert scale (1 = not ironic at all, 5 = very ironic). The stimuli were divided into 2 lists of stimuli, each including one version of each stimulus so that each participant saw a story in only one context condition. The 44 target sentences presented with an ironic context ( $M = 4.5$ ,  $SD = 0.3$ ) were deemed to be significantly more ironic than their counterpart presented with a literal context ( $M = 1.2$ ,  $SD = 0.2$ ) ( $t(86) = 61.1$ ,  $p < 0.0001$ ). In a second pretest, the speaker occupations were selected amongst a sample of 80 occupations following the procedure used by Pexman & Olineck (2002) and by Champagne-Lavau & Charest (2015). For each occupation, forty undergraduate students from Aix-Marseille University were asked to imagine that a member of that occupation got a flat tire on the way to work. They were then asked to judge the likelihood that the member of this occupation would make a sarcastic remark about the situation on a 5-point Likert scale (1 = low probability, 5 = high probability). None of these participants were involved in the main experiment or in the previous pretest. There were 2 lists of 40 occupations so that each participant rated one of the 2 lists. From this pretest, we selected the following 15 occupations rated as having the highest probability of sarcastic remarks (“sarcastic occupations”): *actor, talk show host, movie critic, mechanic, truck driver, mover, engineer, ticket inspector, journalist, pizza delivery man, radio host, pilot, driving school monitor, politician, taxi driver* ( $M = 3.5$ ,  $SD = 0.3$ ). The following 15 occupations were judged as having the lowest probability of sarcastic remarks (“non-sarcastic occupations”): *clergyman, soldier, bank teller, nurse, news dealer, winegrower, esthetician, cashier, museum restorer, bricklayer, butler, violinist, ballet dancer, chef, hairdresser* ( $M = 2.1$ ,  $SD = 0.1$ ). These two occupation conditions were significantly different ( $t(28) = -19.6$ ;  $p < 0.0001$ ). Following these pretests, each speaker occupation selected was used twice in 2 different stories and applied in both context conditions.

### ***Procedure***

Participants were asked to read each story attentively and to answer a comprehension question about the context (e.g., for the non-sarcastic occupation condition: *Is Claire working with his cousin?*) while their EEG was recorded. This question did not require the participants to understand the speaker ironic intent. The stories were presented visually on a computer screen. The question allowed us to ensure that participants had paid attention to the stimuli. The stimuli were displayed in black font on a white screen, on one or two lines. The experiment was divided into three blocks of 60 stimuli, the literal and ironic version of a given story being always

presented in two different blocks. Experimental conditions were equally divided across the three blocks. Stimulus presentation was randomized within each block. Before the experiment began, participants received instructions and a short practice block to familiarize them with the task. Then, they had to press either button to start the experiment. At the beginning of each trial, a fixation cross was presented in the center of the screen for 500ms. Then the first sentence of the context was presented. Participants read the context, sentence by sentence, in a self-paced manner, each sentence remaining on the screen until he/she pressed a button. The interval between sentences was 500 ms. After reading the context, the target sentence was presented in 3 parts (In French: 1.Noun + verb, 2. Determinant + noun, 3. Adjective), each part being displayed for 800 ms with an interval inter-stimulus of 500 ms. After the end of each story and before the onset of the comprehension question, a fixation cross appeared again for 500 ms. Participants had to answer the comprehension question with a yes or no response by pressing a button. To avoid responses at chance level, half of the answers were “yes”, and half were “no”. The next trial started 1000 ms after the participant response. Participants were asked to avoid blinking after fixation cross displays. Fixation crosses were presented for 500 ms at the center of the screen between each part of the context and of the target sentence to ensure that they refrained from moving their eyes. Participants were informed that they could take a break after each block. The whole experiment lasted about one hour.

### ***EEG recording***

The EEG was continuously recorded using 64-channel BioSemi ActiveTwo AD-box at a sampling rate of 2048 Hz. Signal of the right and left mastoids were recorded as well as four other exogenous electrodes placed as follows: at the outer canthus of each eye and above and below the left eye to record eye movements. The offset of individual electrodes was maintained below 20 mV throughout recording. The raw data were deposited on Zenodo.

### ***EEG data processing***

Data was pre-processed using the Matlab toolbox, EEGLAB (Delorme & Makeig, 2004). Offline, all EEG channels were downsampled to 512 Hz and a FIR bandpass filter between 0.16 Hz and 80 Hz was applied. The EEG signal was re-referenced offline to the mean of right and left mastoids signals. Electrodes with noise contamination were identified in a semi-automatic manner by, firstly, calculating the robust z-score, as implemented in the PREP pipeline (Bigdely-Shamlo et al, 2015) and marking, as potentially bad, those electrodes whose score exceeds 5. These electrodes were excluded only after visualizing both the frequency spectrum and time-

course of these electrodes. In addition, time intervals with a duration of 1 second or longer and whose mean amplitude exceeded  $75\mu\text{V}$  were identified and marked for exclusion as such noise would reduce the performance of the independent components analysis (ICA). ICA was then performed using the infomax ICA algorithm (Bell & Sejnowski, 1995) on the continuous data for all participants. Independent components (ICs) corresponding to ocular activity were identified by applying the ADJUST algorithm (Mognon et al, 2011), which runs as an EEGLAB plugin. ADJUST identifies those ICs that correspond to ocular artifacts by computing the spatial average difference (SAD) and the temporal kurtosis. Only after ICA correction were the excluded electrodes replaced by applying the spherical spline interpolation method implemented in EEGLAB. The data were then segmented into epochs starting 250 ms before the last target sentence word onset and ending 1500 ms after and baseline normalization was carried out. Epochs were time-locked to the onset of the last word of the target utterance. We considered this word to be a *critical word* in French, as it conveyed the key information making the utterance either literal or ironic. Epochs were visually inspected, and trials containing excessive ocular or muscular artifacts were rejected (about 15 % of rejection). The remaining artifact-free trials were averaged separately for each electrode, according to the experimental conditions (context: literal, irony x speaker's occupation: sarcastic, non-sarcastic, no occupation). Following the procedure used in Filik and al., (2014) (see also Dien and Santuzzi, 2005), we pooled lateral electrode in regions of interest (ROIs), on topographical factors: a left-right, an anterior-to-posterior, and a dorsal-ventral dimensions which yielded to the following ten ROIs: left-anterior-ventral (AF7, F7, FT7, F5, FC5, C5, T7), left-anterior-dorsal (AF3, F3, FC3, F1, FC1, C1, C3), left-posterior-ventral (TP7, CP5, P5, P7, P9, PO7), and left-posterior-dorsal (CP3, CP1, P3, PO3, P1, O1), midline-anterior (AFz, Fz, FCz, Cz), midline-posterior (CPz, Pz, POz,Oz), right-anterior-ventral (AF8, F8, FT8, F6, FC6, C6, T8), right-anterior-dorsal (AF4, F4, FC4, F2, FC2, C2, C4), right-posterior-ventral (TP8, CP6, P6, P8, P10, PO8), and right-posterior-dorsal (CP4, CP2, P4, PO4, P2, O2). Based on the results from the literature, mean ERPs amplitudes were determined for P200 component (150-250 ms) and P600 component (500-800 ms) time windows. Greenhouse-Geisser corrected repeated measures ANOVAs 2 context (literal, irony) x 3 speaker occupation (sarcastic, non –sarcastic, no occupation) x 10 ROIs were performed on the P200 time window (150-250 ms), the N400 time window (250-500 ms) and the P600 time window (500-800 ms). Pairwise comparisons were used to decompose any significant interaction. Results were considered significant below an alpha level of 0.05 (after Bonferroni correction). Statistical analyses were performed with IBM SPSS version 28.

To study the event-related dynamics of the EEG spectrum, we calculated the event-related spectral perturbation (ERSP) (Makeig, 1993; Makeig et al., 2004). The ERSP compares post-stimulus oscillatory activity to a pre-stimulus baseline; a decrease in post-stimulus oscillatory power compared to the baseline is referred to as an event-related desynchronization (ERD) (Pfurtscheller & Aranibar, 1977), and a power enhancement relative to the baseline period is referred to as an event-related synchronization (ERS; Pfurtscheller, 1992). Importantly, as the ERSP calculation involves carrying out time-frequency decomposition at the single-trial level before trial averaging for each participant, the resulting oscillatory activity includes, not only phase-locked activity, which corresponds to activity revealed by ERP analysis, but also activity that is only time-locked to the critical event, but not phase-locked to it (Roach & Mathalon, 2008), also referred to as *induced* power. This induced power reflects activity at the level of individual trials, thus giving us access to information about activity that varies across trials.

To compute the ERSP for each participant, time-frequency decomposition was carried out at the single trial level over the 4Hz to 80Hz frequency band by convolving the signal of each electrode of interest with a set of complex Morlet wavelets. To ensure satisfactory time-frequency tradeoff at all frequencies of interest, the full width at half maximum (FWHM) of the wavelets varied linearly as a function of frequency; at 4Hz the FWHM is 5Hz and 200ms, at 10Hz the FWHM is 5.2Hz and 189ms, at 40Hz the FWHM is 7.45Hz and 130ms and at 80Hz the FWHM is 20Hz and 50ms. The frequency grid was calculated based on the FFT length and the sampling frequency (512Hz). A mean baseline was computed for each participant by averaging over all single-trial baselines. The post-stimulus interval (0ms to 800ms) of each trial was expressed in decibels in relation to the participant-level mean baseline. We chose to define the upper baseline limit as -50ms to avoid any post-stimulus activity that may leak into the baseline interval due to temporal smoothing and that, as a result of baseline normalization, would pollute the post-stimulus interval.

The ERSP data for each participant was separated into the following conditions: Ironic context with a Non-Sarcastic occupation (NSI), Ironic context with a Sarcastic occupation (SI), Ironic context with No occupation (NoI), Literal context with a Non-sarcastic occupation (NSL), Literal context with a Sarcastic occupation (SL), Literal context with No occupation (NoL). For each participant and each condition, the normalized power for each frequency was averaged across all trials to yield the grand-average power value for all frequencies for each of the six conditions. Three time windows were defined based on previous studies investigating irony understanding (Regel et al., 2010; Regel et al., 2014): an early time window (150-250ms), a middle time window (250-500ms) and a late time window (500-800ms). Seven frequency bands

of interest were also defined: theta band (4-7Hz), the alpha1 band (8-10Hz), the alpha2 band (11-13Hz), the beta1 band (14-20Hz), the beta2 band (20-30Hz), the gamma1 band (30-40Hz) and the gamma2 band (60-80Hz). For each participant, the ERSP at the level of individual electrodes, was averaged over each time window of interest and each frequency band of interest, thus yielding mean ERSP for each time window and frequency band for each electrode. Then the mean ERSP over each ROI was computed by averaging again over the electrodes comprising each ROI, thereby yielding, for each participant, mean ERSP over each ROI for each time window and frequency band. The participant-level data was entered into the subsequent statistical analysis.

### *TFA statistical analyses*

Greenhouse-Geisser corrected repeated measures ANOVAs 2 context (literal, irony) x 3 speaker's occupation (Non-Sarcastic, Sarcastic, No occupation) x 10 ROIs were performed on the mean ERSP data. Pairwise comparisons were used to decompose any significant interaction. Results were considered significant below an alpha level of 0.05 (after Bonferroni correction). Statistical analyses were performed with IBM SPSS version 28.

## **Results**

### *Behavioral results*

The mean correct response rate to the comprehension question was 93.46% (range: 82.22 – 97.78) which indicates that participants were engaged in the task.

### *ERP results*

The repeated measures ANOVAs performed on the 150-250 ms time window and on the 300-500ms time window revealed no main effect or significant interaction with speaker's occupation or context. The repeated measures ANOVA performed on the 500-800 ms time window revealed a main effect of context ( $F(1,21) = 6.859$ ,  $p = .016$ ,  $\eta_p^2 = .246$ ) with larger P600 amplitude for ironic than for literal context. The interaction Context x speaker's occupation was not significant ( $F(2, 42) = 2.782$ ,  $p = .095$ ,  $\eta_p^2 = .117$ , achieved power = .519). Visual inspection of the ERPs (cf. Figure 1a, 1b and 1c) for the different occupation conditions suggested differences between ironic and literal context for the non-sarcastic occupation condition in the P600 time window which was found to be significant. Pairwise comparisons revealed that for the non-sarcastic occupation condition, ironic context entailed a larger P600 amplitude than literal context over all

ROIs ( $p = .020$ , achieved power = .672) while this difference did not exist for the two other occupation conditions ( $p > .05$ ).

(Figure 1a, 1b & 1c about here)

### ***TFA results***

#### **Early time window (150-250 ms)**

##### **Theta band**

Statistical analyses revealed a significant Context x occupation interaction ( $F(2, 42) = 3.517$ ,  $p = .043$ ,  $\eta_p^2 = .143$ ) and a significant occupation x ROI interaction ( $F(18, 378) = 2.670$ ,  $p = .023$ ,  $\eta_p^2 = .113$ ). Pairwise comparisons showed a greater synchronization for ironic context compared to literal context in the non-sarcastic occupation condition ( $p = .046$ ). No difference was found for the other occupation conditions ( $p > .05$ ) (cf. Figure 2).

(Figure 2 about here)

##### **Alpha1 band**

A significant context x occupation x ROI interaction ( $F(18, 378) = 2.670$ ,  $p = .034$ ,  $\eta_p^2 = .113$ ) and a significant occupation x ROI interaction ( $F(18, 378) = 2.433$ ,  $p = .035$ ,  $\eta_p^2 = .104$ ) were found. Pairwise comparisons revealed that, in the non-sarcastic occupation condition, ironic context elicited a greater desynchronization compared to literal context over the central posterior ( $p = .038$ ) electrodes as well as over the right posterior dorsal electrodes ( $p = .041$ ). This is in contrast to the no occupation condition, which presented a greater desynchronization for literal compared to ironic context over the left posterior ventral electrodes ( $p = .016$ ). The sarcastic occupation condition did not present any significant differences ( $p > .05$ ) (cf. Figure 3).

(Figure 3 about here)

##### **Gamma2 band**

Statistical analyses showed a significant context x occupation interaction ( $F(2, 42) = 8.144$ ,  $p < .002$ ,  $\eta_p^2 = .279$ ). Pairwise comparisons revealed that, in the sarcastic occupation condition ( $p = .004$ ), the ironic context elicited a greater synchronization compared to the literal context whatever the ROI. In the no-occupation condition ( $p = .014$ ), the inverse pattern was found. Such difference was not found in the non-sarcastic occupation condition ( $p > .05$ ) (cf. Figure 4).

(Figure 4 about here)

### **Middle time window (250-500 ms)**

#### **Alpha2 band**

Statistical analyses revealed a significant main effect of context condition ( $F(1, 21) = 4.547, p = .045, \eta_p^2 = .178$ ) showing a greater desynchronization for ironic context ( $M = -.52, SE = 0.15$ ) compared to literal context ( $M = -.26, SE = 0.13$ ) (cf. Figure 7 in supplementary material for Time-frequency map of grand average ERSF).

### **Late time window (500-800 ms)**

#### **Theta band**

Statistical analyses revealed a main effect of context ( $F(1, 21) = 9.585, p = .005, \eta_p^2 = .313$ ), meaning that the ironic context elicited a synchronization while the literal context elicited a desynchronization. Visual inspection of topographic maps suggested a difference between ironic context and literal context in the non-sarcastic condition which was found to be significant ( $p < .026$ , achieved power = .624) (cf. Figure 5).

(Figure 5 about here)

#### **Alpha1 band**

The interaction context x occupation x ROI was marginally significant ( $F(18, 378) = 1.967, p = .085, \eta_p^2 = .086$ , achieved power = .664). Pairwise comparisons revealed that, in the non-sarcastic occupation condition, ironic context elicited a greater desynchronization than literal context over the left posterior ventral electrodes ( $p = .006$ , achieved power = .830), left posterior dorsal electrodes ( $p = .024$ , achieved power = .652), Central posterior electrodes ( $p = .022$ , achieved power = .624), right posterior ventral electrodes ( $p = .018$ , achieved power = .684) and right posterior dorsal electrodes ( $p = .031$ , achieved power = .598). Such difference was not found in the no occupation and the sarcastic occupation condition ( $p > .05$ ) (cf. Figure 6).

(Figure 6 about here)

#### **Alpha2 band**

Statistical analyses revealed a main effect of context ( $F(1, 21) = 4.204, p = .053, \eta_p^2 = .167$ ), meaning that the ironic context ( $M = -.13, SE = -.49$ ) elicited a desynchronization while the

literal context ( $M = .17$ ,  $SE = -.18$ ) elicited a synchronization whatever the occupation condition. A significant occupation x ROI condition was also found ( $F(18, 378) = 3.034$ ,  $p = .011$ ,  $\eta_p^2 = .126$ ) (cf. Figure 8 in supplementary material for topographic map of grand average ERSP).

### **Beta1 band**

Statistical analyses revealed a main effect of context ( $F(1, 21) = 4.938$ ,  $p = .037$ ,  $\eta_p^2 = .190$ ), meaning that literal context ( $M = .30$ ,  $SE = 0.10$ ) elicited a greater synchronization compared to ironic context ( $M = .12$ ,  $SE = 0.10$ ) whatever the occupation condition (cf. Figure 9 in supplementary material for topographic map of grand average ERSP).

### **Discussion**

The aim of the present study was to investigate the neurocognitive processes underlying the integration of extra-linguistic information during irony comprehension. We explored neuronal oscillatory activity during a task of irony understanding where information on the speaker (i.e., speaker occupation stereotypes) was manipulated to cue, or not to cue, ironic intent. We analyzed the data focusing specifically on the 150-250 ms, 250-500 ms and the 500-800 ms time windows after the critical word onset.

### **Early effect of the speaker occupation stereotypes on irony processing**

The main results showed that speaker occupation stereotypes are taken into account in the early stage of irony processing. Time frequency analyses revealed this early effect (150-250 ms time window) as we found a greater desynchronization (ERD) for ironic context compared to literal context in the alpha1 band (8-10Hz) and a greater synchronization (ERS) in the theta band (4-7Hz) when the speaker had a non-sarcastic occupation. This difference was not found for the sarcastic occupation condition. It was concentrated over the central posterior electrodes as well as over the right posterior dorsal electrodes in the alpha1 band. Time frequency analyses also revealed an effect in the upper gamma band (60-80Hz), namely a greater ERS in the ironic context condition compared to the literal context condition for the sarcastic occupation condition. The inverse pattern was found in the no-occupation condition and no difference was revealed in the non-sarcastic occupation condition. These results are in line with those of Regel et al. (2010) who found an early P200 effect of the speaker communicative style on irony interpretation when this communicative style (i.e, ironic versus non-ironic speaker) was congruent with the stimulus condition (i.e., respectively ironic utterances versus literal utterances). Other studies (Spotorno et al., 2013; Regel et al., 2014; Akimoto et al., 2017; Rothermich et., 2022) investigating irony

processing with TFA did not report these activities in an early time window, probably because they did not manipulate speaker information and its impact on irony processing. These results suggest that such early activities in the alpha1, theta and upper gamma bands are prompted by the processing of the speaker information. In line with the literature exploring neural oscillatory activities associated with language prediction, the greater ERS that we observe in the gamma band suggests that sarcastic occupation of the speaker strongly predicts ironic interpretation, especially since such activity was only found in the sarcastic occupation condition. Studies have suggested that an increase in gamma synchronization may reflect the level of upcoming word predictability in a semantically constraining context (Wang et al., 2012; Rommers et al., 2013; Monsalve et al., 2014; Lewis et al., 2015; Wang et al., 2018). In the present study, the speaker occupation predicts the interpretation (ironic or literal) of the target sentence. In other words, when the speaker has a sarcastic occupation, this would constrain the sentence to irony and the ironic interpretation would be expected, while this would not be the case in the literal context condition where the sarcastic occupation did not constrain the literal interpretation. In this condition, memory representation associated with the highly predictable interpretation (i.e., ironic interpretation) is pre-activated. The increased gamma band synchronization in the congruent conditions (speaker sarcastic occupation condition with ironic context condition) reflects the match between this pre-activated representation and the actual interpretation (Lewis et al., 2015). Gamma oscillations have also been found to reflect semantic unification (e.g., Hald et al., 2006; Bastiaansen & Hagoort, 2015; Lam et al., 2016). “*Semantic unification refers to the integration of word meaning into an unfolding representation of the preceding context. ... In the interaction with the preceding sentence or discourse context, the appropriate meaning is selected or constructed, so that a coherent interpretation results.*” (Hagoort et al., 2009, p. 819). Different extra-linguistic information such as knowledge of the speaker or world knowledge has been shown to have an immediate effect on semantic unification (Hagoort et al., 2004; Hagoort 2019). Thus, we suggest that the gamma-band activity we observed in the 150-250 time window following the final critical word onset for the ironic condition compared to the literal condition when the speaker had a sarcastic occupation reflects processes of semantic unification or prediction of the upcoming word in a semantically constraining context. The present study did not enable us to disentangle these two hypotheses.

Our findings regarding the synchronization in the theta band for the non-sarcastic occupation condition were consistent with those of Lam & Hagoort (2016) who observed theta effects specific to the context analysis in the right parietal regions and bilateral frontal regions. In the context of sentence comprehension, theta activity has been interpreted in terms of higher lexical

semantic retrieval demands, for words unexpected after the prior sentence context, and increased working memory demand (Bastiaansen et al., 2005; Lam et al., 2016; Rommers et al., 2017; Meyer, 2018). In the present study, the target word of the final sentence (e.g., *Léa is a helpful neighbor/ Léa est une voisine aidante*) is unexpected after the ironic context compared to the literal context. It has been proposed that the desynchronization in the alpha band reflects increasing processing demands or more extensive processing for irony compared to literal interpretation (Akimoto et al., 2017; See Prytauka & Lewis (2019) for a review). As activity in this alpha band was found for ironic context compared to literal context when the speaker occupation did not cue the ironic interpretation, it makes sense to suggest that this activity reflects the involvement of domain-general mechanisms such as verbal working memory storage (Meyer et al., 2013) or attentional demand during sentence comprehension (Lam et al., 2016). It would require more cognitive resources to interpret the target sentence as ironic when the speaker occupation did not cue such interpretation (Spotorno et al., 2013).

Thus, our results in the 150-250 ms time window suggest that speaker occupation stereotypes allow participants to form strong predictions for the ironic interpretation in the early stage of processing, supporting previous behavioral results from the psycholinguistic literature showing that speaker occupation stereotypes cue ironic intent (Pexman & Olineck, 2002; Champagne-Lavau & Charest, 2015). Our results are also consistent with those of Pexman et al. (2000) who used a moving window task to show that such information on the speaker is taken into account in the early stage of processing even if participants were not required to make any explicit decision about the speaker ironic intent, as in our study.

### **Late processes of pragmatic reanalysis**

In line with the literature described above, other main results of the present study pointed out that inferential processing costs increase when the ironic interpretation was not expected as this is the case when the speaker occupation did not constrain the interpretation (non-sarcastic occupation condition). These main results, though explorative, showed a larger P600 elicited for the ironic context compared to the literal ones when the speaker has a non-sarcastic occupation. This P600 effect elicited in the non-sarcastic occupation condition is in line with results of Regel et al. (2010) and Regel & Gunter (2017) who found such a P600 effect when the ironic interpretation was not cued by the speaker's communicative style or by means of quotation marks coherent to pragmatic conventions for irony. It has been shown to reflect processes of integration of semantic and extra-linguistic information (Lattner & Friederici, 2003). During ironic interpretation, this effect has been interpreted as reflecting late processes of pragmatic inference

and reanalysis, processes required to derive the intended meaning (Regel et al., 2010, 2011; Bouwer et al., 2012) and that are correlated with integration difficulty (Bouwer et al., 2012). These processes would be all the more important as, in contrast to the sarcastic occupation, the speaker non-sarcastic occupation does not constrain the ironic interpretation.

Other main results showed, in this later stage of processing (500-800 ms time window), a greater ERS for literal context compared to ironic context in the beta1 band (14-20Hz) and a greater ERD for ironic context compared to literal context in the alpha2 (11-13Hz) band. In fact, our results reveal that ERD in the alpha2 band was already present in 250-500 ms time window. This effect in the beta band was also reported by Rothermich et al. (2022) in the late time window. It has been proposed to reflect maintenance of the current cognitive set (Lewis et al., 2015 ; Prytauka & Lewis, 2019). Results also showed a greater ERS for ironic context in the theta (4-7 Hz) band and a greater ERD in the alpha1 band. These effects in the theta and alpha1 bands were revealed when the ironic interpretation was not constrained by the speaker's occupation and confirms the results of previous studies showing theta-band (Spotorno et al., 2013; Regel et al., 2014; Akimoto et al., 2017) and alpha-band activity (Spotorno et al., 2013; Akimoto et al., 2017; Rothermich et al., 2022) in the same time window when comparing the processing of ironic stimuli to literal stimuli. Thus, we suggest that, in the ironic condition, the contextual incongruity between the context and the target sentence leads to a pragmatic reanalysis of the target sentence in order to derive the ironic interpretation. We wish to highlight that the pairwise comparisons results, observed in the 500-800 ms time window revealing a difference between ironic and literal context for the speaker non-sarcastic occupation condition were explorative since we performed them based on visual inspection or marginal significant interaction. While achieved power reported for these results were higher than 50% (below which the statistical power is considered low), most of them were lower than the typically recommended one (80%). Thus, these results should be considered with caution and confirmed with a larger sample of participants.

Results obtained in the 500-800 ms time window could be interpreted in two different ways. A first hypothesis could be that the speaker non-sarcastic occupation does not constrain the ironic interpretation while the sarcastic occupation constrains it. As a consequence, the revision of the ongoing interpretation increases the working memory demand compared to the literal condition where interpretation did not have to be revised (the final target word is expected), and compared to the condition where the speaker has a sarcastic occupation that cues ironic interpretation where such theta activity was not found. A second hypothesis could be that the non-sarcastic occupation constrains expectations towards a literal interpretation leading to an increase of

processing demand for the non-sarcastic occupation when the context is ironic. Both hypotheses are valid if we rely only on the results in the 500-800 ms time window, i.e., the lack of difference between ironic and literal context conditions for the no occupation and the sarcastic occupation conditions in the theta and alpha1 bands. But given that the results obtained in the 150-250 ms time window for the upper gamma band are not compatible with the second hypothesis, they allow us to disentangle these two hypotheses. If the second hypothesis was valid, we would expect a greater ERS in literal context compared to ironic context for the non-sarcastic occupation condition in this frequency-band. We did not find such an effect. Taken together, these theta, alpha1 and gamma frequency-band activities suggest that the speaker non-sarcastic occupation would not constrain the ironic interpretation. In addition, upper gamma band results were different in the sarcastic occupation and the no occupation conditions; we found a greater ERS in the literal context condition for the no occupation and a greater ERS in the ironic context condition for the sarcastic occupation. In other words, the pattern of greater ERS observed in this frequency-band respectively suggest that the speaker no occupation predicts the literal interpretation while the speaker sarcastic occupation predicts the ironic interpretation. The lack of difference between ironic and literal context conditions for the sarcastic occupation and no occupation conditions in the alpha1 and theta bands could reflect a low-cost processing in terms of cognitive resources explained by the fact that these occupation conditions constrain the ironic interpretation and the literal interpretation respectively.

### **Integration of information on the speaker with linguistic information (constraint satisfaction model)**

Taken as a whole, our findings support predictions of the constraint satisfaction model (Pexman et al., 2000; Katz, 2005; Pexman, 2008; Campbell & Katz, 2012; Rivière & Champagne-Lavau, 2020) suggesting that during irony understanding, extra-linguistic information such as information on the speaker is used as soon as it is available, in the early stage of processing. This type of extra-linguistic and linguistic information are continuously evaluated and integrated during the process of irony understanding leading to an ironic interpretation that fits the available information (Pexman et al., 2000). In the present study, when the speaker had a sarcastic occupation (e.g., actor), this information constraining the interpretation of the speaker utterance as ironic was used immediately, in the early stages of the comprehension, leading to lower processing cost. Whereas if the speaker occupation did not constrain the ironic interpretation (non-sarcastic occupation, e.g., chef), the interpretation of the sentence as ironic was more time consuming and resource-demanding requiring pragmatic reanalysis, as shown mainly by the

synchronization in the theta band and the desynchronization in the alpha band (in the 500-800ms time window) for the non-sarcastic occupation condition.

Our results, in line with those of Pexman et al. (2000), suggest that constraints related to the speaker occupation stereotypes were created through a general impression formed automatically rather than by a motivated perception of speaker identity since participants were not asked to make an explicit decision about the speaker ironic intent. In both studies, they had to answer a comprehension question about information presented in the context. According to Utsumi (2000), speakers indirectly express a negative attitude toward a situation when they utter an ironic statement. Speaker occupation stereotypes activate characteristics of the speakers that contribute or not to the expression of this negative attitude. Pexman & Olineck (2002) showed that members of the sarcastic occupations (e.g. actor) are characterized by their tendency to be funnier, more critical, and less sincere than members of the non-sarcastic occupations (e.g. clergyman). Thus, sarcastic speaker occupations cue ironic interpretation because they convey this negative attitude through these characteristics. As described in the literature (see Thagart & Kunda, 1996; Quadflieg & Macrae, 2011 for a review), stereotypes affect the meaning of behavior. Stereotypes activation is enhanced when people encounter a target in an expected situation, like sarcastic speaker occupation in ironic context in the present study.

## **Conclusion**

Our findings regarding the impact of knowledge on the speaker (i.e., stereotypes on the speaker's occupation) on the interpretation of target sentences as ironic or not confirm those of Lattner & Friederici (2003) and Van Berkum et al. (2008) which showed a similar effect on literal language comprehension by manipulating speaker information like gender or speaker identity conveyed by his/her voice. Time-frequency analyses highlighted that speaker characteristics conveyed by occupation stereotypes influence early-on the linguistic comprehension process. This is particularly obvious in the understanding of irony where this social extra-linguistic knowledge is integrated with linguistic and contextual information to constrain the interpretation. Such results support predictions of the constraint satisfaction according to which multiple sources of information are used as soon as they are available, in the early stage of processing.

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**Declaration of interest statement**

The authors report there are no competing interest to declare.

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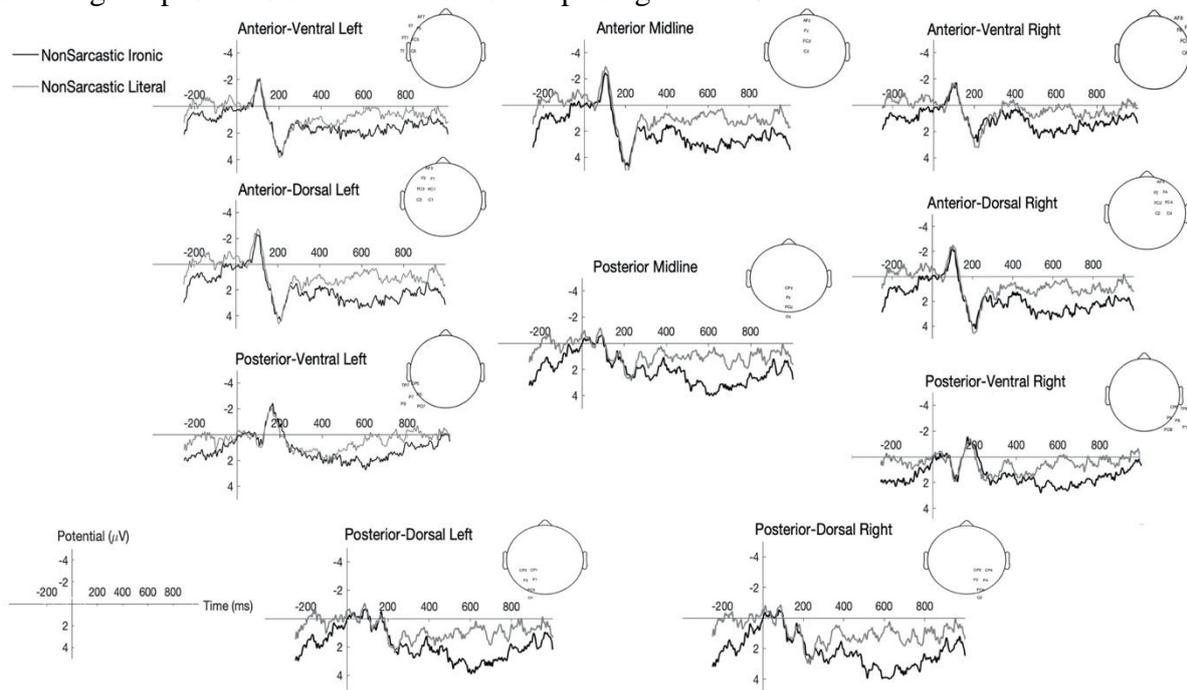
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## Table and Figures

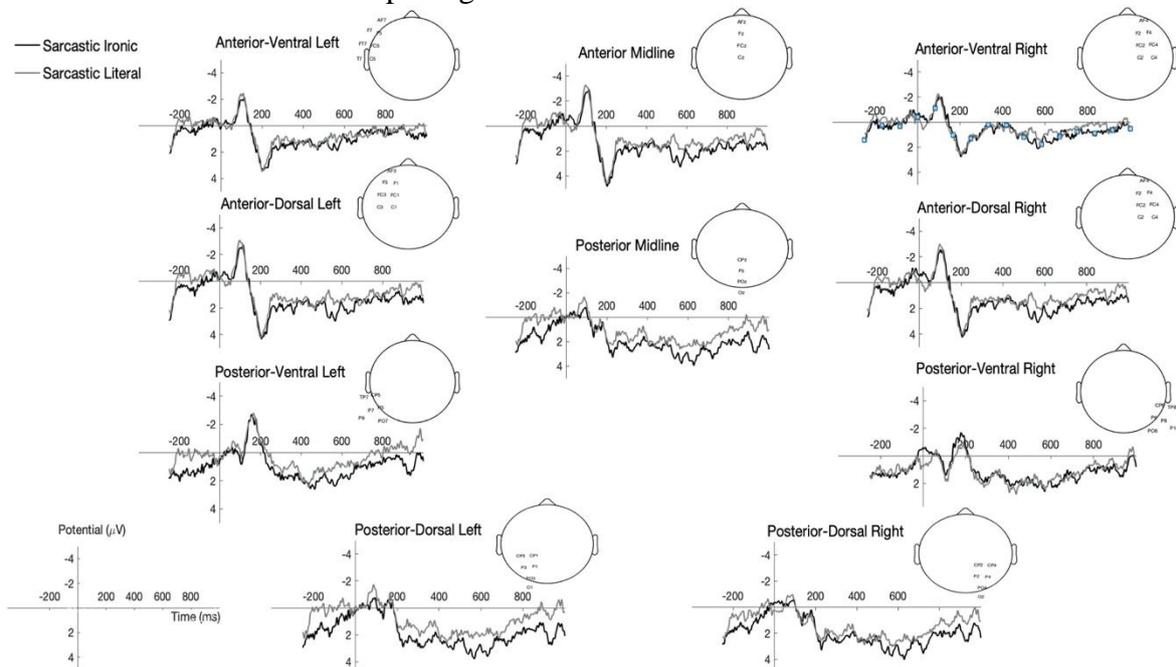
Table1. Example of stimulus translated from French

	<b>Ironic condition</b>	<b>Literal condition</b>
<b>Non-sarcastic occupation</b>	<p>A <b>chef</b> works with his cousin Claire in his restaurant. <i>Customers are unhappy because the food arrives late.</i> The <b>chef</b> says: “<u>Claire is an efficient worker</u>”.</p> <p>Un <b>chef cuisinier</b> travaille avec sa cousine Claire dans son restaurant. <i>Les clients sont mécontents car les plats arrivent tardivement.</i> Le <b>chef cuisinier</b> dit : « <u>Claire est une employée efficace</u> »</p>	<p>A <b>chef</b> works with his cousin Claire in his restaurant. <i>Customers find that food always arrives quickly.</i> The <b>chef</b> says: “<u>Claire is an efficient worker</u>”.</p> <p>Un <b>chef cuisinier</b> travaille avec sa cousine Claire dans son restaurant. <i>Les clients trouvent que les plats arrivent toujours rapidement.</i> Le <b>chef cuisinier</b> dit : « <u>Claire est une employée efficace</u> ».</p>
<b>Sarcastic occupation</b>	<p>An <b>actor</b> is invited to attend his friend Melanie’s dance show . <i>She falls several times during her poor performance.</i> The <b>actor</b> says: “<u>Melanie is a graceful dancer</u>”.</p> <p>Un <b>comédien</b> est invité à assister au spectacle de danse de son amie Mélanie. <i>Mélanie tombe plusieurs fois durant sa mauvaise performance.</i> Le <b>comédien</b> dit : « <u>Mélanie est une danseuse gracieuse</u> ».</p>	<p>An <b>actor</b> is invited to attend his friend Melanie’s dance show. <i>She makes a performance that dazzles all the spectators.</i> The <b>actor</b> says: “<u>Melanie is a graceful dancer</u>”.</p> <p>Un <b>comédien</b> est invité à assister au spectacle de danse de son amie Mélanie. <i>Mélanie fait une performance qui éblouit tous les spectateurs.</i> Le <b>comédien</b> dit : « <u>Mélanie est une danseuse gracieuse</u> ».</p>
<b>Filler</b>	<p>Louise is moving house today and Michel told her that he would come and help her. <i>Michel never came and never gave any news.</i> Louise says: “<u>Michel is a nice man</u>”.</p> <p>Louise déménage aujourd’hui et Michel lui a dit qu’il viendrait l’aider. <i>Michel n’est jamais venu et n’a jamais donné de nouvelles.</i> Louise dit : « <u>Michel est un homme gentil</u> ».</p>	<p>Louise is moving house today and Michel told her that he would come and help her. <i>Michel arrives on time and he helps her to move.</i> Louise says: “<u>Michel is a nice man</u>”.</p> <p>Louise déménage aujourd’hui et Michel lui a dit qu’il viendrait l’aider. <i>Michel vient tôt le matin et aide même Louise à défaire ses cartons après le déménagement.</i> Louise dit : « <u>Michel est un homme gentil</u> ».</p>

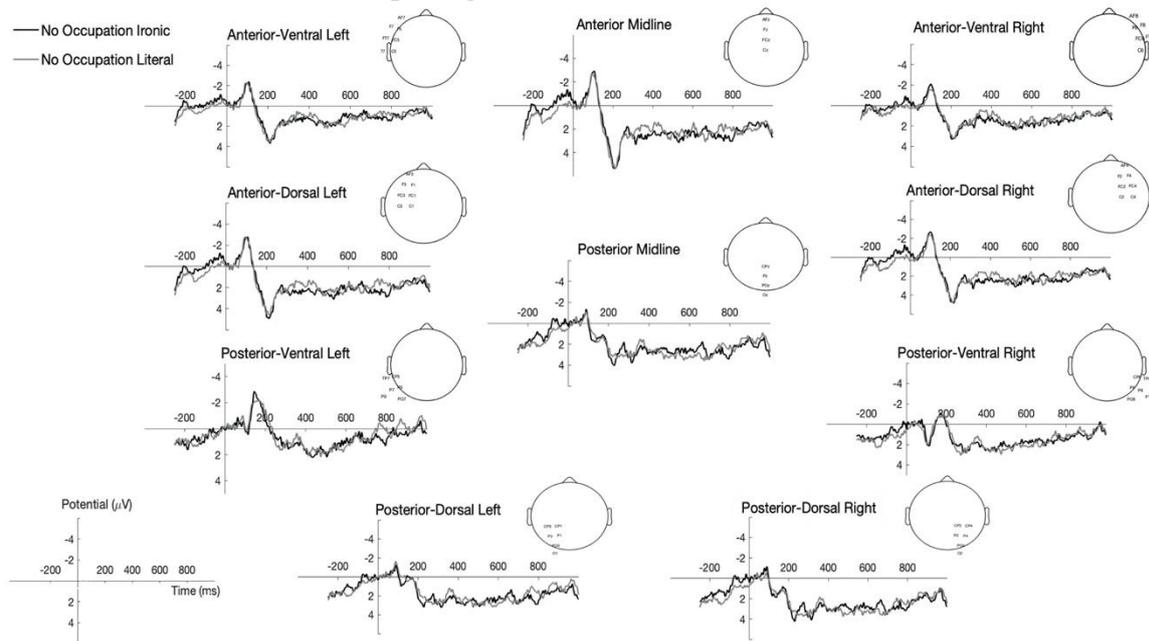
**Figure 1a:** ERPs of Ironic vs. Literal context condition for the Non sarcastic occupation condition. The average ERP over each of the ten ROIs are presented along with the headplot showing the positions of the electrodes comprising each ROI.



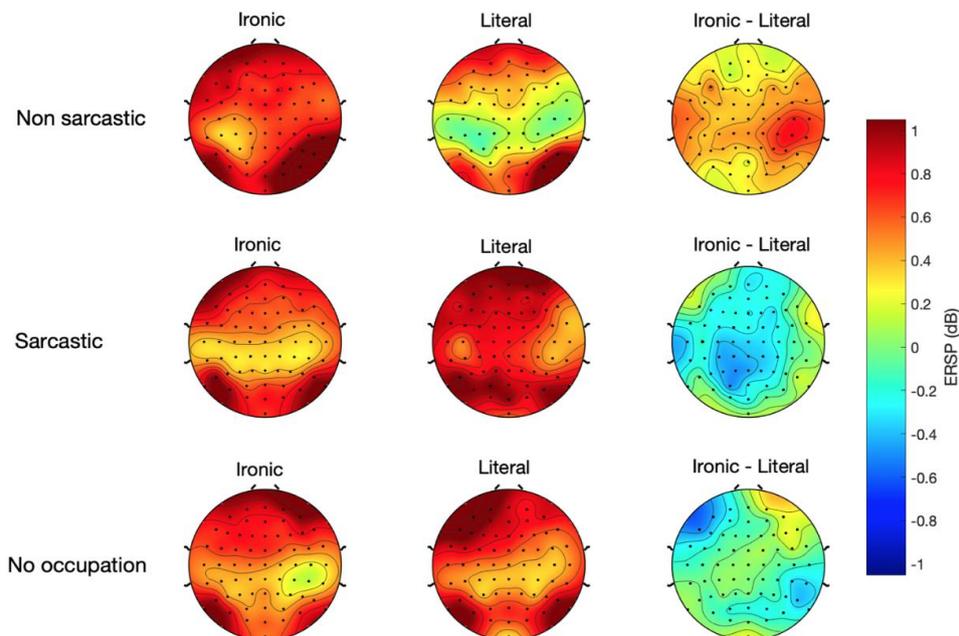
**Figure 1b:** ERPs of Ironic vs. Literal context condition for the Sarcastic occupation condition. The average ERP over each of the ten ROIs are presented along with the headplot showing the positions of the electrodes comprising each ROI.



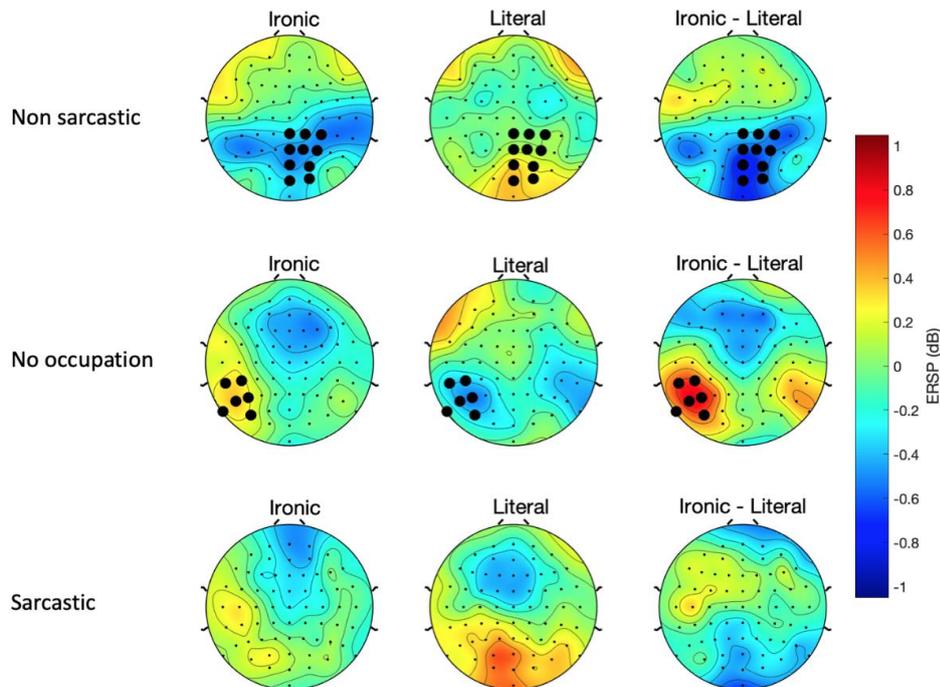
**Figure 1c:** ERPs of Ironic vs. Literal context condition for the No occupation condition. The average ERP over each of the ten ROIs are presented along with the headplot showing the positions of the electrodes comprising each ROI.



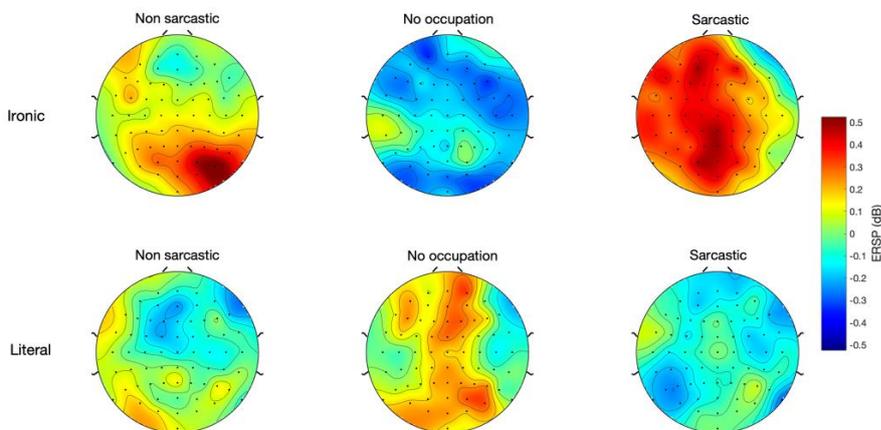
**Figure 2:** Topographic maps of grand average theta frequency band (4-7Hz) over the early window (150-250ms) for Ironic vs. Literal contexts for (top) Non sarcastic, (middle) Sarcastic and (bottom) No occupation conditions. For each occupation-type condition, the Ironic – Literal difference is plotted.



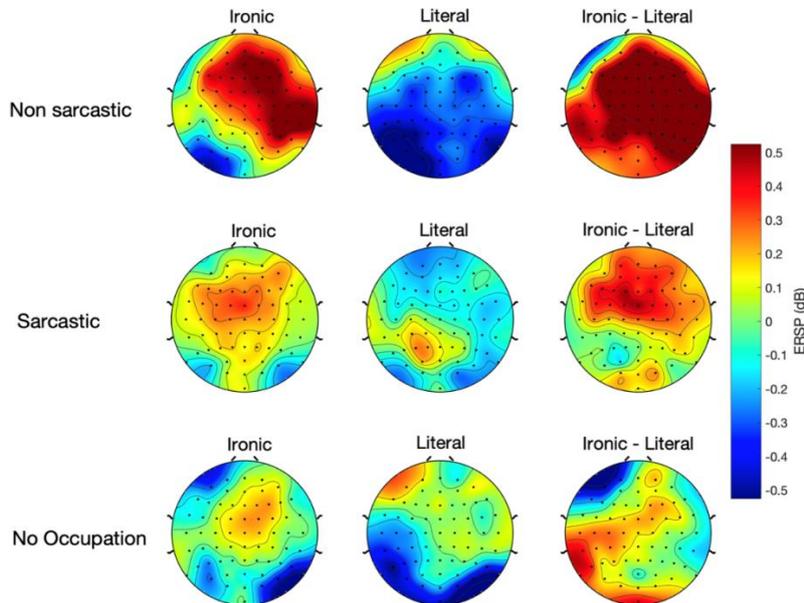
**Figure 3:** Topographic maps of grand average alpha activity over early time window (150-250ms) for (top) Non-Sarcastic (middle) No occupation and (bottom) Sarcastic conditions. For each occupation type, Ironic and Literal conditions and the Ironic – Literal difference are presented. To highlight the context x occupation x ROI interaction found by statistical analysis, the midline posterior and right posterior dorsal electrodes are highlighted for the Non-Sarcastic condition and the left posterior ventral electrodes are highlighted for the No Occupation condition.



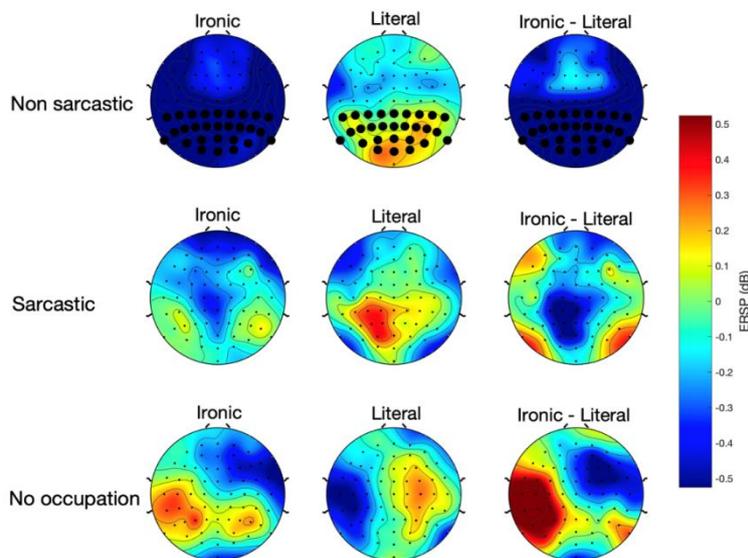
**Figure 4:** Topographic maps of grand average gamma2 activity over early time window (150-250ms) for (top) Ironic: Non-sarcastic, No occupation and Sarcastic and (bottom) Literal: Non-sarcastic, No occupation and Sarcastic occupation conditions



**Figure 5:** Topographic maps of grand average theta (4-7Hz) activity over the 500-800ms time window for all three occupation conditions: (Top) Non-sarcastic, (middle) Sarcastic and (bottom) No occupation. For each occupation condition, Ironic and Literal context conditions and the Ironic – Literal difference are presented.

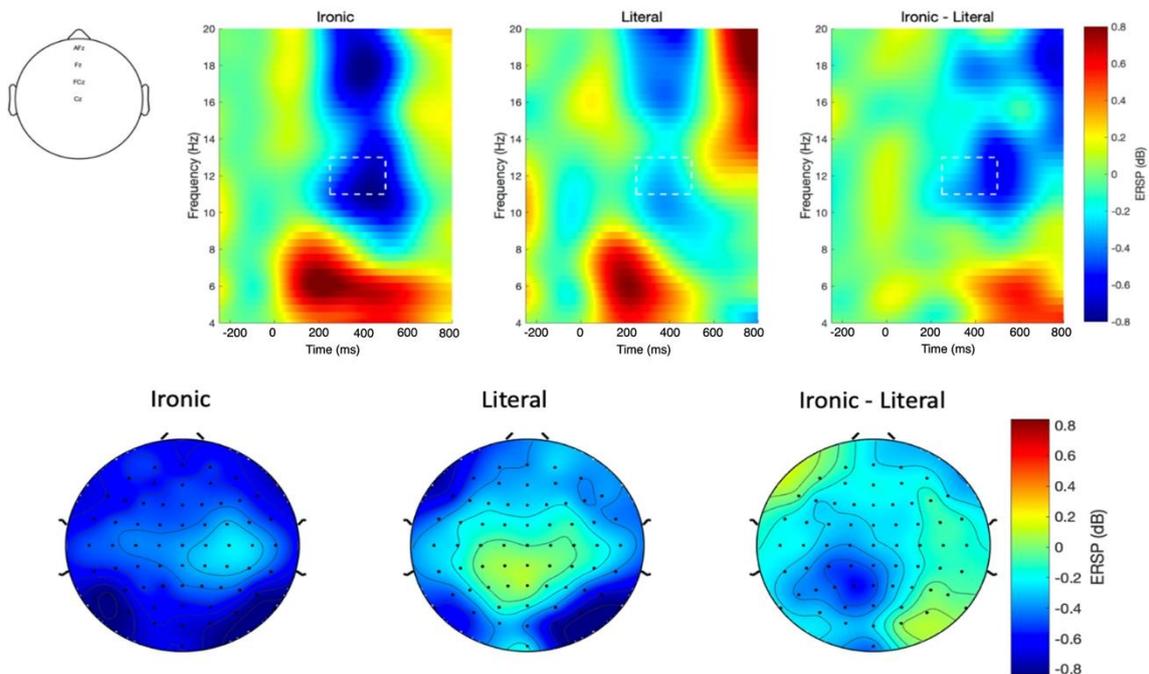


**Figure 6:** Topographic maps of grand average alpha (8-10Hz) activity over the 500-800ms time window for all three occupation conditions: (Top) Non-sarcastic, (middle) Sarcastic and (bottom) No occupation. For each occupation condition, Ironic and Literal context conditions and the Ironic – Literal difference are presented. For the Non sarcastic occupation condition the electrodes comprising the left posterior dorsal and ventral, the posterior central and right posterior dorsal and ventral are highlighted to indicate the significant context x occupation x ROI effect.

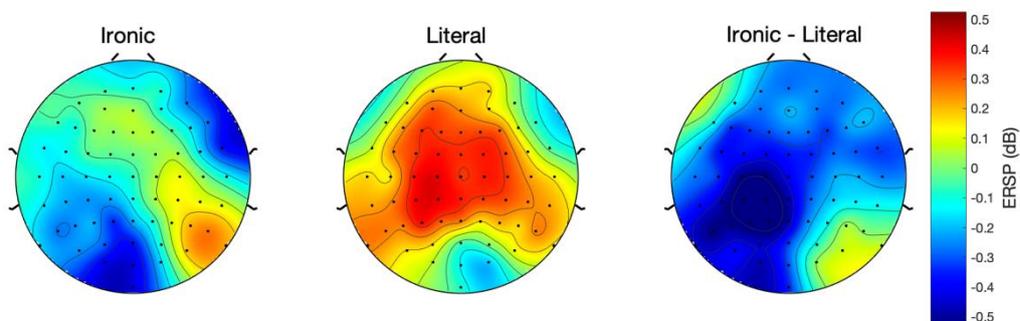


## Supplemental data

**Figure 7: (Top).** Time-frequency map of grand average ERSP over the Anterior Central ROI for (left) Ironic (NSI + SI + NoI), (middle) Literal (NSL + SL + NoL) and (right) Ironic – Literal difference. The tile-frequency region corresponding to the middle time window (250-500ms) and the alpha2 frequency band (11-13Hz) is highlighted. Those electrodes comprising the Anterior Central ROI are presented to the left. **(Bottom).** Topographic maps of grand average alpha2 (11-13Hz) activity over the 250-500ms time window for (left) Ironic (NSI + SI + NoI), (middle) Literal (NSL + SL + NoL) and (right) Ironic – Literal difference.



**Figure 8:** Topographic maps of grand average alpha2 (11-13Hz) activity over the 500-800ms time window for (left) Ironic (NSI + SI + NoI), (middle) Literal (NSL + SL + NoL) and (right) Literal – Ironic difference.



**Figure 9:** Topographic maps of grand average beta1 (14-20Hz) activity over the 500-800ms time window for (left) Ironic (NSI + SI + NoI), (middle) Literal (NSL + SL + NoL) and (right) Literal – Ironic difference.

