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The Social Sense of Belief-based Action Prediction in Adults

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ABSTRACT

The social dimension plays a decisive role in our life, shaping our cognitive abilities in relation to the world. Successful social interactions essentially depend on the ability to track the mental states of others, and to make use of this knowledge to predict how these internal states will influence their behavior. However, the way social relationships are built, determines how we perceive and predict others' actions. In relation to this, there are specific cues that bias people's social perception, and induce them to form certain affiliations with particular others. Specifically, in the current study we asked whether the generation of action predictions can be modulated by two social cues. First, by means of the perception of an individual as one's own social group depending on the native language; and second, through the attribution of specific attentional attachment as a result of the socio-economic status. The indication of action prediction was assessed by a false belief task, analysing the sensorimotor beta suppression as a measure of motor cortex activation. The task was performed by an agent with a higher status, an agent with a lower status, and an agent speaking a foreign language that participants could not understand. Results show two types of patterning: on the one hand, the prediction of an action given a false belief is more accurate when the intentions are held by a person that has been distinguished as highly profiled. On the other hand, false belief action predictions become softened and dispersed when the person do not seem to catch our social attention nor our in-group preference. Hence, this mechanism for inferring others' mental states and behaviors seem to have a crucial social sense for interpersonal understanding and, therefore, to be one essential requirement for the development of social structures in human society.

Key words: Theory of Mind; Social cognition; Action prediction; False belief task

INTRODUCTION

Humans have several cognitive abilities in the social domain involving communication, social learning, mind-reading or imitation, without which our society would be barely imaginable. As a matter of fact, successful social interactions critically depend on the ability to track the mental states of others and infer their intentions and beliefs. Human beings are guided by internal states, and the aptitude at

inferring others' mental states, might be seen as one of the evolutionary requirements for the development of the cooperative social structure in human societies (Meltzoff, 1999; Ward, 2012).

The ability to think about what others know or believe, and the fact of using this knowledge to generate predictions about how mental states will influence the behavior is referred as Theory of Mind (ToM). However, the foundational dexterity is not only inferring what other people are thinking, believing, intending, perceiving or desiring, but rather understanding their intentions of interpreting what is being precisely done at the moment. Then, it is the way for humans to understand the perceptions of others and predict their deliberate actions, what creates these species-unique processes of cultural cognition and evolution (Kovács, Téglás, & Endress, 2010).

Mechanisms of emotion and action understanding

The neural mechanisms that allow us to directly process the mental states supporting this social behaviour remain largely unexplored (Rakoczy, 2014). Some research posits that mentalizing is a developmentally protracted ability tied to conceptual reasoning, and that an accurate prediction of someone's behaviour is usually computed through different stages. First, one needs to identify the goal impelling others' actions. Second, it is necessary to think what the others believe about it and, finally, one has to use these meta-representations to predict how they are going to influence their behavior (Southgate & Vernetti, 2014).

Even though it was first assumed as a thoughtful capacity acquired well after the first year of life, it has been recently demonstrated that even 6 and 7-month-old infants have an early developing ability to interpret the action of others as goal-directed, attribute to them some intentionality and generate action predictions (Kovács et al., 2010; Southgate & Vernetti, 2014; Kim & Song, 2015). This may suggest that humans automatically compute others' beliefs as a parallel representation of the environment, which can potentially influence their own behavior similarly to their own beliefs (Van Der Wel, Sebanz, & Knoblich, 2014). Nonetheless, there is still much contradictory evidence concerning the extent to which such automatic sensitivity to others' mental states should be interpreted as a genuine understanding of belief (Daum, Attig, Gunawan, Prinz, & Gredebäck, 2012).

Notwithstanding, according to some researchers, the ToM mechanism is solved in such a way that, to directly understand the meaning of the actions of others, it is necessary to internally replicate or recreate the mental processes on ourselves without any explicit mediation (Gallese, Keysers, & Rizzolatti, 2004; Iacoboni, 2009; Rizzolatti & Fabbri-Destro, 2008). Within this simulat-simulating framework, Gallagher distinguished two slants inside the so-called Simulation theory: one more

explicit, by creating a narrative-like simulation of someone else's situation to understand it; and another more implicit, in which we might unconsciously activate the neural substrates for producing the same situation in our own brain (Gallagher, 2007). In fact, this latter version is used as a base to build the idea of an unconscious coupling of perception and action in the current study.

In relation to the possible neural mechanisms of interpersonal understanding, here it will be argued that the capacity to directly grasp in the mind of others is mediated by structures within the mirror neuron system, that are thought to be involved in shared sensorimotor representations (Gallese et al., 2004; Iacoboni, 2009). The novelty of this approach is based on the fact that this mechanism, rather than transforming action-related sensory information into a motor format, implements the motor activation as the result of goal identification of an impending action. Thus, to understand others' behaviors, intentions and goals, specific brain areas of our motor system are recruited to generate predictions about others' mental states and their consecutive actions (Gallese et al., 2004; Southgate & Begus, 2013).

Basis of social cognition and interpersonal understanding

Humans tend to define themselves socially, in terms of specific associations with particular others. The social and cultural identity of a person can be well constructed in terms of the different groups she or he belongs to, and the shared roles that join individuals together. For instance, representing oneself in a group in relation to the nationality, ethnicity, religion, political allegiance or socio-economic status, because of the common traditions, skills, rituals, norms or expectations that are comprised as common attributes of the group (Ward, 2012).

There is a tendency to align with our fellow group members and make ourselves similar to the people around us. In fact, it is not surprising to think that our learning is influenced by the model's group membership. For example, it has been observed that 14-month-old infants already selectively imitate and adopt the social functions of in-group versus out-group members (Buttelmann, Zmyj, Daum, & Carpenter, 2013). And, there is also evidence that even preverbal infants, as well as adults, conform to affiliates of their social group and also expect them to act alike (Powell & Spelke, 2013; Abrams et al., 2014).

In fact, this automatic imitation or transmission might be seen as a way of affiliation, alignment or identification with others during early and later-development. With or without an extensive intergroup experience, we tend to perceive social groups as sharing behavioral tendencies and traits,

and then we use this knowledge to predict and explain the behavior of these particular group members.

One specific cue for in-group membership is language, which may be seen as a potential source of information that is relevant in our community or culture. Given that language perception triggers assumptions about the social significance and power of people, and their national, social and ethnic group identity, it appears to be one of the most important cues to differentiate group membership.

There is a deeply rooted connection between language and social cognition that guides the development of social preferences to interact with members of our own linguistic group. Young infants look reliably longer at, and demonstrate selectivity towards information from people that speak in their native language. Infants also show a tendency to select as friends and accept toys from native speakers (Kinzler, Dupoux, & Spelke, 2007; Rakoczy, 2014) . Even variations in accent are sufficient to shift social predisposition, a preference that has been observed in infants that are not still able to produce or comprehend speech to older children that are fully capable of understanding the foreign-accented speech (Kinzler, Corriveau, & Harris, 2011).

In contrast, it has been observed a preference for unfamiliar characteristics of individuals under certain conditions. As example, recent research in adult Social Psychology has demonstrated that in a context of competition and manipulation, people can be more willing to interpret and understand the perspectives of out-group members than that of in-group members (Todd, Hanko, Galinsky, & Mussweiler, 2011). However, there is wide evidence that further supports the human tendency to divide the social world into groups, preferring the interaction with members of their own group and disfavoring others. Actually, this merely reflects the fact that these close social affiliations are decisive for interpersonal understanding and interpretation, imitation, cooperation, compliance, conformity and trust.

Besides the development of linguistic group preference, there is another sheltered component under the umbrella of social perception that also triggers specific social associations: the establishment of social hierarchies. People tend to consider people in terms of social categories given the assessment of a collection of behavioral cues (e.g. posture, face cues, pride), the skills qualification and the success (e.g. social, economic, educational). And, in turn, much of this patterning imposed to human perception tend to bias our interpersonal understanding, and our behaviors and roles inside the society (Cummins, 2005; Ward, 2012).

There is ample evidence supporting the impact of social hierarchy perception in several cognitive processes. It has been recently demonstrated the importance of social status in perceiving specific cues, such as faces and emotions. In fact, high-status faces seem to be recognized significantly better than low-status faces, because they are better attended and processed more accurately than low-status faces. Furthermore, the facial expression of specific emotions is perceived sooner and tend to last longer for those faces corresponding to high-status individuals compared to low-status individuals (Dalmaso, Galfano, Coricelli, & Castelli, 2014).

More relevant for the present study, it has been demonstrated that the individuals included in a high status rank tend to receive more attention than the individuals perceived in a low status rank. Social attention can be defined as the ability to change the direction of attention in response to specific social cues that are perceived from others, like gaze, head and body orientation. These visual signals underlying social attention allow individuals to infer different elements provided by others, especially for the case of their current goals, beliefs and intentions (Nummenmaa & Calder, 2009; Shepherd, 2010; Beasley, Sabatinelli, & Obasi, 2012).

Regarding this, it has also been found an effect of social hierarchy perception on the executive function. There are studies demonstrating the impact of social status on the capacity of monitoring the environment and the performance. For example, high profiled individuals are better in distinguishing goal-directed actions and have better abilities in performing specific goal-directed tasks. So, social status has a clear role in regulating social interactions among humans, which can be reflected on the ability to attract the attention, admiration, and performance of others (Boksem, Kostermans, Milivojevic, & De cremer, 2012; Prabhakaran & Gray, 2012).

Current study

Over the last decades there is an emerging interest in social cognition and its relations with ToM. As an example, it has been recently found that a higher capacity to mentalize in infants was systematically related with a facilitation at inferring and anticipating social inclusion on the basis of social atypicality in intergroup contexts (Abrams et al., 2014). But so far, there is no investigation of how social cognition is related to the aptitude of thinking about individuals as affiliates of a social group; but neither how social cognition is associated to the ability of predicting a certain action, depending on the ascribed mental states of these individuals.

The current study analyses the connection between the social perception and the ability to understand the mental states of others, and the capacity to predict their behavior given our

disposition to track events from their perspectives. Specifically, it investigates if the generation of action prediction can be modulated by the perception of an agent as one's own social group depending on her native-language speech, or by the attribution of special social attention depending on her socio-economic status.

We sought evidence that the meta-representations of others may be influenced by the perception of those individuals as members of their own group, and by the development of specific attentional attachment. Intuitively, one expect to comprehend better in-group over out-group individuals, and to readily shift the attention towards high-profiled individuals as opposed to low-profiled ones; something that goes along with an increase of accurateness at attributing their mental states and predicting their behavior. So, in a broad sense, this work addresses how the social perceptual bias influences people's impressions about the inner qualities and outward behaviors of other individuals.

The approach to measure action prediction in adults will be the motor activation in the sensorimotor cortex recordable on EEG as a decrease in the beta rhythm. Moreover, this frequency reduction associated with cortical processing of action-related information, is thought to be due to a desynchronization of beta rhythm activity. In previous research, it has been demonstrated that motor cortex activation is correlated with the prediction of an action. This even occurs during the anticipation of non-executable actions in infants, and during the identification of a goal irrespectively of motor correspondence for both infants and adults ([Gergely & Csibra, 2008](#); [Southgate & Begus, 2013](#)).

There is evidence that mu and alpha frequency bands are also sensorimotor rhythms that modify the pattern of electrical activity, as a result of a goal-directed action representation. Actually, it has been found both in infants and adults, a decrease of these frequency bands linked to action perception, production and anticipation, suggesting these neural rhythms as another possibility of measuring the mirror neuron activity ([Southgate, Johnson, Osborne, & Csibra, 2009](#); [Marshall & Meltzoff, 2012](#); [Ward, 2012](#); [Southgate & Verneti, 2014](#)). However, here it will be primarily assessed the beta rhythm, emulating the experimental procedure of [Southgate & Verneti, 2014](#).

This account would predict a correlation between the tendency to represent an ideomotor action and the ability to empathise with the person that is going to execute it. Theories of empathy have suggested that there are subtle, but potentially crucial different ways to accurately understand people's emotions that directly engage some cognitive brain regions related to affective and motor processing. As a matter of fact, evidence has demonstrated that individuals, observing other people

experiencing highly sensitive emotions and performing specific goal-directed actions, engage the same neural substrates that are also operative when the observers are the ones that undergo these emotional and motor events. So, this poses that neural mirroring engaging sensorimotor areas solves the problem of empathy, by accessing and understanding the minds of others (Iacoboni, 2009; Zaki, Bolger, & Ochsner, 2009).

In this study, action prediction is assessed through the false-belief task, where subjects will predict a person's behavior based on the person's false belief while ignoring their own true belief. The stimuli presented are four belief scenarios that generate different action predictions depending on the Agents' beliefs (A) and the Observers' beliefs (O). These conditions are accomplished by changing the position of a ball inside/outside a box with the agent present/absent in the scene.

In the True Positive belief condition (A+O+) both believe the ball to be hidden inside a box placed in front of the agent, whereas in the True Negative belief condition (A-O-) neither the participant nor the agent believe the ball to be occluded in the box. During the False Positive belief (A+O-) only the agent falsely thinks the ball to be inside the box, because she was out of scene when the ball rolled away; while in the False Negative belief (A-O+) is the agent but not the observer who has the false belief about the ball's location outside the box, because she was absent when the ball returned.

These conditions are performed by three different agents that are introduced themselves before performing the experiment. As noted before, these agents are rated as in-group or out-group members given their native or foreign language speech, but they are also categorised into a higher or a lower socio-economic status. Thus, we expect to see discordant motor components depending on each of the scenarios generated by the different conditions and agents.

The first effect we expect to see is a different generation of action prediction depending on false belief scenarios. We hypothesise that the false belief condition (False Positive A+O-) and the true belief condition (True Positive A+O+) elicit a similar motor activation because of an expectation of the agent's action to reach the ball. This increase of motor activation is measured as a decrease in sensorimotor beta suppression that takes place when the participants expect the agent to reach for the box, basing their action prediction on what the agent believed to be the case.

As opposite, we hypothesise that the false belief condition (False Negative A-O+) and the negative belief condition (True Negative A-O-) would not elicit activity in the motor activation and sensorimotor beta suppression due to the absence of expectation of action.

The second effect we expect to see is a different generation of action prediction depending on the social status and the language speech. We hypothesise that in case of a high social status, the subjects would care more about the agent's belief (A+ or A-), in comparison to low social status, in which case the subjects would care more about the presence or not of the ball (O- or O+). In the same way, we also hypothesise that for the conditions related to the native language speakers, subjects would focus more on the agent's belief (A+ or A-); whereas for the foreign language speakers, participants would concern more about the presence or not of the ball (O- or O+).

Thus, in the cases of high social status and native language, we expect to observe higher desynchrony between A+O+ and A+O-. Otherwise, in the situations of low social status and foreign language we expect to see higher desynchrony between A+O- and A-O-, and between A-O+ and A+O+; but we expect to see lower desynchrony between A+O- and A+O+, and between A-O+ and A-O-. Therefore, we predict a similar pattern for the experimental conditions associated to the lower social profile and the foreign language profile.

This proposal incorporates an underlying mechanism that relates in some way our capacity to share meaning actions, intentions and emotions. It is likely that the role of the motor system in action anticipation can be underpinned by the social identification with others, that is, having higher sensitivity to other's mental states facilitates us to predict what others will do next.

METHODS

Participants

Ten right-handed female students (mean age of 23.3 years) contributed to the final sample of the study. Two participants were tested but excluded because of excessive noise and technical noise during data acquisition. Participants were randomly assigned to four different groups depending on the order of the assigned agent and psychological profile (see [Appendix Table 2](#)).

All the participants were tested at the laboratory of Neuroscience at Pompeu Fabra University. Participants were not informed about the purpose of the studies in advance; they were told to perform a visual detection task. The participation was voluntary, and the participants signed an informed consent form before the study was initiated. Participants received monetary compensation for participation.

Stimuli

The stimuli consisted of two types of animated movies, an Introduction video of the agent and the Test trials. All videos were presented on a (24.1") screen.

The Introduction video started with one of three different female agents introducing herself during approximately 40 seconds, and placed in front of a table with a closed box (see Appendix Figure 1). There were three different agents corresponding to three distinct psychological profiles: one of them introduced herself in a native language as a successful person with a medium/high socio-economic status, another introduced herself in a native language as an unprosperous person characterized by a lower socio-economic status, while the third presented herself in a foreign language (German) that participants could not understand (see Appendix of Profile's text).

The Test trials consisted in videos of 11 seconds where the agent performed four belief conditions, each paired with two different outcomes (ball present inside the box and ball absent): A+O+ (True Positive belief), A+O- (False Positive belief), A-O- (True Negative belief), A-O+ (False Negative belief) (see figure 1). Remarkably, the agent's true or false beliefs were never mentioned during the study and were irrelevant to the task.

In the video corresponding to the **True Positive** condition (**A+O+**) first the agent appears, then the lid of the box opens, the ball rolls towards jumping into the box. The box closes and the ball remains hidden inside the box. A curtain is pulled down occluding the agent but not the closed box. The ball is staying inside the box. When the curtain is raised, revealing the agent placed stationary and looking downward at the box. Then the agent remains stationary (1500 ms) before reaching towards and grasping the ball (1500 ms). Here, both the participant and the agent belief the ball to be inside the box.

In the **False Positive** condition (**A+O-**) the trial also begins with the ball rolling towards and jumping into the box. After the curtain is pulled down, the box opens again and the ball jumps out and rolls out of the scene. The lid then closes and the curtain is raised revealing the agent on the scene. At this point, the agent behaved with her belief, first she remained stationary (1500 ms) and then she reached and grasped the lid of the box. The agent had the *false belief* of the ball being inside the box.

In the **True Negative** condition (**A-O-**) first the agent appears, the box opens and the ball jumps out rolling away from the scene. The box closes and a curtain is pulled down occluding the agent and

leaving her out of the scene. The ball does not re-enter the box so, when the curtain is pulled up and the agent appears, the agent remains stationary looking downward the box (3000 ms). Both the participant and the agent believe that there is no ball inside the box.

In the **False Negative** condition (**A-O+**), the test trial also begins with the box that opens and the ball that jumps out, rolling away from the scene. After the curtain is pulled down, the lid of the box opens again and the ball re-enters the scene, rolling towards and jumping into the box. The lid then closes and the curtain is raised revealing again the agent. At this point, the agent remained stationary looking the closed box (3000 ms). The agent had the *false belief* of the ball being outside the box.

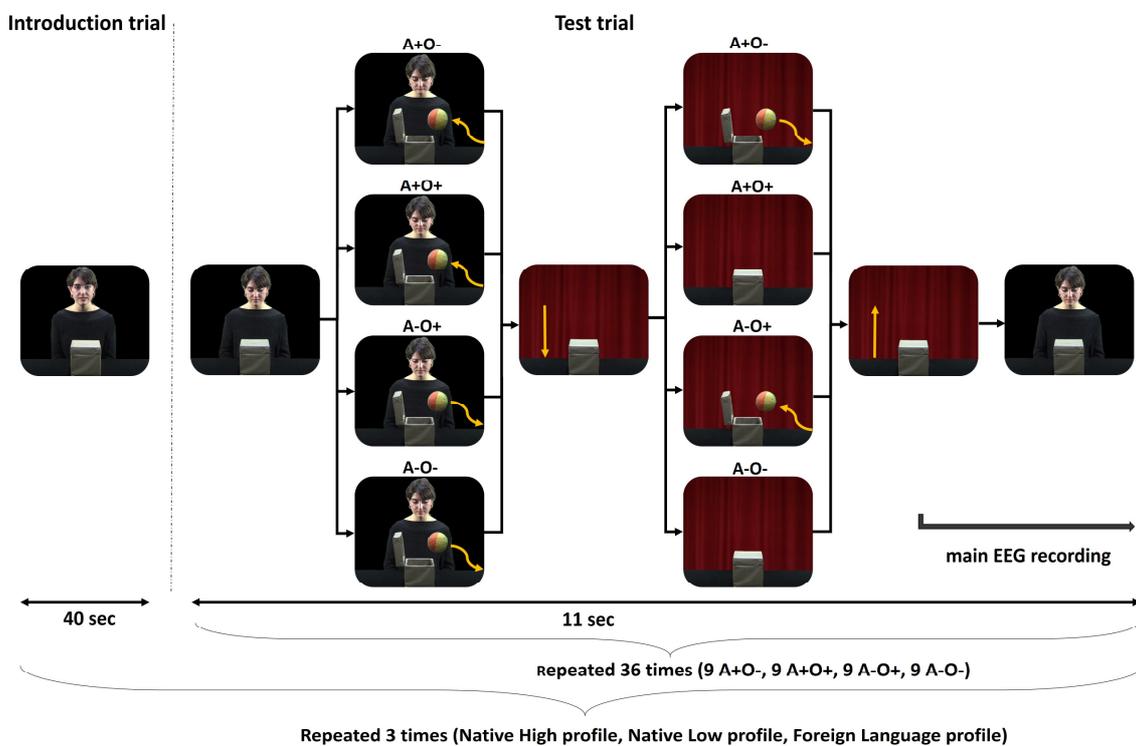


Figure 1. The Introduction trial and the four types of Test trials presented during the study. Each condition began with an introduction of the agent, followed by the four possible belief conditions (A+O-, A+O+, A-O+, A-O-). The duration and the time repetitions of each video are also shown.

Main EEG recording is located in the final 3000 ms-lasting phase of the four conditions. The trigger was sent at the precise moment when the curtain was completely raised up to reveal the agent entirely visible (9 sec time in the test trial video, 0 sec time in the ERSP plot). A baseline period of 400 ms was taken before the onset of the trigger, taken into account that this time window shows always the same the pre-onset of the stimulus for each of four belief conditions, that is, the onset of the

curtain raising to reveal the agent. Main activity was subtracted during 500 ms after the trigger was sent, point at which action prediction is given (see figure 2).

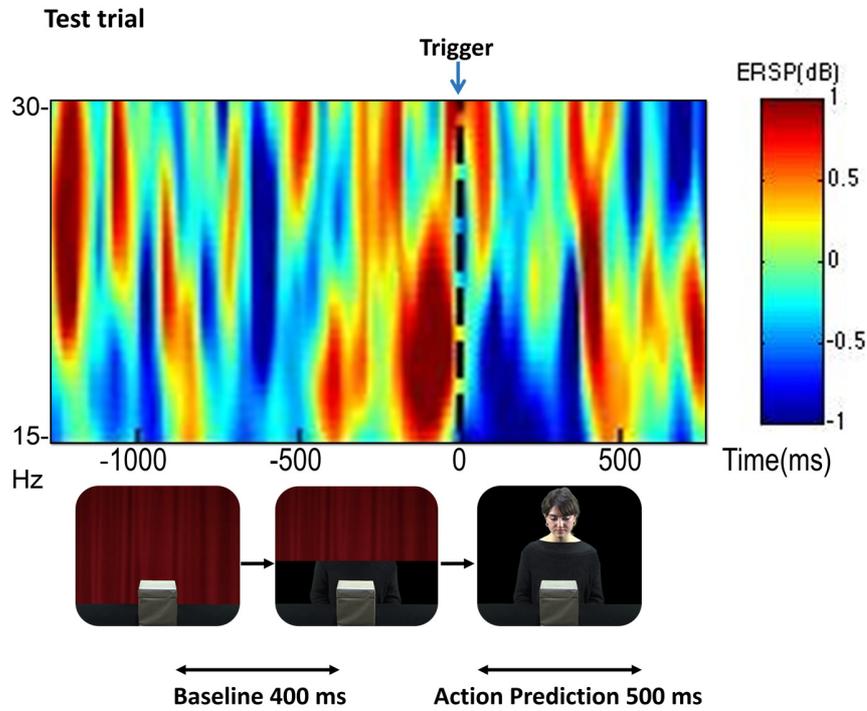


Figure 2. Main EEG recording of test trial. Time-frequency plots show in the time point of 0 ms the onset of agent reappearance. The activity averaged on the first 500 ms was compared to the 400 ms baseline period.

Experimental setup and procedure

The experiment consisted in three blocks, each block corresponding to one profile. High Native and Low Native profiles were presented in blocks 1 and 2 counterbalanced across participants, and the video of the Foreign language profile was always presented last, in block 3. Every block started with the Introduction video of each agent followed by the corresponding Test trials of each agent. Twelve test trials were presented in a pseudo-randomized order, repeating each of the four belief conditions a total of three times per agent. In order to avoid unexpected repeated sequences of elements, the experimental conditions were arranged embodying all possible combinations of four elements. Between each profile there was a pause.

This section, divided in three blocks, was repeated a total of three times, granting to the participants a pause among sections. Thus, participants were presented with nine repetitions of each belief

condition per agent, and totaling thirty-six test trial videos per each of the three represented psychological profiles (see figure 1). After artefact rejection, participants contributed between 6 and 8 (median= 7,4) A+O+ trials, between 6 and 8 (median= 7,2) A+O- trials, between 6 and 9 (median= 7,5) A-O- trials, and between 7 and 9 (median= 7,6) A-O+ trials.

EEG Data processing

EEG was recorded for about 30 minutes using a 128-electrode Hydrocel Geodesic Sensor Net System (EGI inc) while participants watched the videos. It was sampled at 500 Hz, recorded with respect to the vertex electrode and referenced to the average prior to analysis.

The ongoing EEG activity recorded during the study was processed as shown in Figure 3. First a 0.1 Hz high-pass, a 50 Hz Notch and a 60 Hz low-pass filters were applied to remove any current shift in the EEG activity. Then, a montage operation was conducted across all electrodes using the Hydrocel Geodesic Sensor Net 128 1.0 average reference, and EEG data was segmented into 4000 ms segments, starting 2000 ms before, and ending 2000 ms after, the time point at which the agent reappeared on the scene. Thus, epochs with the last phase of each experimental condition were isolated from the continuous signal of the EEG data previously recorded.

Following segmentation of epochs, an artefact detection function was used to remove artefacts from the recording. Channels were marked as bad if they contained more than 20% of segments, and segments were marked as bad if they contained more than 10 bad channels, contained an eye blink or an eye movement. The bad channel threshold was set at a maximum minus minimum amplitude of $>200 \mu\text{V}$, the eye-blink threshold was set at a maximum minus minimum amplitude of $>140 \mu\text{V}$, and the eye movement threshold was set at a maximum minus minimum amplitude of $>55 \mu\text{V}$. All of them were calculated for an entire segment using a window size of 640 ms post stimuli onset performing within moving average of 80 ms.

A visual inspection of the results previously obtained in the artefact detection procedure was performed, and all bad channels were replaced using Geodesic default algorithm for bad channel replacement. Finally, the last phase of the experimental conditions already processed was subsequently exported as Matlab files for the time-frequency analysis.

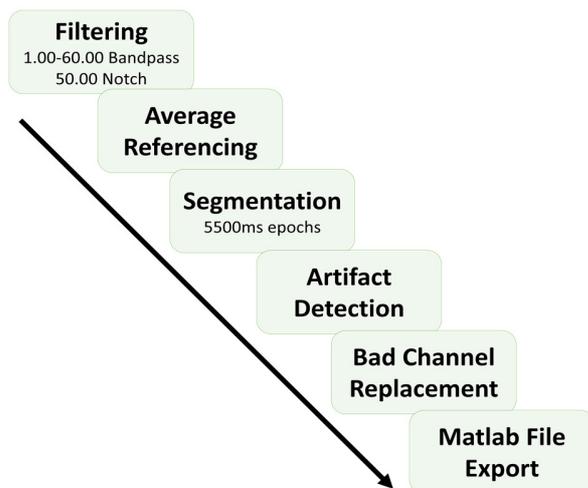


Figure 3. EEG Data processing. Different analytical tools were consecutively applied to process raw EEG data to obtain individual refined segments of the last experimental phase.

Time-frequency analysis

Time-frequency analyses were performed on each EEG segment previously extracted using Matlab EEGLAB library with the inbuilt function `newtimef`. Event-related spectral perturbation (ERSP) and Inter-trial coherence (ITC) were calculated to measure the event-related changes in the amplitude and phase of the EEG frequency spectra as a function of time. To measure the percentage of power change in each epoch, a period of 400 ms (beginning 1000 ms before the reappearance of the agent) was chosen as baseline period (see figure 2).

The averaged activity extracted from the baseline was subtracted from the first 500 ms starting after raising the curtain, moment in which the agent reappeared stationary in front of the closed box. To calculate induced power, the FFT coefficients of each single-trial were then averaged within participants. The activity was analysed across the entire frequency range of beta band (10-30 Hz) at both left and right sensorimotor electrodes (electrodes 30, 36, 37 and 42 from right hemisphere, and electrodes 87, 93, 104 and 105 from left hemisphere). This was selected for data collection according to previous research, which indicates the presence of strong motor activation in beta band for adults limited to these investigated electrodes (Southgate & Vernetti, 2014)

RESULTS

Two three-way ANOVA were performed for the average activity in the 15-30 Hz range. Concretely, the activity was compared in a 3 x 4 x 2 ANOVA with Profile (High native, Low native, Foreign language), Trial type (A+O-, A+O+, A-O+, A-O-), and Time (baseline vs. agent reappearance/trigger) as within-

subject factors for both right and left hemisphere. Only the analysis for the left hemisphere electrodes was significant for the interaction between Trial type and Time ($F= 3,974$; $p= 0,0181$) (see Appendix of ANOVA for further details).

A possible explanation for this lateralization of the activation to the left sensorimotor cortex relies on the fact that the action of reaching the box was produced by the right hand of the agents, placed in the left field of the scene. This lateralization is supported by previous findings, which have shown in infants a strong activation during action prediction in the left sensorimotor cortex (Powell & Spelke, 2013; Southgate, Johnson, El Karoui, & Csibra, 2010; Southgate, Johnson, Osborne, & Csibra, 2009).

Henceforth, all analyses were limited to the amplitude obtained only from the left hemisphere. First, it was observed the averaged activity prompted by each experimental condition (A+O-, A+O+, A-O+, A-O-), without taking into account the existence of different profiles. For that, an average was performed for the frequency values of the three profiles, and the results obtained were represented in different event-related spectral perturbation (ERSP) plots (see figure 4 (a-d)).

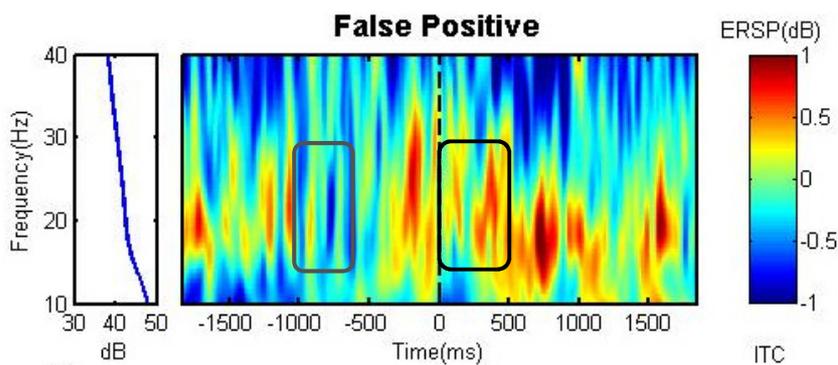


Figure 4 a. ERSP of False Positive (A+O-) experimental condition. Baseline time is shown in a grey square, trigger time is shown in a black square.

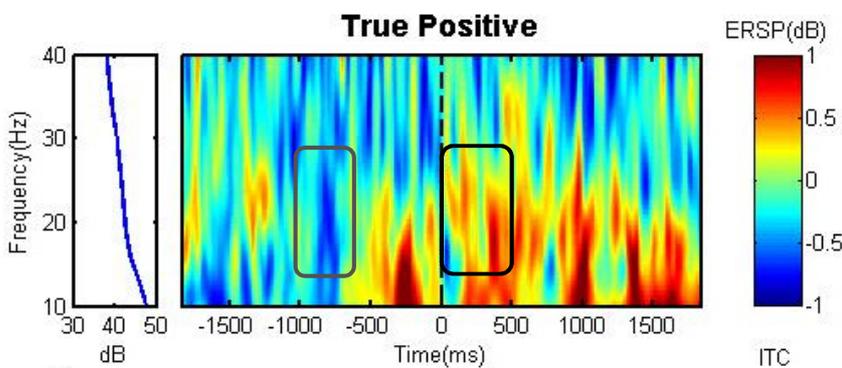


Figure 4 b. ERSP of True Positive (A+O+) experimental condition. Baseline time is shown in a grey square, trigger time is shown in a black square.

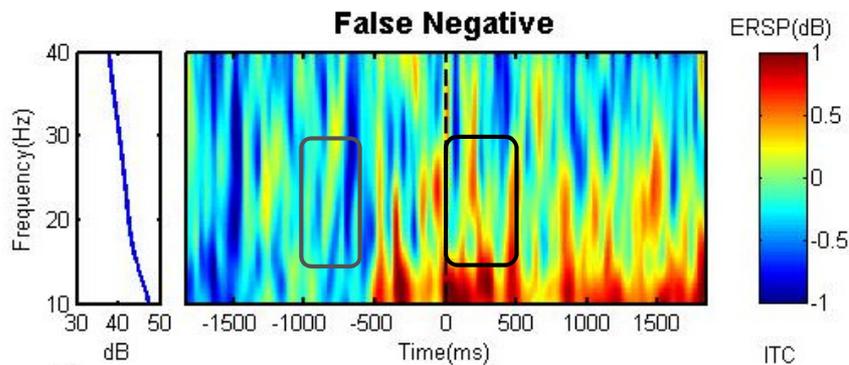


Figure 4 c. ERSP of False Negative (A-O+) experimental condition. Baseline time is shown in a grey square, trigger time is shown in a black square.

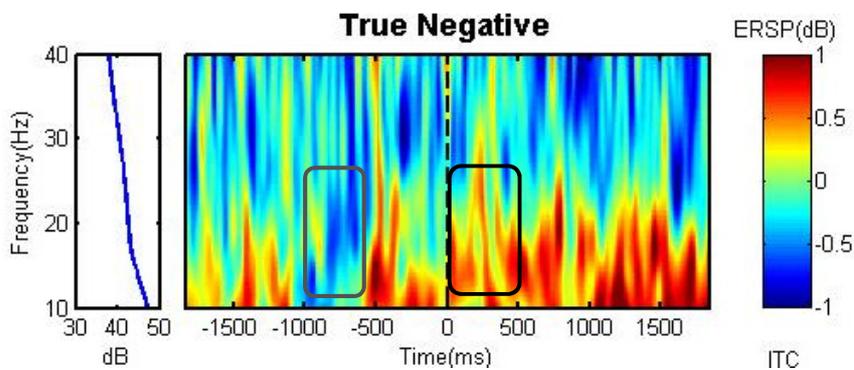


Figure 4 d. ERSP of True Negative (A-O-) experimental condition. Baseline time is shown in a grey square, trigger time is shown in a black square.

Considering that there was visually clear changes in the amplitude of the EEG frequency spectra between conditions, it was consequently compared the difference of amplitude between the baseline time and the trial time at each condition.

Paired-samples t-tests showed that there was no significant decrease of amplitude for A-O+ trials ($p=0,259$; mean baseline= $-0,014$; mean trigger= $0,021$), A-O- trials ($p=0,288$; mean baseline= $-0,158$; mean trigger= $-0,183$) and A+O+ trials ($p=0,179$; mean baseline= $-0,267$; mean trigger= $-0,224$). Strikingly, there was a significant increase of amplitude from baseline to agent reappearance for A+O- trials ($p=0,029$; mean baseline= $-0,033$; mean trigger= $0,075$) (see Appendix of Paired-samples t-tests for more details).

Paired t-tests demonstrated quantitatively that there is no apparent pattern exhibiting a notable decrease in the amplitude of the frequency spectra as a function of time for True Positive and False Positive conditions. Therefore, there might be some interference hampering the final result. However,

it is highly noticeable both in the ERSP plots and the statistical analysis that there is no big difference between baseline and trigger time per every condition. Thus, it was analysed the amplitude between speakers to search for the patterns prompted by the different profiles. An average of baseline and trigger periods of every condition was obtained and plotted.

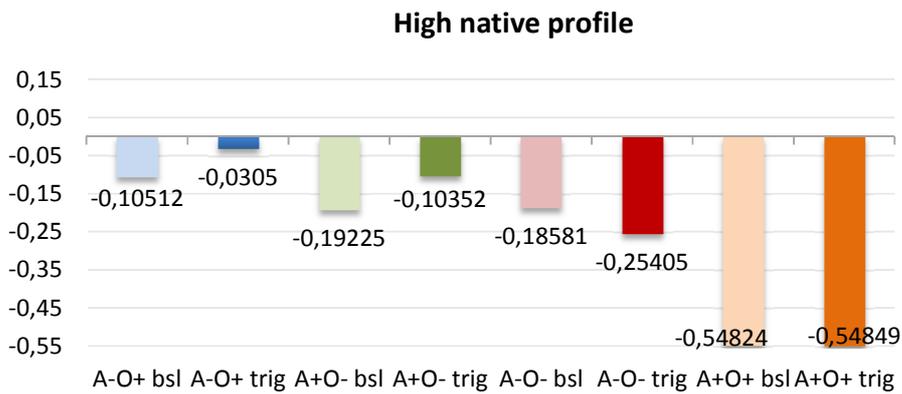


Figure 5 a. Baseline (bsl) and trigger (trig) values per each condition of High native profile.

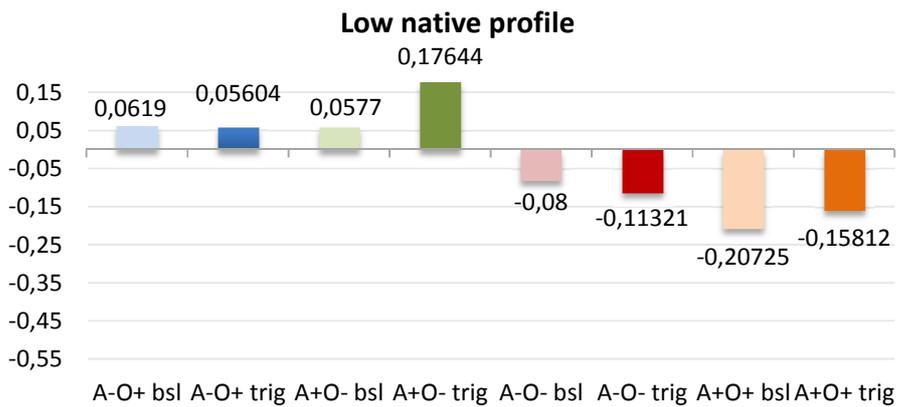


Figure 5 b. Baseline (bsl) and trigger (trig) values per each condition of Low native profile.

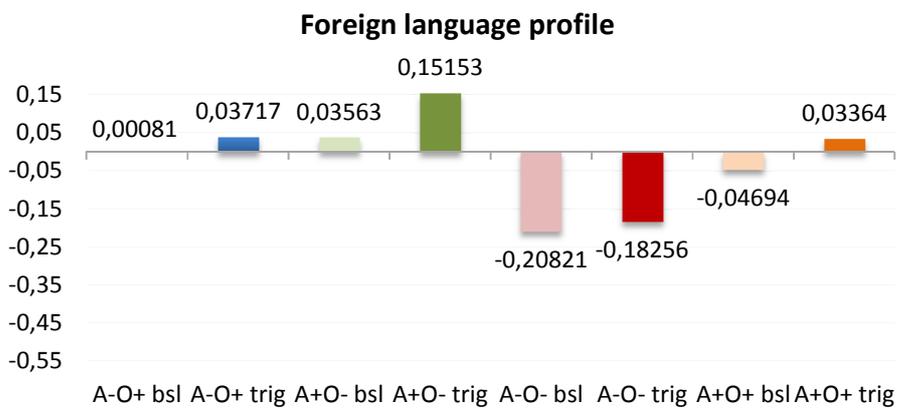


Figure 5 c. Baseline (bsl) and trigger (trig) values per each condition of Foreign language profile.

As represented in [Figure 5 \(a-c\)](#), baseline periods seem to pattern with the trigger periods in every condition. Baselines, even those including the same actions before the agents reappears, do not induce the same activity. This is true within profile and across them. For example, A+O+ and A-O+ trials show the ball jumping inside the box when the agent is out of the scene, during the baseline. However, paired-samples t-tests not only have shown that the baseline of A+O+ and A-O+ conditions are different in the High native profile ($p=0,056$; mean A-O+= $-0,105$; mean A+O+= $-0,548$), but also that the baseline of A+O+ trials of different profiles (High native and Foreign language profile) are significantly different ($p=0,022$; mean High= $-0,548$; mean Foreign= $-0,047$) (see [Appendix Paired-samples t-tests for more details](#)).

Differences in the baseline challenge the main analysis comparing changes between baseline and trigger time. Nevertheless for the sake of this work, we will assess how our original hypotheses analysing the amplitudes at the trigger time.

A two-way ANOVA was performed for the average activity in the 15-30 Hz range for the trigger period, that is, from 0 to 500 ms. The activity was compared in a 3 x 4 ANOVA with Profile (High native, Low native, Foreign language) and Trial type (A+O-, A+O+, A-O+, A-O-) as within-subject factors for left hemisphere. This was performed in order to look for a specific combination between the profiles and the conditions. However, the analysis showed no significant interaction for these two variables ($F=0,352$; $p=0,906$) (see [Appendix of ANOVA for further details](#)).

Planned comparisons were performed comparing each Trial type across Profiles. We expected to see in the High native profile higher desynchronization for A+O- and A+O+ events shifted by the action prediction, compared with the Low native and Foreign language profiles. Only the A+O+ trials of High and Foreign language profiles were significantly different ($p=0,021$), while the A+O- trials of High native and Low native profiles approached significance ($p=0,086$) (see [Appendix of ANOVA for further details](#)).

Moreover, paired-samples t-tests did not show any trend to significance for the A-O+ and A-O- trials in none of the three profiles, suggesting that activity was similar for these trials between the three profiles studied (see [Appendix Paired-samples t-tests for more details](#)).

DISCUSSION

Humans are more than individual physical bodies; we are exquisitely social species carrying an essential sentient core. It is a fundamental aspect of our life-living, mostly from an evolutionary fittest point of view, to understand the mental states of others in order to thrive in complex social interactions.

In a broad sense, human behavior is inexorably linked to social affiliations. There is a tribalist predisposition for dealing with those perceived as members of our own linguistic group, and with those that positively bias our social attention inside the group. The current investigation represents a step in this direction, trying to discover the relation of social cognition in the sense of group membership and social attention, and the ability of predicting a certain action depending on the ascribed mental states (Markovsky, 1994; Ward, 2012; Rakoczy, 2014).

There is some evidence in the present study that provides support for this assertion. We included a neutral false belief task inside a social context, expecting to see different modulations of the sensorimotor cortex activation depending on the person that was perceived. Concretely, we analysed changes in the beta band in an attempt to measure participants' action prediction, when seeing three different actors who differ in their social status and language background. Unexpectedly, we observed fluctuations in the baseline period that prevented us from comparing changes between baseline and trigger times. We decided to analyse the changes in the trigger time.

We observed that in the A+O- and A+O+ trials, the High native profile differed from the two other profiles, while all trials appeared to be relatively similar in the Low native and Foreign language profiles. The True Positive condition showed a significant decrease in the High native profile, as opposed to the Low native and Foreign language profiles. The False Positive condition also had a negative tendency in the High native profile, in comparison to the positive values corresponding to the Low native and Foreign language profiles.

The A-O+ and A-O- conditions did not differ across the three profiles: in case of A-O+ trials, values are settled around 0, and in case of A-O- trials, values tend to be slightly negative. All these patterns can be observed in [Figure 2 of Appendix](#), where amplitude values of the four conditions were averaged and plotted depending on each profile.

As just summarised, the present results exhibit two types of patterning: on the one hand, the generation of the action prediction given a false belief is more accurate when the intentions are held

by a person that has been distinguished as highly-profiled. On the other hand, the false belief action predictions become softened and dispersed when the person do not seem to catch our attention nor our preference for interpersonal understanding and interpretation of the developing action.

In a related vein, it has been recently found that preverbal infants show higher motor activation when the agent holding a false belief action representation was a native speaker, in contradistinction to a foreign language speaker. These conclusions further confirm that positive affiliation with one's social group is seen as a fundamental base of human existence, and develops very early in human ontogeny (Colomer, 2015).

In our society, how people form impressions about the inner aptitudes and outward behaviors of other individuals plays a key role in facilitating cooperation and collaboration. It is obvious that the more strongly someone's identity is linked to a precise social role or category, the greater is the extent to which this person empathises with other constituents of that role or category (Markovsky, 1994; Ward, 2012).

In this line, it is important to stress that the current study do not claim that the understanding of someone else's action and emotion is solely mediated by a sensorimotor mechanism. It determines a cognitive interpretation of the observed social stimuli that creates a bridge between the others and ourselves, unifying the perspective of the neural basis of social perception and empathy.

So, even though we use motor activation for measuring how social perception influences the ability to produce belief-based action predictions, this does not thoroughly indicate that the sensorimotor system has a function in inferring these beliefs, judgments or expectations. Some lines of research have rejected the role of the mirror system in empathy and mental state attributions (P Jacob, 2008; Pierre Jacob & Jeannerod, 2005). However, this study defend the involvement of the sensorimotor system in predicting *how* an action will unfold, given the formulation of particular *impressions* and *expectations* about the person that is developing that action.

There is little evidence addressing people's recognition of the implications of beliefs for action. Here, we demonstrate different action predictions depending on the social perception of the agent. However, it is necessary to consider the combination of this social affiliation with other possible factors more consequential for actions. As a matter of fact, results show a high variability between conditions and profiles. One can expect that, more than social hierarchy and linguistic group cognition, the observer may have weighted other individual's characteristics to form an overall impression of the agent.

We might consider the linguistic and hierarchical bias as concept with a multifaceted nature, that lies at the heart of the perspective from which the people are judged. Even though social association may take place across several dimensions, these are not always independent, and a collection of attributes may be tight together.

The study has been carried to disentangle any possible combined effect of observer's expectancies and agent's traits, specifying the circumstances under which either set of factors (native or foreign language, higher or lower social hierarchy) prevails in determining social perception. However, considering all the possibilities, the experimental analyses executed during the study is another potential factor that needs to be considered as a source of variation in the action prediction.

In functional terms, adults are correctly predicting actions for A+O+ trials based on the mental states of the High native profile. Nonetheless, it is certain that we also found motor activation for trials without an impending action prediction, and even the baseline period did show an inconsistent pattern across trials and profiles. This could be explained by the fact that subject's action prediction begins long before the agent reappears, or by the generation of a higher motor activity in other frequency bands.

Hence, one possible solution to implement in future analysis would be to displace the baseline window to an earlier time period where the observer, under no circumstances would be able to anticipate the behavior and create early expectancies. That would help to clarify the origin of the increased values in the A+O+ baseline condition. Furthermore, the analyses should be performed on the mu (alpha) waves, which have been demonstrated to correlate with the ability to integrate beliefs with perceived and anticipated actions.

Our procedure was inspired by [Southgate & Verneti, 2014](#), who found that preverbal infants and adults make accurate action predictions based on the agent's representation of the world. Their study differs from the current one in an important way as they only used two false-belief experimental conditions (A+O-, A-O+) (and without any type of social context). First, in their study, as soon as the ball jumped in or out of the box in presence of the agent before the curtain pulls down ([see figure 1](#)), participants had all the information about the experimental condition. In our study, it is not after the curtain pulls down that the experimental condition is set. Second, in [Southgate & Verneti, 2014](#), participants were always exposed to false belief conditions, while in our study both true and false belief conditions were present. These changes in the experimental set up may have influence observers' mental representations, and therefore changed the patterns of neural activation.

CONCLUSIONS

The Social Psychological literature has reported unconscious influences of the social environment on a myriad of complex behaviors. So, social perception cannot be explained only by thinking in the contents of someone's mind. Whether or not our meta-representations of others' behavior are directly influenced by the way we represent the world from one perspective or another, this study gives an innovative insight into our and others' mind through a motor-mediated type of action and emotion understanding.

Considering the fact that the representation of the others' action predictions appear to be influenced by the social perception and categorization of those individuals; this direction studied here, may serve as a starting point for future investigations, searching for the social sense of interpersonal comprehension and interpretation. Thus, even we might study the social cognition from one direction or another, what all these arguments clearly point to is the need for more research on the burgeoning field of ToM tied to social cognition.

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APPENDIX

Text of Introduction videos

The variables to introduce in the test trials are three different psychological profiles representing the three speakers: a native agent with high profile, a native agent with low profile, and an agent speaking in a foreign language.

- **High native psychological profile**

Description of the character: young woman dressed up in black speaking in Spanish, native language of the subjects. She presents herself as a successful person, with medium/high socio-economic status. She seems optimistic and seeks the complicity of the viewer.

Text: Hola, mi nombre es Marta Ferrer, tengo 25 años y vivo en Sant Cugat. Terminé la carrera de Empresariales hace poco y mi ilusión es montar una pequeña empresa con un grupo de amigos de la universidad. *(Pause)* Sin embargo, con la formación universitaria no tengo bastante y me he apuntado a un curso para jóvenes emprendedores que organiza el ayuntamiento. También he empezado a estudiar idiomas, en serio, por si lo de la empresa no sale bien y me toca ir al extranjero a forrarme. *(Pause)* Me gusta mucho leer, salir con los amigos a tomar algo, ir al cine... y bueno, creo que eso es todo.

- **Low native psychological profile**

Description of the character: young woman dressed up in black speaking in Spanish, native language of the subjects. She presents herself as a humble person, with low socio-economic status, and seems to neglect the spectator.

Text: Hola, me llamo Jennifer, tengo 24 años y soy de Cornellá. En estos momentos tengo un trabajo temporal como cajera de supermercado y espero que me lo renueven; aunque la verdad es que me pagan una miseria. *(Pause)* Dejé los estudios en el instituto porque me costaba mucho; estudiar no es lo mío. Pero ahora que lo pienso, si hubiese seguido, a lo mejor ahora tendría un trabajo mejor. *(Pause)* Participo en este estudio, entre otras cosas para ganar algún dinerillo y bueno, ya que estamos, para ver si aprendo alguno nuevo sobre este rollo de la ciencia.

- **Foreign language psychological profile**

Description of the character: young woman dressed up in black with naïve appearance and speaking in a neutral tone.

Text: Hallo, ich heiße Lena, ich bin 25 Jahre alt und komme aus Frankfurt, Deutschland. Ich habe Philosophie an der Universität Frankfurt-Mainz studiert und wohne seit drei Monaten in Barcelona. *(Pause)* Ich habe diese Stadt gewählt, weil mit meiner Bildung weiter machen möchte und der postgraduiertenstudium über ästhetik der Kunst erschaffen. Ich möchte in einer Kunstgalerie arbeiten, weil ich die modernistische Kunst der Stadt liebe. *(Pause)* Ich habe in diesem Experiment teilgenommen, da die Neurowissenschaften mich immer sehr interessiert haben und vielleicht lerne ich damit etwas neues.

Translation of the text: Hola, me llamo Lena, tengo 25 años y soy de Frankfurt, Alemania. Estudié la carrera de Filosofía en la universidad de Mainz-Frankfurt y desde hace 10 meses vivo en Barcelona. *(Pausa)* Elegí esta ciudad para seguir con mi formación y hacer el postgrado sobre estética del arte. Me gustaría trabajar en una galería de arte porque me encanta el arte modernista de la ciudad. *(Pausa)* Me he apuntado a este experimento porque las neurociencias siempre me han interesado y a lo mejor consigo aprender algo nuevo.

Experimental setup of the Test videos

Participants watched 11 s long animated movies, generated using Adobe Premiere Pro CC software. The videos involved an agent, a ball and a box placed on a table. There were four belief conditions involving the beliefs of the agent (A) and the beliefs of the observer (O), each paired with 2 different outcomes (ball present inside the box and ball absent): A+O+ (True Positive belief), A-O+ (False Negative belief), A+O- (False Positive belief), A-O- (True Negative belief). This was accomplished by changing the final location of the ball before the curtain was raised, and the time at which the ball was last seen by the observer and the agent (whether the agent left the scene before or after the ball reached its final location).

Experimental condition/Phase	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
True Positive belief condition	A appears	Ball hiding A+O+	Curtain down	Ball stays inside A+O+	Curtain up	A returns (true belief)
False Positive belief condition		Ball hiding A+O+		Ball leaves A+O-		A returns (false belief)
True Negative belief condition		Ball leaves A-O-		Ball does not return A-O-		A returns (true belief)
False Negative belief condition		Ball leaves A-O-		Ball returns A-O+		A returns (false belief)
Timing	0 s	3 s	1 s	3 s	1 s	3 s

Table 1 Appendix. Phases of the experiment.

The videos in all experimental conditions had six phases with the same duration across conditions. The first, the third and the fifth phase were physically identical in each of the four test conditions; whereas the other phases varied depending on the condition presented. In the last phase of all four trials the agent reappeared in the scene always at 8 s, moment at which the trigger was sent to obtain the main recording during the next 3 s of the movies. The following descriptions refer to the differing phases 2, 4 and 6 during the four experimental conditions (Table 1 Appendix).

In the True Positive belief condition, the ball rolled inside the box in phase 2 (ball last seen by the agent at 3 s), and then remained occluded in phase 4 (ball last seen by the participant at 3 s). So, the participant and the agent believed the ball to be inside the box in phase 6 (A+O+) (Table 1 Appendix).

In the True Negative belief condition, the ball rolled away from the box in phase 2 (ball last seen by the agent at 3 s), and the remained out of scene in phase 4 (ball last seen by the participant at 3 s). Thus, neither the participant nor the agent believed the ball to be inside of the box in phase 6 (A-O-).

In the False Positive belief condition, the ball rolled towards the box in phase 2 (ball last seen by the agent at 3 s), and then rolled away from the scene in the agent's absence during the phase 4 (ball last seen by the participant at 7 s). So, only the agent but not the observer believed the ball to be occluded inside the box in the phase 6 (A+O-). The agent had the false belief about the ball's location (Table 1 Appendix).

In the False Negative belief condition, the ball rolled away from the box in phase 2 (ball last seen by the agent at 3 s), and then rolled inside the box in the agent's absence during the phase 4 (ball last seen by the participant at 7 s). Thus, only the observer but not the agent believed the ball to be occluded inside the box in the phase 6 (A-O+). The agent had the false belief about the ball's location (Table 1 Appendix).

The timing properties were perfectly controlled, matching the time-point of the events across all trials. It was also operationally defined the trajectory the ball crosses in the scene, hence in all conditions, the ball covered the same total visible distance in the scene. The path the ball always travels ranges from the midline of the scene where the box is placed to the right edge of the screen (Table 1 Appendix).

Three different blocks corresponding to three distinct profiles were shown to the participants. Each profile presentation lasted approximately 40 s, placing therefore the 11 s-lasting videos of the four

conditions repeated three times. The section including the Introduction and Test trial videos of the three agents lasted a total of 516 s (8 min 2 s).

As a result of the design, the four test trials paired with each of the three introduction videos of the agents resulted in twelve different movies, each seen nine times. So, each participant watched 108 trial movies presented in pseudo-randomized order. Nine clusters were created embodying all possible combination of three series (three repetitions inside every block) of four elements (four experimental conditions), which were presented randomly during the study in order to avoid repeated sequences of elements and as a method for controlling any possible order effect (Figure 1 Appendix).

For each participant each section including the three profiles was displayed a total of three times, so that the total duration of the experiment was 1548 s (25 min 48 s) (Figure 1 Appendix). Among these three repetitions participants were given the opportunity to make two short breaks. The total duration of the experiment was 50 min including 10 min for EGI preparation, 30 min experiment and 10 min for washing the hair.

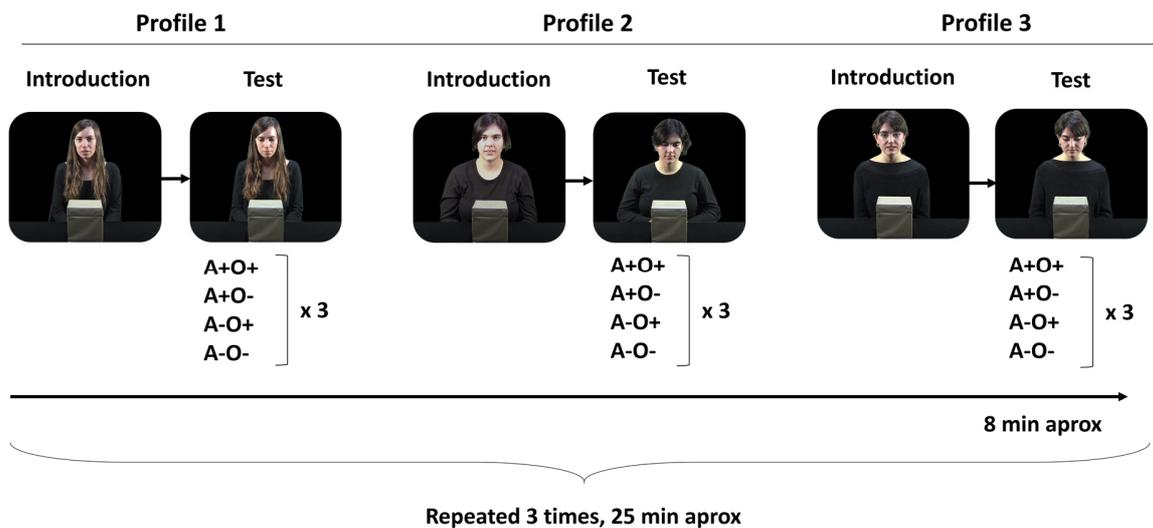


Figure 1 Appendix. Experimental design including Introduction and Test trials of every profile, trial repetitions and duration of the study.

Moreover, for each participant it was alternated the order of the character and profile's appearance organizing four different groups: A, B, C and D. Four participants were randomly assigned to the A group, three participants to the B group, four participants to the C group, and three to the D group.

This was done for counterbalancing any possible effect prompted by the agent herself or by the order of profile appearance (Table 2 Appendix).

Group/Block	Block 1	Block 2	Block 3
Group A	Agent 1 – High Profile	Agent 2 – Low Profile	Agent 3 – Foreign language Profile
Group B	Agent 1 – Low Profile	Agent 2 – High Profile	Agent 3 – Foreign language Profile
Group C	Agent 2 – High Profile	Agent 1 – Low Profile	Agent 3 – Foreign language Profile
Group D	Agent 2 – Low Profile	Agent 1 – High Profile	Agent 3 – Foreign language Profile

Table 2 Appendix. Groups for agent and psychological profile alternations.

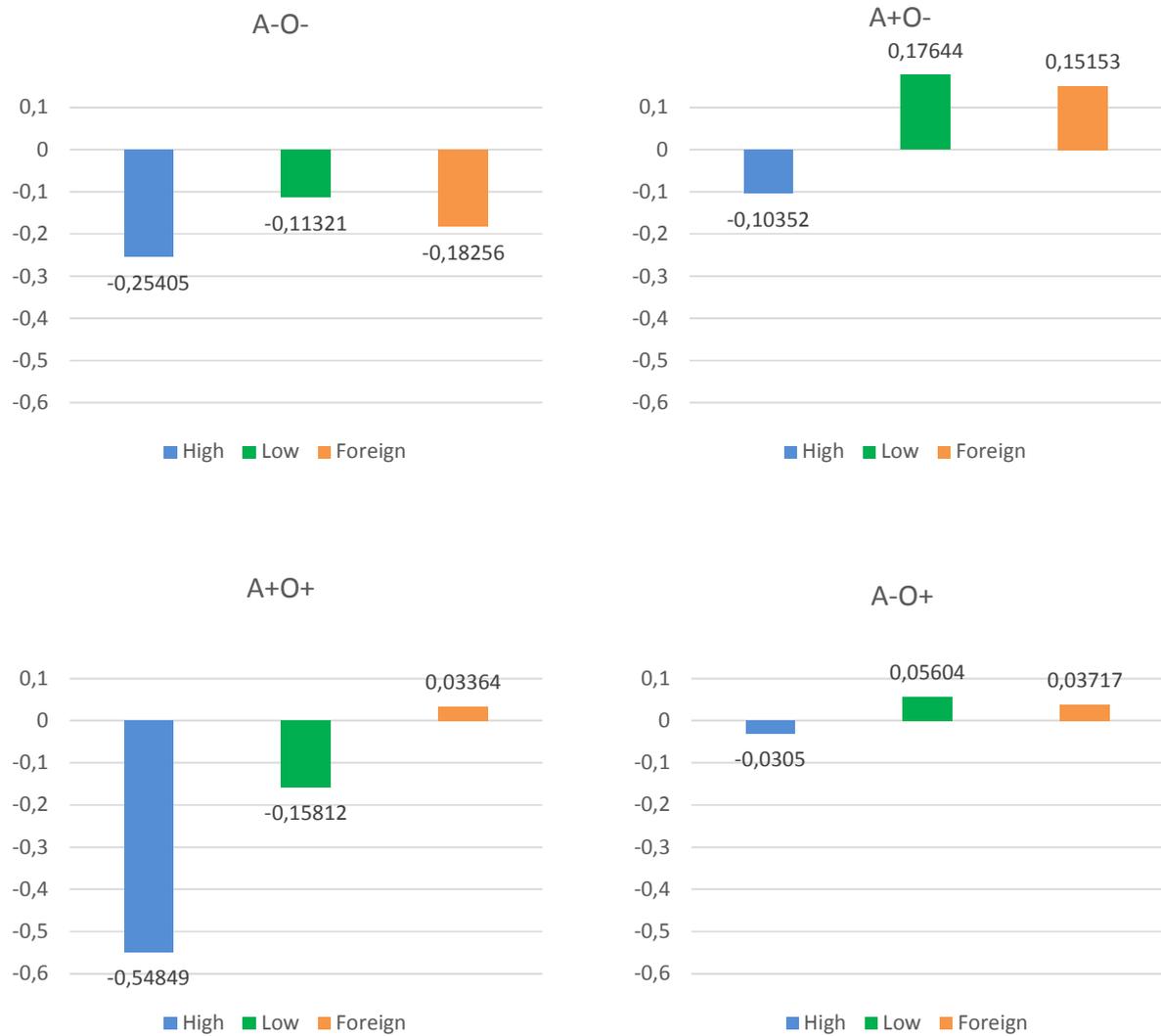


Figure 2 Appendix. Average amplitude values of High native profile (High), Low native profile (Low), Foreign language profile (Foreign) are compared per every experimental condition (A-O+, A+O-, A-O-, A+O+).

Three-way ANOVA left hemisphere (3 x 4 x 2 ANOVA)

Three-Way Analysis of Variance with Repeated Measure on Three Factors (within-subjects) Table.

SOV	SS	Df	MS	F	P
Between-Subjects	14,538	9			
Within-Subjects	77,168	230			
Profile	2,627	2	1,313	1,985	0,1663
Error (Profile)	11,908	18	0,662		
Trial	3,094	3	1,031	1,544	0,2258
Error (Trial)	18,032	27	0,668		
Time	0,097	1	0,097	0,944	0,3566
Error (Time)	0,923	9	0,103		
Profile x Trial	1,627	6	0,271	0,393	0,8803
Error (Profile x Trial)	37,246	54	0,690		
Profile x Time	0,019	2	0,009	0,586	0,5669
Error (Profile x Time)	0,286	18	0,016		
Trial x Time	0,133	3	0,044	3,974	0,0181
Error (Trial x Time)	0,302	27	0,011		
Profile x Trial x Time	0,039	6	0,007	0,0435	0,8524
Error (Profile x Trial x Time)	0,816	54	0,015		
Total	76,544	239			

Three-way ANOVA right hemisphere (3 x 4 x 2 ANOVA)

Three-Way Analysis of Variance with Repeated Measure on Three Factors (within-subjects) Table.

SOV	SS	Df	MS	F	P
Between-Subjects	25,767	9			
Within-Subjects	67,438	230			
Profile	0,237	2	0,118	0,201	0,8195
Error (Profile)	10,584	18	0,588		
Trial	2,183	3	0,728	1,116	0,3601
Error (Trial)	17,611	27	0,652		
Time	0,026	1	0,026	0,286	0,6059
Error (Time)	0,818	9	0,091		
Profile x Trial	2,147	6	0,358	0,596	0,7322
Error (Profile x Trial)	32,418	54	0,600		
Profile x Time	0,006	2	0,003	0,256	0,7767
Error (Profile x Time)	0,224	18	0,012		
Trial x Time	0,021	3	0,007	30,414	0,7444
Error (Trial x Time)	0,456	27	0,017		
Profile x Trial x Time	0,074	6	0,012	1,067	0,3937
Error (Profile x Trial x Time)	0,627	54	0,012		
Total	93,199	239			

Two-way ANOVA trigger time (3 x 4 ANOVA)

Repeated measures Two-way Analysis of Variance Table.

SOV	SS	Df	MS	F	P
Subjects	9,743	9	1,083	2,589	0,0101
Profile	1,471	2	0,736	1,723	0,2066
Error (Profile)	7,682	18	0,427		
Trial	1,696	3	0,656	1,694	0,1919
Error (Trial)	10,462	27	0,387		
Profile x Trial	0,910	6	0,152	0,352	0,9055
Error (Profile x Trial)	23,246	54	0,430		
Total	55,484	119			

Paired-samples t-tests Baseline and Trigger time difference

t-Test: Paired Two Sample for Means A-O+

	Baseline	Trigger
Mean	-0,01413666	0,020903333
Variance	0,043870109	0,104077887
Observations	10	10
Pearson Correlation	0,893084343	
Hypothes Mean Diff	0	
Df	9	
t Stat	-0,67119675	
P(T<=t) one-tail	0,259474312	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,518948624	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means A+O-

	Baseline	Trigger
Mean	-0,03297333	0,074816667
Variance	0,096809429	0,192417823
Observations	10	10
Pearson Correlation	0,969679298	
Hypothes Mean Diff	0	
Df	9	
t Stat	-2,17608892	
P(T<=t) one-tail	0,028769982	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,057539964	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means A-O-

	Baseline	Trigger
Mean	-0,15800666	-0,1832733
Variance	0,122308723	0,18385161
Observations	10	10
Pearson Correlation	0,957600441	
Hypothes Mean Diff	0	
Df	9	
t Stat	0,58018555	
P(T<=t) one-tail	0,288012478	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,576024955	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means A+O+

	Baseline	Trigger
Mean	-0,26747666	-0,22432333
Variance	0,240345393	0,268022437
Observations	10	10
Pearson Correlation	0,962065927	
Hypothes Mean Diff	0	
df	9	
t Stat	-0,96470081	
P(T<=t) one-tail	0,179949385	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,35989877	
t Critical two-tail	2,262157163	

Paired-samples t-tests Baseline

t-Test: Paired Two Sample for Means

	A-O+	A+O+
	<i>High</i>	<i>High</i>
Mean	-0,10512	-0,54824
Variance	0,295419	0,537872
Observations	10	10
Pearson Correlation	0,247791	
Hypothes Mean Diff	0	
Df	9	
t Stat	1,757442	
P(T<=t) one-tail	0,056358	
t Critical one-tail	1,833113	
P(T<=t) two-tail	0,112716	
t Critical two-tail	2,262157	

t-Test: Paired Two Sample for Means

	A+O+	A+O+
	<i>High</i>	<i>Foreign</i>
Mean	-0,54824	-0,04694
Variance	0,537872	0,376547
Observations	10	10
Pearson Correlation	0,511605	
Hypothes Mean Diff	0	
df	9	
t Stat	-2,35288	
P(T<=t) one-tail	0,021551	
t Critical one-tail	1,833113	
P(T<=t) two-tail	0,043101	
t Critical two-tail	2,262157	

Paired-samples t-tests Trials and Profiles

t-Test: Paired Two Sample for Means

	A-O+	A-O+
	<i>High</i>	<i>Low</i>
Mean	-0,0305	0,05604
Variance	0,427996156	0,261949
Observations	10	10
Pearson Correlation	0,103137639	
Hypothes Mean Diff	0	
Df	9	
t Stat	-0,34730729	
P(T<=t) one-tail	0,368171972	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,736343945	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

	A-O+	A-O+
	<i>High</i>	<i>Foreign</i>
Mean	-0,0305	0,03717
Variance	0,427996156	0,665056
Observations	10	10
Pearson Correlation	-0,59077383	
Hypothes Mean Diff	0	
df	9	
t Stat	-0,16300447	
P(T<=t) one-tail	0,437058155	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,87411631	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

	A-O+	A-O+
	<i>Low</i>	<i>Foreign</i>
Mean	0,05604	0,03717
Variance	0,261949212	0,665056
Observations	10	10
Pearson Correlation	0,171314962	
Hypothes Mean Diff	0	
Df	9	
t Stat	0,067393024	
P(T<=t) one-tail	0,473871129	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,947742258	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

	A+O-	A+O-
	<i>High</i>	<i>Low</i>
Mean	-0,10352	0,17644
Variance	0,522245988	0,226647
Observations	10	10
Pearson Correlation	0,570033394	
Hypothes Mean Diff	0	
df	9	
t Stat	-1,48240909	
P(T<=t) one-tail	0,086188408	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,172376815	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

	A+O-	A+O-
	<i>High</i>	<i>Foreign</i>
Mean	-0,10352	0,15153
Variance	0,522245988	0,352773
Observations	10	10
Pearson Correlation	0,225221066	
Hypothes Mean Diff	0	
Df	9	
t Stat	-0,97686762	
P(T<=t) one-tail	0,177079929	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,354159858	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

	A+O-	A+O-
	<i>Low</i>	<i>Foreign</i>
Mean	0,17644	0,15153
Variance	0,226647089	0,352773
Observations	10	10
Pearson Correlation	0,078725312	
Hypothes Mean Diff	0	
Df	9	
t Stat	0,107705497	
P(T<=t) one-tail	0,458296082	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,916592163	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

	A-O-	A-O-
	<i>High</i>	<i>Low</i>
Mean	-0,25405	-0,11321
Variance	0,608908229	0,448524
Observations	10	10
Pearson Correlation	0,125836923	
Hypothes Mean Diff	0	
Df	9	
t Stat	-0,46285209	
P(T<=t) one-tail	0,327228926	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,654457851	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

	A-O-	A-O-
	<i>Low</i>	<i>Foreign</i>
Mean	-0,11321	-0,18256
Variance	0,448523732	0,741327
Observations	10	10
Pearson Correlation	-0,21246879	
Hypothes Mean Diff	0	
Df	9	
t Stat	0,183078913	
P(T<=t) one-tail	0,429397006	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,858794012	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

	A+O+	A+O+
	<i>High</i>	<i>Foreign</i>
Mean	-0,54849	0,03364
Variance	0,710596185	0,395468
Observations	10	10
Pearson Correlation	0,477999451	
Hypothes Mean Diff	0	
Df	9	
t Stat	-2,37796602	
P(T<=t) one-tail	0,020682683	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,041365367	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

	A-O-	A-O-
	<i>High</i>	<i>Foreign</i>
Mean	-0,25405	-0,18256
Variance	0,608908229	0,741327
Observations	10	10
Pearson Correlation	-0,02276261	
Hypothes Mean Diff	0	
df	9	
t Stat	-0,19238734	
P(T<=t) one-tail	0,42585492	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,85170984	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

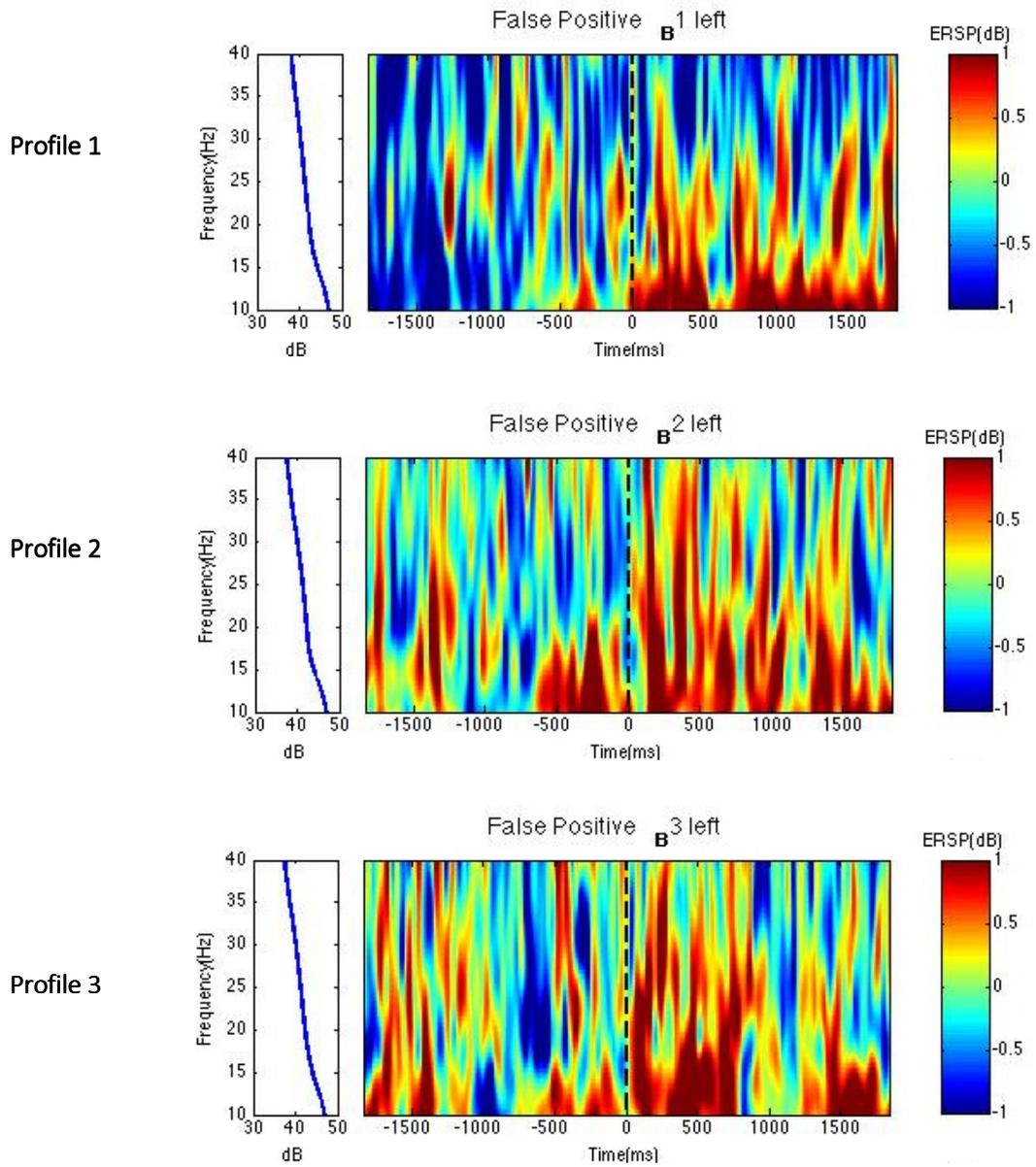
	A+O+	A+O+
	<i>High</i>	<i>Low</i>
Mean	-0,54849	-0,15812
Variance	0,710596185	0,320054
Observations	10	10
Pearson Correlation	0,05221654	
Hypothes Mean Diff	0	
df	9	
t Stat	-1,24645294	
P(T<=t) one-tail	0,12203162	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,24406324	
t Critical two-tail	2,262157163	

t-Test: Paired Two Sample for Means

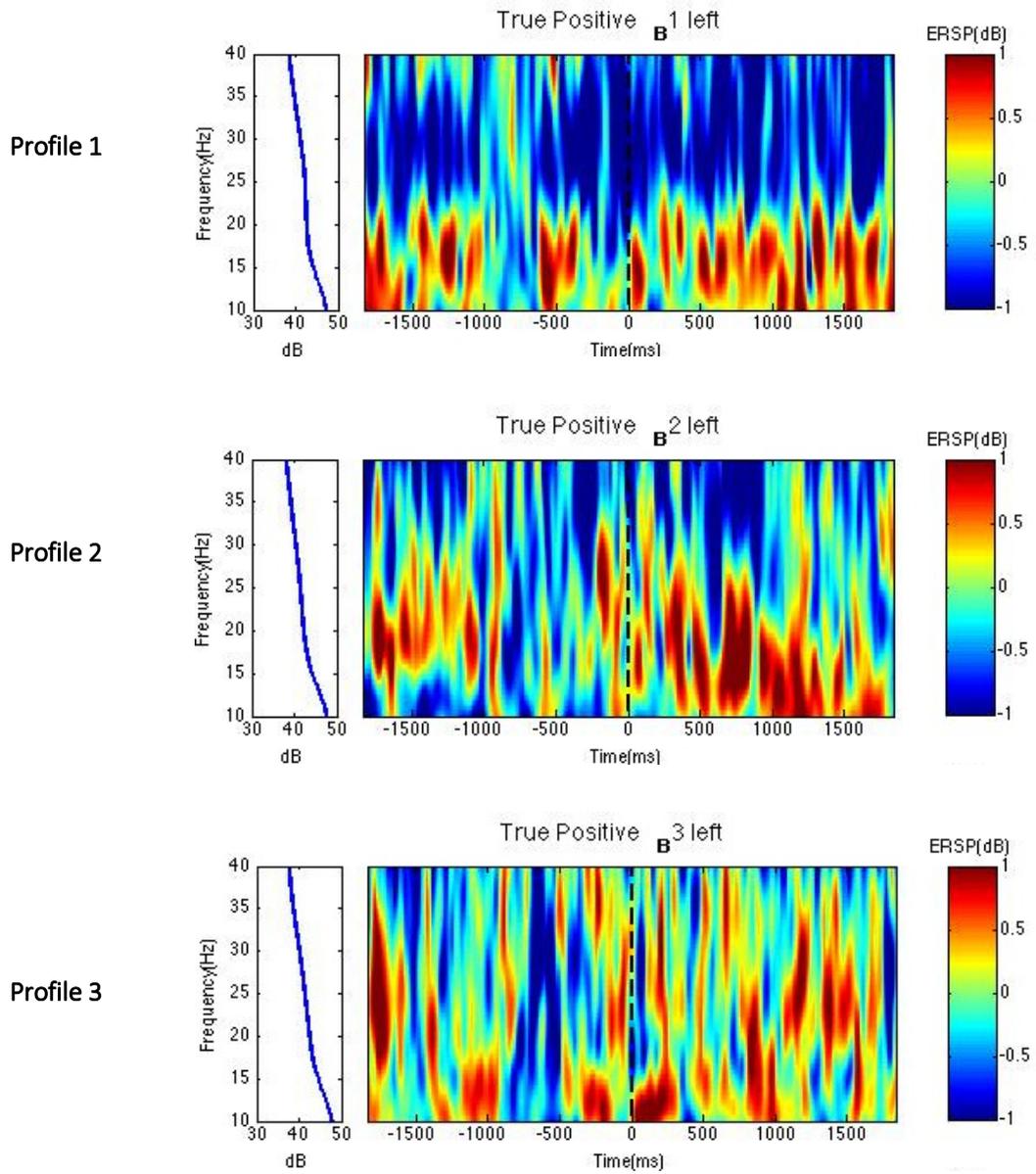
	A+O+	A+O+
	<i>Low</i>	<i>Foreign</i>
Mean	-0,15812	0,03364
Variance	0,32005408	0,395468
Observations	10	10
Pearson Correlation	0,603613477	
Hypothes Mean Diff	0	
df	9	
t Stat	-1,13384299	
P(T<=t) one-tail	0,143079094	
t Critical one-tail	1,833112933	
P(T<=t) two-tail	0,286158188	
t Critical two-tail	2,262157163	

ERSP PLOTS OF EVERY CONDITION PER PROFILE (BLOCK)

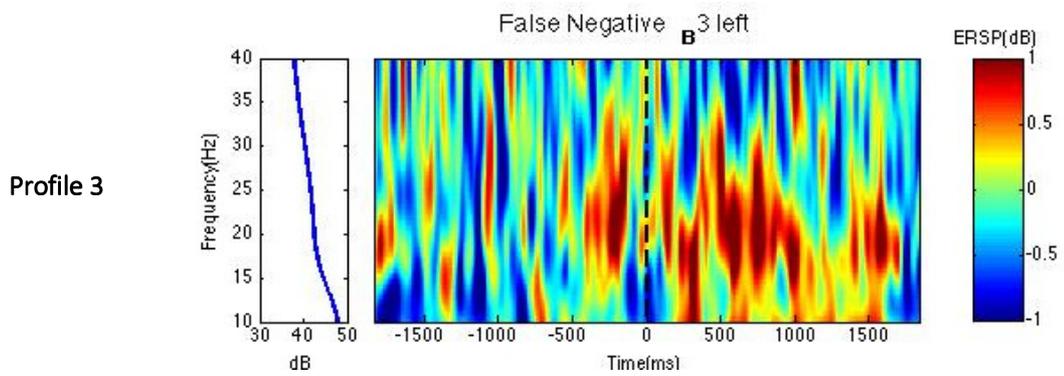
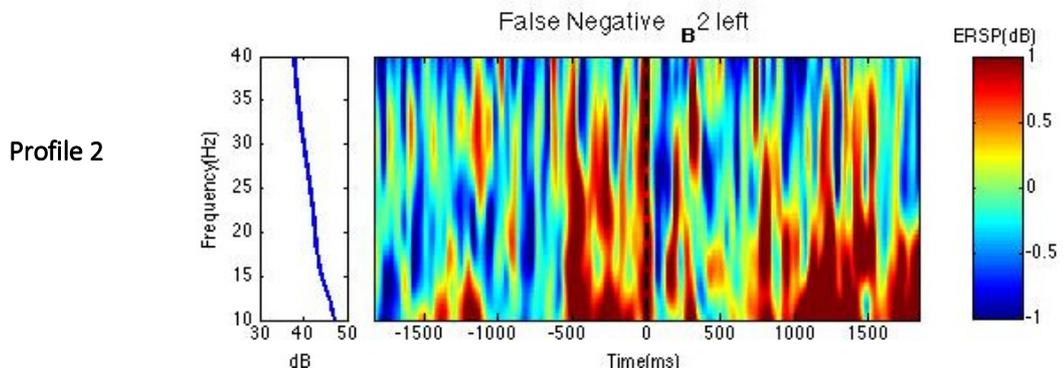
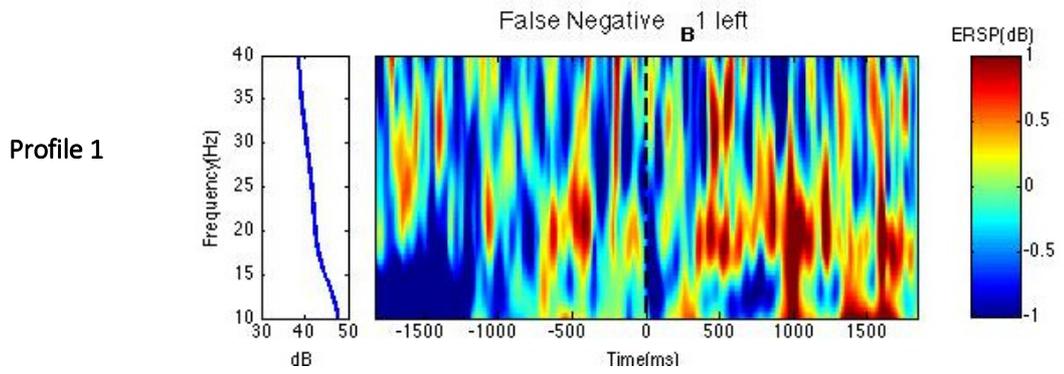
False Positive Condition A+O-



True Positive Condition A+O+



False Negative Condition A-O+



True Negative Condition A-O-

