

UNIVERSIDAD COMPLUTENSE DE MADRID

FACULTAD DE PSICOLOGÍA



TESIS DOCTORAL

The influence of facial information on language comprehension: an event-related brain potential study on syntax and semantics

La influencia de la información facial en la comprensión del lenguaje: estudio con potenciales cerebrales evento-relacionados sobre sintaxis y semántica

MEMORIA PARA OPTAR AL GRADO DE DOCTOR

PRESENTADA POR

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Madrid



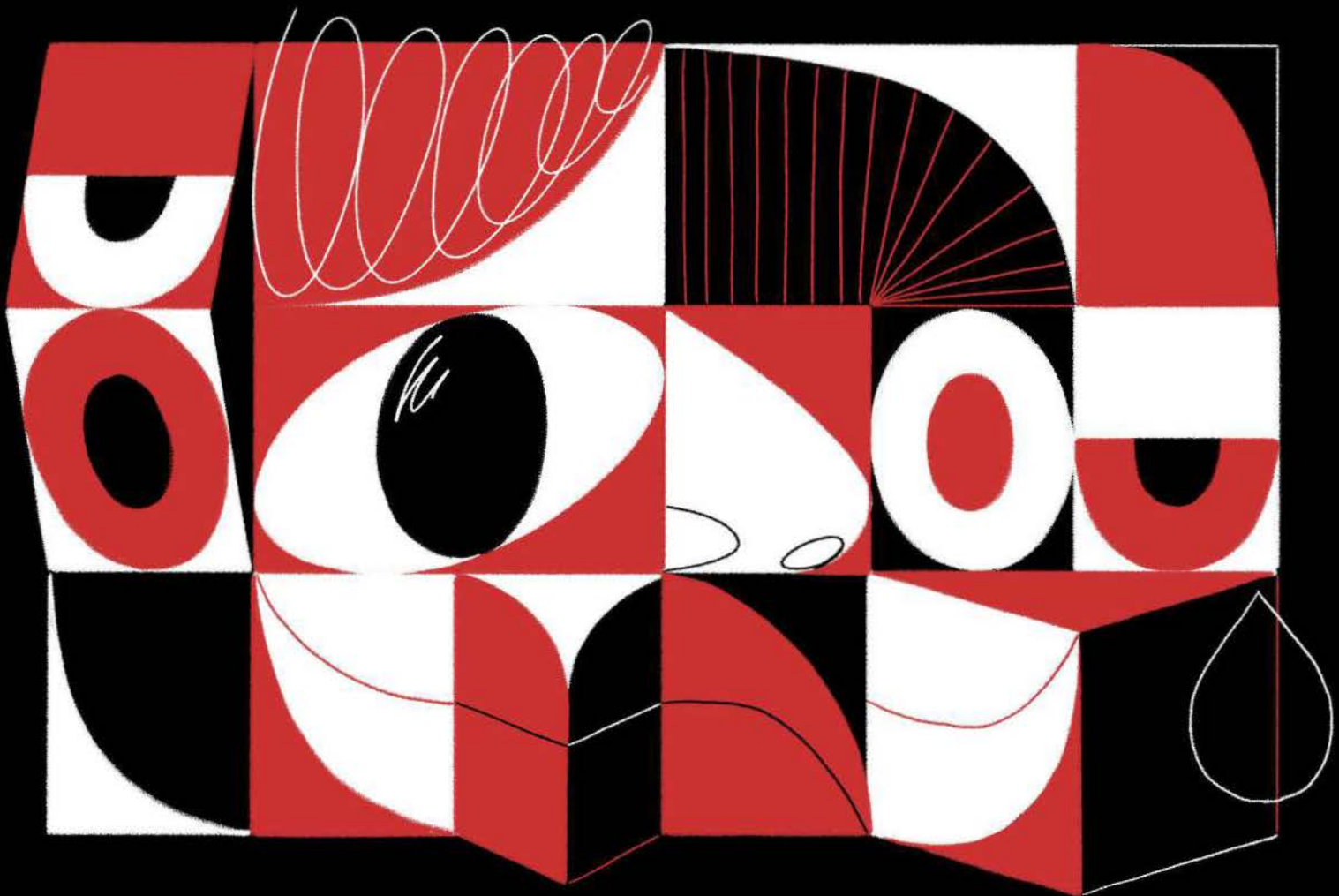
THE INFLUENCE OF FACIAL INFORMATION ON LANGUAGE COMPREHENSION: AN EVENT-RELATED BRAIN POTENTIAL STUDY ON SYNTAX AND SEMANTICS

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Madrid, 2019

FACULTAD DE PSICOLOGÍA

Dept. Psicobiología y Metodología en Ciencias del Comportamiento



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A todas aquellas personas que han estimulado mi curiosidad por conocer

A mis padres, por brindarme oportunidades, no dogmas

“Homo sum, humani nihil a me alienum puto”

Hombre soy, nada humano me es ajeno

Publio Terencio, *Heautontimorumenos*, 165 a.C.

1. AGRADECIMIENTOS

A pesar de que esta tesis la firme yo, todo el trabajo que está detrás es compartido con mucha gente. Llegar aquí ha sido fruto de trabajo, ilusión y esfuerzo; pero sobre todo de haberme rodeado de las personas adecuadas. Además, mi motivación para poder llevar a cabo la tesis tiene en gran parte su origen en la gente que me acompaña en mi vida personal, más allá del laboratorio y de mi vida académica. Y es que, aunque este último año he llegado a dudarlo, creo que soy humano y por ende social.

En primer lugar, quiero dar las gracias a mis amigos del grupo de investigación, que incluso han acabado siendo compañeros, ¿o era al revés? Muchos llevan conmigo desde el día que llegué al Centro de Evolución y Comportamiento Humanos. Recuerdo que el David de aquella época medía 1,60 m y pesaba 50 kg... ¡cómo he cambiado!

Gracias a mis dos directores de tesis, Manolo y Paco. Como director del grupo de investigación, Manolo, me gustaría agradecerte la confianza que depositaste sobre mi desde el primer momento para ser responsable de mi propio experimento. Me has dado la oportunidad de trabajar de manera autónoma y de desarrollar unas habilidades que serán básicas para mi carrera científica. Gracias por tu dirección de la tesis. Prometo hacerte caso y no escribir artículos con introducciones de quince páginas y ochenta referencias. Nadie maneja el “paper pruning” como tú, Manolo. Eso es arte.

Por otro lado, gracias Paco por estar ahí en el día a día, por animarme y mostrarte siempre disponible a ayudarme con cualquier aspecto de la investigación. Fue una muy buena idea que me codirigieras la tesis. Lo único que me fastidia es no haber tenido suficiente tiempo para poder aprender más de ti. Sabes que admiro tu curiosidad por aprender nuevos análisis de datos y por los aspectos metodológicos del EEG. He disfrutado trabajando codo con codo contigo. Siempre nos quedará el recuerdo de esas

cervezas mientras atardecía en la playa de Vancouver (dejo ya el relato, que mis lágrimas caen por el ordenador y al final me quedo sin tesis...).

Mil gracias, Sabela, por animarme hace 9 años a escribir a Manolo para empezar mi colaboración en el ISCIII. Si no fuera por ti yo no habría escrito esta tesis. Seguramente estaría trabajando y tendría dinero, pero no pasa nada, no te tengo rencor. Has sido y eres una amiga necesaria, me has ido abriendo camino y es una maravilla tenerte en mi vida. Nos hemos desahogado juntos y me has aportado más de lo que crees. Gracias por la complicidad, Sabelix.

Por otro lado, gracias Pili por ser como una madre conmigo, por tu cariño, por preocuparte por mí y tenderme una mano siempre que lo he necesitado; por ayudarme sin esperar nada a cambio con todas las gestiones en el Departamento y cuando he dado clases en la Facultad. Además, casi das tu vida por mí en aquel tándem en San Francisco, nunca lo olvidaré (en realidad no fue por mí, pero hay que darle un poco de emoción a esto).

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Gracias José, a pesar de llevar menos tiempo en el laboratorio eres una persona especial para mí y te tengo mucho cariño. Sin tu ayuda habría sido imposible acabar de preparar el material experimental. Eres un excelente compañero, al nivel de tu persona.

A pesar de mirarte con ojos raros cuando en vez de comer sales al jardín a hacer tus ejercicios, yo te apoyo, José. Solo espero en un futuro poder juntarnos con Philip Glass a tomar algo (y entonces pasaré por alto que pidas una botella de agua).

Gracias también al resto de compañeros con los que he trabajado en la Sección de Neurociencia Cognitiva: Javi, Clara, María, Joaquín, Miguel, Íker, Zahara e Irina. Todos habéis puesto vuestro granito de arena de un modo u otro en esta tesis. Además del resto de compañeros del UCM-ISCI, los vecinos de Atapuerca: Jaime, Elena, Mónica, Virginia, Álvaro, Ana, Maicu, Mila... Da gusto tener a mi alrededor gente así en el día a día, aunque me reprochéis que ya ni como con vosotros. En breve vuelvo, lo prometo.

La gente de la Universidad Humboldt de Berlin también se merecen mi agradecimiento. Especialmente los profesores Werner Sommer y Rasha Abdel Rahman. La estancia que realicé en el laboratorio de Psicología Neurocognitiva me permitió desarrollar una colaboración científica que ha dado lugar a uno de los estudios de la tesis. Gracias por vuestra confianza y por vuestra manera tan constructiva de hacer correcciones y sugerencias sobre mi trabajo. Pude aprender mucho de vosotros y ampliar mi visión sobre la investigación en neurociencia cognitiva.

Quiero también agradecer a César su ayuda con Matlab (“será muy fácil” ...decía, “será divertido” ...decía). Ojalá en un futuro aunemos fuerzas y publiquemos algo juntos, aunque igual el proceso acaba siendo más significativo que el fin. Te tengo en un pedestal, primo. Del mismo modo, gracias Rober por tus clases de Illustrator y tu ayuda con la preparación de las imágenes. Por si fuera poco, me has diseñado una portada digna de ser enmarcada, ¡crack! Si no fuera por vuestra ayuda aún estaría codificando el material experimental a mano y haciendo las figuras con ceras Manley y un punzón.

Hay dos amigos que habéis sido clave desde que comencé la carrera hasta el día de hoy: Xabi y Lucas. Las discusiones que hemos mantenido sobre psicología han sido de las conversaciones más interesantes que recuerdo, impensables con otras personas. Habéis reforzado mi criterio científico, me habéis motivado a querer saber más y más sobre cómo funciona la mente humana y habéis fortalecido mi amor por esta disciplina. Sois ambos irremplazables y únicos. No os meto en mi currículum vitae porque quedaría raro, pero espero teneros siempre cerca.

De manera muy especial quiero dar las gracias a mis padres. Es seguro que sin ellos esta tesis no existiría, ni en particular yo mismo. Si empecé a interesarme por la psicología fue por ti, mamá. Recuerdo cuando estuviste a punto de comenzar la carrera por la UNED y te compraste varios libros. Finalmente me he dedicado a algo que nada tiene que ver con la idea de psicología que tenías tú, pero mira...fuiste una influencia necesaria para que yo esté escribiendo esto. Gracias también, papá, por animarme siempre a dedicarme a aquello que me hiciera feliz, sin importar el qué fuera. Me has transmitido la importancia de ser disciplinado con el trabajo y esforzarme, pero sin perder de vista que la vida está para vivirla y disfrutarla. Creo que ese equilibrio ha sido clave para poder aguantar todos estos años de tesis. Gracias a los dos de todo corazón por vuestra ayuda, vuestra preocupación, vuestro amor y por estar siempre ahí. No sabéis lo importantes que sois para mí.

Por último, gracias también mi pareja y compañera de aventuras vitales, Mónica. Gracias por tu paciencia, por animarme día tras día cuando parecía que la tesis no tenía fin, por tu comprensión y tu empatía durante el tiempo que pasé de estancia y por ser un pilar en mi vida en el que apoyarme a descansar. Contigo voy asegurando el terreno sobre el que se sucede el resto de mi vida, entre la que se incluye mi labor científica. Esta carrera no es fácil y recibir tu apoyo para que siga intentando vivir de lo que me gusta me da la seguridad que necesito. Gracias por el buen amor. Te quiero.

2. PREFACE

Nine years ago, recently arrived from an Erasmus internship in Amsterdam, I attended a UCM summer course about “Neuroesthetics” in El Escorial. I was a Psychology pregraduate student who had just finished third course, and I was extremely curious about neuroscience and experimental psychology. It was in that summer course where I met Sabela, a girl who was completing her PhD about cognitive neuroscience of religion at the Center for Human Evolution and Behaviour UCM-ISCIII. After talking to her for a while, I made her know I was interested on psychological science, and she encouraged me to contact the head of her group, Manuel Martín-Loeches, to collaborate with them. Said and done. In September 2010, after the summer break, my adventures began at the Cognitive Neuroscience Section of that Center... up to this day. Here I had my first contact with scientific research, I did my Neuroscience Master thesis, I had the opportunity to write my first paper and it is in this group where I completed the present doctoral dissertation. This period may be approaching its end and, therefore, this thesis means for me more than just a procedure to obtain a PhD title that will allow me for continuing my scientific career (or at least to try it!).

I started working on this thesis in April 2015, when I got an FPI pre-doctoral fellowship. However, I have spent almost one third of my life in this group. During this time, I have changed a lot; an inevitable consequence of learning, I guess. I also had some difficult times (an inevitable consequence of doing a PhD?) but, mostly, I have grown up and I have spent a great time with lots of laughs. I have shared very good moments with my colleagues, for sure; so they have ended up being a second family for me. I only hope that this dissertation could be at the level of this nine-year season.

The three studies that conform the basis of present PhD thesis have been mostly performed at the Center for Human Evolution and Behaviour UCM-ISCIII, in Madrid. But

part of this research has also been performed at the Humboldt University of Berlin, by virtue of a research internship that I completed in 2016 under the supervision of Prof. Werner Sommer. In particular, the data collection and part or the analyses of the first study were performed in Berlin. The other two studies have been entirely performed in Madrid.

To conclude, I would like to name the persons that have been involved in these experiments, who are already or will be co-authors of the corresponding scientific publications (in alphabetic order):

*Study One**: Rasha Abdel Rahman, Manuel Martín-Loeches, Francisco Muñoz-Muñoz, Annekathrin Schacht, Werner Sommer

Study Two: Rasha Abdel Rahman, Pilar Casado, Javier Espuny, Sabela Fondevila, Laura Jiménez-Ortega, Manuel Martín-Loeches, Francisco Muñoz-Muñoz, Irina Noguer, Jose Sánchez-García, Werner Sommer

Study Three: Pilar Casado, Javier Espuny, Sabela Fondevila, Zahra Khosrowtaj, Laura Jiménez-Ortega, Manuel Martín-Loeches, Francisco Muñoz-Muñoz, Jose Sánchez-García, Werner Sommer

* Published: Hernández-Gutiérrez, D; Abdel Rahman, R; Martín-Loeches, M; Muñoz, F; Schacht, A; Sommer, W. (2018). Does dynamic information about the speaker's face contribute to semantic speech processing? ERP evidence. *Cortex*, 104, 12-25

PREFACIO

Hace nueve años, recién llegado de un Erasmus en Ámsterdam, asistí a un curso de verano de la UCM sobre “Neuroestética” en El Escorial. Yo era un estudiante de Psicología que acaba de terminar tercero de carrera con una curiosidad enorme por la neurociencia y la psicología experimental. Fue allí donde conocí a Sabela, una chica que estaba realizando su doctorado sobre neurociencia cognitiva de la religión en el Centro de Evolución y Comportamiento Humanos UCM-ISCIH. Tras hablar más de lo divino que de lo humano, le comenté que tenía interés por “eso de la ciencia psicológica” y me animó a escribir al director de su grupo, Manuel Martín-Loeches, para colaborar con ellos. Dicho y hecho. Terminó el verano y en septiembre de 2010 comenzaron mis aventuras por la Sección de Neurociencia Cognitiva de dicho centro... hasta el día de hoy. Es aquí donde tuve mi primera toma de contacto con la investigación científica, donde posteriormente realicé el TFM del Máster de Neurociencia, donde pude escribir mi primer artículo científico y donde se ha desarrollado esta tesis doctoral. Parece que esta etapa se aproxima a su fin, por eso esta tesis supone para mi mucho más que un trámite para obtener el título de doctor y seguir mi carrera científica (¡o al menos intentarlo!).

Esta tesis se ha desarrollado desde abril de 2015, cuando comencé el contrato predoctoral FPI, hasta la actualidad. Sin embargo, en este laboratorio he pasado casi un tercio de mi vida. En todo este tiempo he cambiado mucho, consecuencia inevitable del aprendizaje; también lo he pasado mal (¿consecuencia inevitable de hacer una tesis?); pero sobre todo he crecido, he disfrutado y me he reído mucho. Desde luego, he pasado muy buenos momentos junto a mis compañeros de laboratorio, que son como una segunda familia. Solo espero que la tesis esté a la altura de esta temporada de nueve años y sirva así como broche a la misma.

Los tres estudios que forman la tesis se han llevado a cabo en el Centro de Evolución y Comportamiento Humanos UCM-ISCIH y en la Universidad Humboldt de Berlín, gracias a la estancia de investigación que realicé en 2016 bajo la supervisión del profesor Werner Sommer. En concreto, la recogida de datos para el primer estudio de la tesis y parte de los análisis se llevaron a cabo en Berlín. Los otros dos estudios se han llevado a cabo en su totalidad en Madrid.

Por último, me gustaría nombrar a las personas que han participado en la realización de los experimentos que forman la tesis y que son o serán coautores de las publicaciones científicas correspondientes (en orden alfabético):

*Estudio Uno**: Rasha Abdel Rahman, Manuel Martín-Loeches, Francisco Muñoz-Muñoz, Annkathrin Schacht, Werner Sommer

Estudio Dos: Rasha Abdel Rahman, Pilar Casado, Javier Espuny, Sabela Fondevila, Laura Jiménez-Ortega, Manuel Martín-Loeches, Francisco Muñoz-Muñoz, Irina Noguer, Jose Sánchez-García, Werner Sommer

Estudio Tres: Pilar Casado, Javier Espuny, Sabela Fondevila, Zahra Khosrowtaj, Laura Jiménez-Ortega, Manuel Martín-Loeches, Francisco Muñoz-Muñoz, Jose Sánchez-García, Werner Sommer

* Publicado: Hernández-Gutiérrez, D; Abdel Rahman, R; Martín-Loeches, M; Muñoz, F; Schacht, A; Sommer, W. (2018). Does dynamic information about the speaker's face contribute to semantic speech processing? ERP evidence. *Cortex*, 104, 12-

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3. ABSTRACT

Psycholinguistic research has traditionally focused on the study of the processes that make possible the comprehension of a linguistic message. Despite language is an inherent social capacity, face-to-face contexts have not received enough attention. In such situations, language comprehension entails an audiovisual processing, that is, auditory speech rapidly combines with visual information from the speaker's face. Further, just seeing the speaker situates language processing in a social context. In this dissertation I investigate the effect of speaker's face-related factors on semantic and morphosyntactic processing. Along three studies, participants listened to connected speech while seeing the speaker's face. Meanwhile, an electroencephalogram (EEG) was recorded. The event related-potentials (ERPs) were computed to the critical words, which varied either on semantic congruency, expectancy or morphosyntactic correctness.

In *Study One*, which comprised three experiments, the presence of the dynamic facial features (eyes and mouth) was manipulated, comparing also a video of the speaker with a still picture of his face. Meanwhile sentences that could contain semantically unexpected words were presented. Contrary to our hypothesis, the N400 component to unexpected words was not affected by the facial movements, but a late posterior positivity appeared to expected words in the dynamic condition compared to the still face condition. This effect diminished when either visual speech or the eyes of the speaker were unavailable.

Along two experiments, *Study Two* investigated the effect of visual social context on the semantic and morphosyntactic processing of speech, respectively. Contrary to the first study, which always situated language processing in a social context, here the dynamic speaker's face was substituted by a scrambled face, as a control condition for

the still face picture. This manipulation was expected to increase the language-related ERP amplitudes in the face condition. In line with this prediction, the N400 effect to the comparison of congruent and incongruent words was larger when seeing the speaker's still face compared to the scrambled face. However, the morphosyntactic processing was not affected, being the LAN and P600 effects not modulated by this manipulation.

Study Three also consisted of two experiments. Here, the emotional facial expression of the speaker was investigated, which could be fear, happiness, or neutral. In the semantic experiment no effect of emotion was found on the semantic N400 effect. However, the semantic P600 effect was reduced when facing the speaker with fear and happy emotional facial expressions. In the syntactic experiment however, the speakers with fear expression triggered a larger LAN effect to morphosyntactic violations, compared to the other emotional conditions. This component was barely visible when facing the happy speaker's face. Subsequently, the P600 effect in the fear condition appeared reduced in amplitude compared to the other conditions, being the happy speaker's face the one showing the largest P600 effect.

The evidence discussed here demonstrates that language comprehension cannot be completely understood apart from its natural social context, which seems to convey a number of significant issues. Overall, this dissertation constitutes a first approach to the psychophysiological study of semantic and syntactic language processing taking into consideration speaker's facial factors.

RESUMEN

Tradicionalmente, la investigación en psicolingüística se ha centrado en el estudio de los procesos que hacen posible la comprensión de un mensaje lingüístico. Sin embargo, a pesar de que el lenguaje es una capacidad humana inherentemente social, los contextos cara a cara no han recibido atención suficiente. En tales situaciones la comprensión del lenguaje es un proceso audiovisual y el habla auditiva se combina rápidamente con información visual procedente de la cara del hablante. Además, solo ver al hablante es suficiente para contextualizar socialmente el procesamiento lingüístico. A lo largo de tres estudios, esta tesis investiga el efecto que tienen diferentes variables relacionadas con la cara del hablante sobre el procesamiento semántico y morfosintáctico. Los participantes escucharon oraciones mientras veían la cara del hablante y al mismo tiempo se registró su actividad eléctrica cerebral mediante un electroencefalograma (EEG). Además, se calcularon potenciales evento-relacionados (PERs) a las palabras críticas, las cuales, dependiendo del experimento, variaban en congruencia semántica, expectativa o corrección morfosintáctica.

En el *Estudio Uno*, constituido por tres experimentos, se manipuló la presencia de los componentes faciales dinámicos (boca y ojos), y se presentaba un video del hablante o una imagen estática de su cara, mientras escuchaban oraciones que podían contener una palabra semánticamente imprevisible. En contraposición a nuestra hipótesis inicial, el componente N400 generado ante palabras semánticamente imprevisibles no se vio afectado por los movimientos faciales; sin embargo, una positividad posterior tardía apareció en la condición dinámica ante las palabras previsibles, en comparación con la condición facial estática.

A lo largo de dos experimentos, en el *Estudio Dos* se investigó el efecto del contexto visual social en el procesamiento morfosintáctico y semántico del habla,

respectivamente. Al contrario que en el primer estudio, en el que el procesamiento lingüístico siempre sucedió en un contexto social, en este caso la cara dinámica del hablante se sustituyó por la imagen de una cara visualmente desordenada (*scrambled face*) como condición control de la imagen de la cara estática. En la condición facial estática se esperaba un aumento de amplitud de los componentes asociados con el procesamiento lingüístico. De acuerdo con esta hipótesis, se encontró un aumento del efecto semántico N400 cuando los participantes veían la cara del hablante en comparación con la condición control. Sin embargo, el procesamiento morfosintáctico no se vio afectado, de manera que los componentes LAN y P600 no sufrieron variaciones significativas.

El *Estudio Tres* lo forman también dos experimentos. En este caso se investigó el efecto que tiene sobre la comprensión del lenguaje la expresión facial emocional de hablante, que podía ser de miedo, de alegría o neutra. En el experimento semántico no se encontró ningún efecto de la emoción sobre el componente N400, si bien el efecto P600 semántico se redujo al ver al hablante con expresión de miedo y de alegría. En el experimento sintáctico los hablantes con expresión emocional de miedo mostraron un efecto LAN ante errores morfosintácticos mayor que las otras condiciones emocionales, el cual prácticamente desapareció ante el hablante alegre. Seguidamente, el efecto P600 en la condición de miedo redujo su amplitud respecto a las otras expresiones faciales emocionales, siendo la de alegría la que mostró el mayor efecto.

Los resultados obtenidos en la presente tesis demuestran que la comprensión lingüística no puede ser entendida en su totalidad mediante el estudio de sus procesos de manera aislada del contexto social en el que suceden de manera natural. En general, la tesis supone un primer acercamiento al estudio psicofisiológico del procesamiento semántico y sintáctico del lenguaje teniendo en cuenta las variables faciales del hablante.

4. CHAPTER 1. INTRODUCTION

Psycholinguistic research discovers complexity on something that intuitively is very simple and automatic. We can talk, we can understand speech, and no one remembers himself investing amounts of effort to gain proficiency on his native language. Let's imagine an individual who suddenly observe human behaviour for the first time. With the eyes of innocence, it would be incredibly strange to see how humans usually emit particular sounds when accompanied by other humans. It would be possible to see how humans usually stop doing what they do to look at a specific part of other's body, the face, while this happens. An interesting discovery would be that certain sounds emitted by a human can make other humans do things. Therefore, the behaviour and motivations of a person can be modified by those coordinated sounds coming from another individual. Indeed, language is much more fascinating than that. Probably the curious observer would never realize that human language makes possible to take the past back to the present and even travel to the future to coordinate an event with other humans in that specific moment. This imaginary exercise exemplifies the complexity of this common and at the same time peculiar human faculty.

Thus, human language makes possible to generate mental states in others "just" through generating sound waves that a listener receives, processes and transforms into a meaningful stimulus. Behind this ability there are different components (phonetics, semantics, syntax, pragmatics) that, despite been widely studied, we cannot yet completely explain how language can be understood and what its neural bases are. Humans use language to communicate meaning through words, which are symbols that have no inherent meaning (Hockett, 1960). Moreover, words can be combined to create new meanings that result in a very detailed output of the speaker's thoughts. The proficiency with a language is directly related to the ability to express our thoughts, to communicate with another person and transmit exactly what we want. This becomes

clear when a sender uses a non-native language that she cannot speak fluently. Depending on her expertise, she might be limited to the use of isolated words and, similarly, when listening to sentences her comprehension might be constrained to a few words. The ability to relate sounds or gestures with specific meanings has been found in other non-human primates too. It is well known the case of KOKO, a gorilla trained by Dr Francine Patterson who was able to learn vocabulary using American Sign Language (Patterson & Cohn, 1990), or the vervet monkeys that have different sounds for each predator (Seyfarth, Cheney & Marler, 1980). However, it would not be correct to say they have a language. The syntax component of human language embodies a system of rules that a person knows when fluently speaking a language, and determines how words can be combined, which elements go together, who made what, and how words can decline depending on the person, the number or the gender they refer to. Contrary to the use of isolated words, this ability is strictly human.

Language is the result of an evolutionary process in a social context. Despite the predominance of the auditory modality (Hickok & Poeppel, 2016), language can be considered an audiovisual adaptation. The importance of vision is easily recognized in a situation of impaired auditory language perception, which hampers language comprehension (Blackburn, Kitterick, Jones, Summer & Stacey, 2019). In that situation, communication is much more effective when seeing the speaker's face compared to a hypothetical telephone conversation, which clearly differs from the social face-to-face context where language evolved. Seeing the speaker's face allows the listener to direct attention to his mouth and facilitates the perception of words. Moreover, by following speaker's gaze the listener could know what he is referring to in case it is a person or an object in the room. On the other hand, the speaker's emotional facial expression might help to infer the meaning of the message. Therefore, language exploits non-linguistic visual cues that facilitate communication. Even if not always necessary, this social

information is used in every face-to-face encounter in which language is used. This is coherent with the fact that humans are an “ultra-social animal” (Tomasello, 2014) and many adaptations in the facial structure have been related to the expression of communicative intentions (see the *Evolutionary perspective* section).

Behavioural and neurophysiological approaches to the study of language comprehension have been typically performed in controlled contexts, where linguistic stimuli are presented visually on a computer screen. This setup facilitates the manipulation and presentation of the linguistic stimuli but implies grapheme-phoneme conversion, so different neural processes underly when compared with auditory modality (Schurz et al., 2010). Although these studies have studied language in the visual modality, more research is necessary from a multisensory perspective, like natural interpersonal communication. This may be important considering the social origins of language.

The present dissertation tries to extend current knowledge in this line, that is, how language comprehension might be biased by face-to-face interaction. In particular, we aim to investigate to what extent the face perception of the interlocutor might affect the syntactic and semantic processing of sentences, simulating a context of human communication. This research is framed into the field of cognitive neuroscience and will use electroencephalography (EEG) to reveal those neural processes elicited by both semantic and syntactic processing, as being modulated by facial stimuli (connected speech).

4.1. The electroencephalography (EEG) and the event-related potential (ERP) technique

Cognitive neuroscience is a broad discipline that aims to study mental processes and behaviour in relation to its underlying neural substrates. For this purpose, one of the

most valuable techniques is the electroencephalography (EEG). By placing electrodes over the scalp, it is possible to measure the postsynaptic potentials of patches of pyramidal neurons that fire synchronously.

The origins of this electrophysiological technique dates to 1875. Richard Caton, a British physiologist, wrote a short text titled "The electric Currents of the Brain" (Caton, 1975). He observed in rabbits and monkeys that "*Feeble currents of varying direction pass through the multiplier when the electrodes are placed on two points of the external surface, or one electrode on the grey matter, and one on the surface of the skull.*" This opened the door to a new field of study that resulted in the first electroencephalogram recording by Hans Berger in 1924, thanks to the technology advances that enabled to amplify the signal (Berger, 1929; Haas, 2003).

However, the raw EEG cannot be used to study individual neurocognitive processes because the ongoing EEG activity is a mix of sensory, motor and cognitive brain activity, as well as random oscillatory activity. The specific neural response associated to individual processes can be isolated by means of the event-related potentials (ERPs) technique, consisting of electrical potentials related to specific events (Luck, 2014). An important characteristic of the ERPs is that the brain signal is time-locked and phase-locked, increasing the signal-to-noise ratio by averaging the EEG activity of several single trials associated to an event. This event can be, for example, the auditory presentation of a critical word within a sentence containing a morphosyntactic agreement violation. In this case, the ERP elicited by the onset a word results in a sequence of waveforms, called ERP components that may have positive or negative voltage at different latencies, reflecting the flow of information through the brain at a specific moment of time (Luck, 2014). The specific modulations of the ERP components to each experimental manipulation may lead to a useful comprehension on the underlying cognitive processes, since they are functionally related to identifiable events. This makes possible

to test hypotheses regarding phonological, syntactic or semantic processes depending on the amplitude and latency variations of certain ERP waves. Each ERP component is also associated with a topographic map, a 2D display of the scalp representing the distribution of ERP voltages across the electrode locations on a specific time (Hari & Puce, 2017). Therefore, each component can be defined by different parameters, namely, amplitude, latency and topography, relative to a stage of cognitive process.

The advantage of the ERPs to study cognitive processes compared to behavioural methods is the direct measurement of the ongoing brain activity. It provides detailed timing of the cognitive operations with a temporal resolution of milliseconds. On the other hand, its weakness compared to other techniques (e.g. fMRI, MEG), is that it offers low spatial resolution and it is not a proper technique to study where a specific cognitive process is being computed within the brain. Therefore, to take advantage of the benefits of the ERP technique it is necessary to make suitable scientific questions focused on the time course of the processing and not on its structural basis.

4.1.1 The electrophysiology of language comprehension

Neurolinguistics uses the theoretical framework provided by psycholinguistics to generate additional knowledge on neural mechanisms of language. ERP experiments are usually adapted from behavioural paradigms and both methods complement each other. Well-known linguistic-related indices are the N400, the LAN, and the P600 components.

The N400 is a default response to a meaningful stimulus and its amplitude to a word in a sentence is related to the degree of congruency within the contextual constraint of previous information (Payne, Lee & Federmeier, 2015; Kutas & Federmeier, 2011). This component peaks around 400 ms from stimulus onset and its topography varies from more central-parietal to posterior sites (Schöne, Köster & Gruber, 2018; Van

Petten, 2014a). Recently, it has been also interpreted as a late Mismatch Negativity (MMN) reflecting precision-weighted prediction errors, but with different latency and topography because of higher stimulus complexity (Bornkessel-Schlesewsky & Schlewsky, 2019). Interestingly, this interpretation extends to all the negative linguistic-related component, including the LAN.

The LAN is a negative component peaking between 200-500 ms at left frontal electrodes usually, after the word onset (e.g. Coulson, King, & Kutas, 1998; Osterhout & Holcomb, 1992). It is typically reflecting morphosyntactic integration difficulty (Friederici, 2002). Despite this wide interpretation, semantic-reversal anomalies -“The window closes (someone)”- compared to correct versions -“(Someone) closes the window”- yield a LAN followed by a P600 (see below), instead of an N400 (Kim & Sikos, 2011, Yano & Sakamoto, 2016). A controversial interpretation of the LAN calls into question the existence of this component, which could be an artefact resulting from the overlap between the N400 and the P600 (Osterhout, 1997; Osterhout, McLaughlin, Kim, Greenwald, & Inoue 2004; Tanner & van Hell, 2014; Tanner, 2019). Even though this is a possible interpretation, the LAN has been found independently from the existence of a P600 component (Molinaro, Barber & Carreiras, 2011).

The P600 is a long-lasting positive component with a variable latency compared to other components like the N400 (Sassenhagen, Schlewsky & Bornkessel-Schlewsky, 2014). Hence, depending on the stimulus and task, the onset of the P600 has been reported from 200 to 700 ms (or even later) and typically reaches its maximum voltage at around 800 ms after the critical word's onset. This component has been related to analysis, repair, or reanalysis processes (Friederici, 2011; Brouwer, Fitz & Hoeks, 2012; Kim & Osterhout 2005) However, this component has been also found to semantic manipulations. The semantic P600 emerges in semantic reversal anomalies (*'The hearty meal was devouring the kids'* compared to *'The hearty meal was devoured*

by the kids') (Kolk, Chwilla, van Herten & Oor, 2003; Vissers, Chwilla & Kolk, 2007) and in the comparison of semantically incongruent vs. congruent sentences (Roehm, Bornkessel-Schlesewsky, Rösler, Schlesewsky, 2007; Van Petten & Luka 2012). Sassenhagen et al. (2014) suggested that the P600 might be revealing general-domain cognitive processes, similarly to P300. Instead of reflecting structural or combinatorial operations, the P600 would relate to recognition and categorization processes, and its amplitude would be related to the salience or degree of significance of this stimulus class. P600 effects are typically elicited in morphosyntactic tasks compared to semantic violations because morphosyntactic violations are more categorical, that is, easy to decide about correctness (Coulson et al., 1998; Sassenhagen et al., 2014). However, when semantic violations are deeply implausible, the N400 is followed by a P600 (van de Meerendonk, Kolk, Vissers & Chwilla, 2010)

4.2. Linguistic processing

One of the most adaptive functions of language is the expression and communication of thoughts (Jackendoff, 2002). For a successful communication, speaker and listener ought to share common knowledge. Apparently, language function takes place automatically. This is at least our subjective perception because, indeed, language comprehension occurs extremely fast in the brain. However, before a listener understands a message from the speaker, different psycholinguistic processes must necessarily take place. For instance, listeners should be capable of discriminating, combining and integrating different linguistic levels (phonological, morphological, lexical) to combine semantic and syntactic information using syntactic rules (Skeide & Friederici, 2018). Moreover, listeners do not limit themselves to the linguistic content in order to generate a mental state that resembles the most what the speaker actually wants to communicate, but also use other elements like the emotional facial expression,

gaze direction and speech prosody. Therefore, language comprehension goes beyond listening to a mere concatenation of words.

The neurobiology of language studies the biological basis of the processes and representations that enable the production and understanding of language in context (Small & Hickok, 2016). Classical approaches to the neural basis of language processing were performed with post-mortem damaged brains. Two structures that sustained language were identified: Broca's area, initially thought to be devoted to language production, and Wernicke's area, initially conceived as for language comprehension (Broca, 1863; Wernicke, 1874). Nowadays, the use of neuroimaging techniques like the functional magnetic resonance imaging (fMRI) and the magnetoencephalography (MEG) is making possible the emergence of a more accurate and complex neural model of language processing. Particularly, the importance of Broca's area has been extended to the inferior frontal cortex, including pars triangularis (BA45) and pars opercularis (BA44) (Hagoort, 2014, Friederici, Chomsky, Berwick, Moro & Bolhuis, 2017). Moreover, Wernicke's area is not the only location within the temporal lobe dedicated to language comprehension; the entire superior temporal gyrus, the superior temporal sulcus and the middle temporal gyrus (BA 22) are also involved (Friederici, 2012). These regions are connected as well to cortical sensory and association areas, and subcortical regions that relate to memory, emotion, speech sequencing and cognitive control processes, among others (Makuuchi & Friederici, 2013, Kotz & Schwartz, 2010; Friederici, 2006; for a review see Skeide & Friederici, 2018). Current proposals of syntax processing include regions in the frontal and posterior temporal lobe (Tyler & Marslen-Wilson, 2007; Wilson et al., 2014; 2016; Blank, Balewski, Mahowald & Fedorenko, 2016). The frontal and temporal areas are interconnected through the inferior fronto-occipital fasciculus -ventral tract- and the superior longitudinal fasciculus -dorsal tract-, including the arcuate fasciculus (Friederici, 2011; Saur et al., 2008).

Even if the processing of the semantic knowledge is distributed across the brain cortex, there are two regions that deserve special attention: the anterior temporal lobe (ATL) and the angular gyrus (AG) (Matchin & Hicock, 2019). Some researchers have emphasized the importance of the ATL in the semantic processing, an area modulated by conceptual and discourse factors independently of syntax (Humphries, Binder, Medler & Liebenthal, 2006; Westerlund & Pylkkänen, 2014). Although this area has been also related to syntactic manipulations (Mazoyer et al., 1993), individuals with lesions in the ATL process syntactic disagreements correctly (Cotelli et al., 2007). The AG has been related to knowledge of events, and hence specific activations of this area were found to complex verb-argument structures (Malyutina & den Ouden, 2017) and thematic relations (Williams, Reddigari, & Pylkkänen, 2017).

Despite general agreement on the components involved in language comprehension, the properties of the linguistic architecture, its internal relationships and temporal dynamics, are under discussion. Psycholinguistic models are usually divided into serial syntax-first models (e.g. Frazier & Clifton, 1996, Frisch, Hahne & Friedrici, 2004) and interactive models (e.g. Jackendoff, 2002; MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell & Tanenhaus, 1994). Syntax-first models are strongly influenced by the modular/encapsulated conception of language processing (Fodor, 1983), which would dominate over semantic processing to determine the syntactic structure (Friederici, 2002). On the other hand, interactive models consider that linguistic components can affect each other (Pulvermüller, Shtyrov & Hauk, 2009), and even a prevalence of semantics over syntax has been reported, modulating syntactic processing (Martín-Loeches, Nigbur, Casado, Hohlfeld & Sommer, 2006). According to Jackendoff (2002), linguistic components are not isolated; they are organized in a *tripartite parallel architecture* consisting on phonological, syntactic and semantic operations that connect to each other through interfaces. Instead of a serial processing,

the semantic stream and the grammar stream would work in parallel during sentence comprehension (Jackendoff, 2007).

Friderici (2002, 2011) proposed a syntactocentric neural model of sentence processing that has become very influential within psycholinguistics. Just 50 ms after a person speaks, the listener initiates the phonological analysis of the stimulus, followed by the lexical-semantic categorization along with a morphosyntactic categorization (40-90 ms). Between 110 and 170 ms there is a retrieval of the lexical information accompanied by the identification of the syntactic structures (120-150 ms). Meanwhile, the prosodic information is processed in the right superior temporal cortex. After that, between 200 to 600 ms, high-level sentence comprehension takes part. Finally, after 600 ms, both semantic and syntactic streams are integrated. This model does not consider an influence of semantic content on the main syntactic processing, and this only happens at late stages. On the other hand, Hagoort (2003) proposed an interactive model (Memory-Unification-Control -MUC- model) of lexicalist nature influenced by Jackendoff's tripartite conception of language. Therefore, phonological, syntactic and semantic processes would operate at the same time and interact with each other. Here unification does not only take place at the syntactic processing level but also at the semantic and phonological levels.

4.2.1. Syntax and morphosyntactic agreement

Syntax possibilities to express an idea by constructing dependencies between words within a sentence (Franck, 2018). This allows a very detailed communication regarding a concept. Therefore, it is not the same to say "dog, girl, see, lay, street" than "the dog that the girl saw is laying on the street", which is also different from "the dog saw the girl laying on the street". Syntax processing includes processes like parsing, structuring, putting together syntactic elements or reordering sentences. Syntactic parsing allows comprehenders to use linguistic cues to interpret a sentence. Both the ventral and

dorsal streams participate differently in syntactic processing (Friederici, 2012; Hagoort, 2013), however the influence of each one is not completely clear (Skeide & Friederici, 2018). Besides, the dorsal stream may participate mainly on the syntactic comprehension of complex structures.

Morphosyntactic agreement sets sentence relationships between words to build the sentence structure. Furthermore, it facilitates coherence by creating long-distance dependencies (Barber & Carreiras, 2005). In Spanish, determinant-noun and noun-adjective relationships share number and gender agreements. An example is given below:

a. *La* fem, sing *cerveza* fem, sing *fría* fem, sing *me encanta*

[Det] [N] [Adj] [Pron] [V]

English translation: *I love cold beer*

b. *Unos* masc, plur *pájaros* masc, plur *bonitos* masc, plur *cantan en ese árbol*

[Det] [N] [Adj] [V] [Pron] [Det] [N]

English translation: *Pretty birds sing on that tree*

In the first example (a) the name “*cerveza*” -*beer*- is feminine singular, which leads to use a determinant and an adjective that matches in gender and number. Similar matching can be seen in the second example (b) regarding “*pájaros*” -*birds*-, being masculine plural. For the study of morphosyntactic brain processing, a typical approach is to present the participants with morphosyntactic errors (gender, number) that require more processing efforts than correct sentences. Molinaro, Barber and Carreiras (2011) identified three stages on morphosyntactic agreement. The first stage comprises the detection of a mismatching between the predictions and current morphosyntactic

violations, reflected by the LAN component. The second stage covers the integration demands of the incoming element with the previous context, reflected by the early P600, which can vary in amplitude depending on integration difficulty. Finally, the third and last stage is the reanalysis and repair of the morphosyntactic agreement mismatch, reflected in the late P600 component.

4.2.2. Semantic comprehension

The semantic system can be divided in a *relational semantic system*, that creates relational structures in the basis of lexical meaning and grammar, and the *interpretive semantic system*, that considers the context to interpret the relational structures (Baggio, 2018). Sentence meaning and speaker's meaning are not the same (Grice, 1989). Hence, in a conversation the listener must consider the speaker's intentions and the overall context where the sentence is uttered for a correct interpretation of the message. Therefore, the semantic processing is demanding and requires the listener to reach a correct interpretation. Irony is a good example in which the sentence meaning is the opposite of the speaker's meaning. For instance, the expression "*What beautiful weather!*" could be used on a rainy day to emphasize just the opposite meaning.

Word processing requires firstly the access to the lexical networks (auditory/visual word forms) and secondly the access to the word meaning in the semantic memory (Balota, Yap, & Cortese, 2006; Collins & Loftus, 1975; Hutchison, 2003; McClelland & Rumelhart, 1985). Studies with clinical population and neuroimaging techniques have demonstrated that meaning and form are processed separately in the brain. Therefore, patients with impaired recognition of words can process concepts (Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996). Moreover, there are common brain regions activated when processing words and pictures, although each category tails also specific neural networks (Vandenberghe, Price, Wise, Josephs, & Frackowiak, 1996). Interestingly, neuroimaging research posits that word processing not only entails

the specific meaning of that word but also task demands. Hence, when listening the word “hammer”, a different pattern of brain activity emerges as compared to when the same word is associated to the action “stick a nail” (Posner, Petersen, Fox & Raichle, 1988).

Briefly, in line with Baggio’s proposal (Baggio, 2018), meaning may not inhabit on words but instead constructed in the brain, considering the lexical information, the previous knowledge of the individual and the context where the sentences emerge.

4.2.3. Language and communication

In the present dissertation, I assume a communication-oriented view of language. However, this is not a general position in language science. For instance, during his recent intervention in the ASU Philosophy Club Conference (March 23rd, 2019), Chomsky manifested in the clearest possible way a contrary opinion on language function: *“Virtually all of the use of language has nothing to do with communication. The idea that language has evolved as a system of communication, or designed for communication, makes no sense”* (Lane, 2019). Chomsky challenges the interpersonal conception of language relegating language function to an organization of thoughts. Therefore, it would not be related to social contexts but for internal purposes (planning, interpretation, etc). Under this perspective, language would not have appeared as an evolution of other communication systems, but suddenly a mutation appeared that allowed humans a single compositional operation: to *merge* -or “unify”- (Chomsky, 2008). Note that the communicative function of language is consistent with the relationship between language and thought but does not reduce language to internal processes. Besides, if language is functionally more related to thought than communication one would expect thought and language to be almost the same. However, scientific research demonstrates that thought does not equate to language (Fedorenko & Varley, 2016).

On the other hand, a strong body of research has demonstrated that language has evolved motivated by communicative pressures, and the different components of language have a trend to reach an efficient structure (Gibson et al., 2019). This conception serves of the information theoretic view of communication. In this sense, an efficient communication would exist when the speaker (source) transmits a message and the listener (destination) processes it accurately with minimal effort. The ambiguity and uncertainty in language communication can be reduced with contextual information (Miller, 1951). According to Gibson et al., (2019), instead of being a problem, ambiguity is a positive characteristic of human communication because consequently language can reduce complexity, being the context responsible of the specific interpretations.

According to the role of ambiguity in human communication, context might be fundamental in language comprehension. It is not only something that can influence communication success, but it has a main role for a successful communication in the daily use of language. Remember, for instance, the irony example given above.

Although this discussion is far from the main aim of this dissertation, it has important consequences for this work. The present research defends the communicative point of view of language and this fact supports the idea that one of the elements according to the theory of communication, the source, can generate an effect on the destination. Therefore, not only the linguistic message is part of the communication, but also non-linguistic information transmitted from the sender to the listener would affect language comprehension. This conception of language gives a special importance to the speaker, who has been typically neglected in previous models of language processing, while it upraises the social context to a relevant position.

4.2.4. The importance of linguistic context

Although psycholinguistics agrees on the importance of context, its definition is not clear, because anything that is not the main process of study can be considered context (Knoeferle, Pyykkönen-Klauck & Crocker, 2016). However, traditionally, first-stage linguistic processes have been considered the main process of study, and context anything else sensitive of affecting the late processing (Rayner, Carlson, & Frazier, 1983; Swinney, 1979). In fact, context is a relative term, and it can also refer to the natural environment where something happens. In this regard the study of language *in context* would mean to investigate the linguistic processes in ecological conditions.

While some studies paid attention to the effect that a prior context has on the comprehension of language and how semantic disambiguation can be determined by this context -for instance, when processing polysemic words- (Duffy, Morris & Rayner, 1988). Others have focused on the concurrent context (Goldin-Meadow, 2006; Shintel, Anderson & Fenn, 2014). Studies that investigate the visual context available during language comprehension deserve special attention. Some of these studies made wide use of the eye-tracking technique and developed the *visual-world paradigm* (Berends, Brouwer & Sprenger, 2016; Tanenhaus, Spivey-Knowlton, 1996). Thus, instead of performing the linguistic experiment in front of a computer, participants had to interact with the visual environment, like seating in front of a table containing several objects. Data obtained from a pioneer experiment by Tanenhaus, Spivey-Knowlton, Eberhard and Sedivy (1995) demonstrated by monitoring eye movements that humans use visual inputs in the resolution of syntactic ambiguities. The linguistic visual context can be a table full of objects, like the one used in the experiment by Tanenhaus et al., (1995). Moreover, it can be a social visual context as well, like a partner who participates on a dialogue or an audience looking at the speaker in a conference.

The idea that language as other cognitive processes should be ideally framed in a social context is not new. Decades ago, in *Steps to an Ecology of Mind* (Bateson, 1972), Bateson defended that both the physical environment and other individuals are necessary for the comprehension of biological organisms. This implies considering the strong difference between social- and linguistic-related processes as an artificial boundary that may facilitate scientific research, but at the same time prevents researchers to achieve a comprehensive understanding of this faculty (Hutchins, 2010). In the last decade, there has been increasing interest in *situated language comprehension*. This emergent trend in psycholinguistic research makes efforts to analyse language in interpersonal contexts, contrary to “context-free” experimental situations. Such approach is very influenced by interactive dynamic accounts of language processing that consider that language can be influenced by extralinguistic factors.

4.3. Face-to-face communication. Social cognition and audiovisual language integration

The typical situation where auditory language is processed includes not only auditory speech but also concomitant perception of visual stimuli, particularly of the speaker. Therefore, face and voice perception occur simultaneously in the brain and although both imply distinct sensory modalities and specific neural processes (see Bruce & Young, 1986; Young & Bruce, 2011 for faces and Belin, Zatorre, Lafaille, Ahad, & Pike, 2000; Pernet et al., 2015 for voices), they also share cognitive and neural representations because similar social information can be extracted from both (Belin, 2017; Yovel & Belin, 2013). Hence, either voices or faces allow the listener to infer the speaker’s age, gender and emotional state. Therefore, the multisensory integration of faces and voices is not only useful for speech perception but also at the social level to obtain a representation of the speaker’s identity. Thus, the listener can infer certain information

from both, and it is necessary to keep a coherence in between since both senses built a common cognitive representation during social perception.

The neural mechanisms for the processing of faces and voices appear very early in infant development, and there is a perceptual narrowing around 6 years old that enables the ability to perceive human faces and speech (Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992; Pascalis, de Haan & Nelson, 2002). Moreover, the orofacial movements for language segmentations are decisive from the first months of life of a baby to isolate words from the continuum of connected speech (Mitchel & Weiss, 2014). Indeed, despite the evident difference between auditory and visual information, both share similar computational processes and neural networks (Yovel & Belin, 2013).

Language comprehension facing the speaker implies many cognitive and brain operations that are absent in, e.g., a telephone call or reading a text. Particularly, it is necessary to highlight the importance of social cognition, which comprises the mental and neural processes that allow individuals to interact in a social environment. Social cognition can be defined as the knowledge about conspecifics (Seyfarth & Cheney, 2015), and though this is not human-specific, the remarkable sociability of the human species is sustained in very developed social cognitive processes. More specifically, the term social cognition refers to the cognitive processes involved in processing information about the self, other people, interpersonal relationships and social interactions (Frith, 2008).

Therefore, in face-to-face contexts the brain invests both cognitive and emotional resources while comprehending linguistic meaning. Both sources of information (auditory and visual) participate in the communicative process; however, it is not clear yet how linguistic processing integrates online multisensory information and which steps are affected. This thesis will try to shed light into this question.

4.4. Evolutionary perspective

Interpersonal communication may have been favoured by natural selection because reproductive success is related to the social bonds within a group. Therefore, the communicative ability to create and maintain relationships, as well as to infer the relationships between other individuals would be considered an evolutionary success (Seyfarth & Cheney, 2015). Since non-verbal information provided by faces has been favoured during evolution, non-human primates have multiple adaptations that evince the importance of faces for communicative purposes.

Studies with macaques highlight the importance of the ventrolateral prefrontal cortex (VLPC) for social communicative processes, an area that integrates audiovisual information from faces and voices (Romanski, 2012). This can be considered an evolutionary precedent of the inferior frontal gyrus (IFG) in humans, which integrates both gestures and speech (Xu, Gannon, Emmorey, Smith, Braun 2009). Further, many regions in the temporal lobe of non-human primates exhibit neural assemblies specialised in the processing of vocalizations of its own species (Romanski & Averbeck, 2009). The superior temporal sulcus (STS) is also an area related to the audiovisual integration of faces and voices in both humans and monkeys (e.g. Schroeder, Lakatos, Kajikawa, Partan & Puce, 2008; and Chandrasekaran & Ghazanfar, 2009; respectively). An analysis of STS neurons suggests that the rhythmic characteristics of human speech resulted from the evolution of the facial-expression rhythm on primates, since macaques' non-vocal facial expressions are generated with a frequency between 2 and 7 Hz, which coincides with human speech (Ghanzanfar, Chandrasekaran, Morrill, 2010). These results are in line with a communicative origin of human language.

A good example of a specific communicative adaptation in humans is the white sclera of the eyes, an adaptation for social communication (Flinn et al., 2005). Gaze can be used to signal, and hence humans can easily discern gaze direction by means of the

high contrast between the sclera and the iris/pupil. Moreover, gaze-signalling is related with co-operative behaviours with other members of the group (Kobayashi, 2011). Therefore, humans do not only have a unique auditory communication system, but also complex non-linguistic abilities to generate mental states in others, expressing intentions and emotions.

The evolution of the human face morphology evinces how communicative pressures have influenced human's present phenotype (Lacruz et al., 2019). For instance, the reduction of the brow ridge along with the retraction of the midface would be related to increasing the mobility of the eyebrows, particularly relevant for social purposes like expression of emotions and signalling dominance and aggression (Godinho, Spikins, O'Higgins, 2018).

Considering these evidences, a full account of human language should take into consideration the communicative audiovisual context where this faculty appeared and evolved. Although language can be studied apart from its context, it will not be possible to completely understand how it works unless we situate it within face-to-face social environments.

5. CHAPTER 2. OBJECTIVES AND HYPOTHESIS

Grounded on previous literature revised in Chapter 1, the main objectives and hypotheses of this thesis are:

General objectives

- Highlight the importance of social contexts in language comprehension
- Explore the effect of facial cues on linguistic processing
- Study the interaction between syntax, semantics, and face-to-face contextual communicative variables
- Emphasize situated language as an ecologically valid paradigm to study language

Specific objectives and hypotheses

To achieve the objectives and test the hypothesis three studies have been performed:

- *Study One:* Investigates the effect that the speaker's facial dynamics of the eyes and mouth have on the semantic processing in the listener.

In the first study, participants were presented with either a video or a still picture of the speaker, concomitant to auditory sentences that could be either semantically expected or unexpected. To investigate the effect separately from each part of the face, we performed three experiments. In Experiment 1 the complete face of the speaker was presented. In Experiment 2 the eyes were covered and in Experiment 3 the mouth was covered. In Experiment 1 visually perceived dynamic facial information was expected to impact semantic processing, evinced in a modulation of the amplitude of the N400 component. In Experiment 2 visual speech conveyed by mouth movements was expected to

increase the amplitude of the N400, and finally in Experiment 3 a reduction of the N400 amplitude was predicted as only the eyes are exposed.

- *Study Two*: Investigates the effect that the mere presence of the speaker's face has on the morphosyntactic and semantic processing of language.

In the second study, participants listened to sentences while facing a still picture of the speaker's face or a scrambled version of that face. In this case, two experiments were carried out. In Experiment 1 sentences could be either correct or contain a semantic incongruency. The N400 effect was expected to be enhanced in the communicative (social) context compared to the control (non-social) condition. In Experiment 2 the morphosyntactic correctness of the critical words was manipulated. In this case the LAN and P600 effects may also increase its amplitude when facing the speaker (social) compared to the control (non-social) condition.

- *Study Three*: Investigates the impact of positive and negative speaker's facial emotional expressions on the semantic and syntactic processing of language.

In the third study, participants will listen to sentences while being presented with a still picture of the speaker's face with three different emotional expressions: fear, neutral or happy. As in *Study Two*, two experiments will be performed, manipulating either semantic congruency -Experiment 1- or morphosyntactic correctness -Experiment 2-, respectively. Emotional facial expressions of the speaker are expected to modulate the N400 and P600 semantic effects. If semantic comprehension is facilitated by the concurrent emotion processing, the N400 will reduce its amplitude and the P600 effect will be enhanced, the opposite happening if a depletion of cognitive resources affects the semantic processing. On the other hand, morphosyntactic processing will be predictably

affected by the speaker's emotional facial expression. Particularly, the angry expression is expected to increase the LAN and reduce the P600 effect compared to the neutral. The opposite is expected to the happy expression, that is, a decrease of the LAN amplitude and an increase of the P600 effect.

6. CHAPTER 3. STUDY ONE

6.1. Introduction

In human verbal communication, there is a natural prevalence for face-to-face interactions, involving the multimodal interplay of visual and auditory signals sent from the speaker to the listener. Though auditory information alone is sufficient for effective communication (Giraud & Poeppel, 2012), seeing the interlocutor's facial motions apparently provides further advantages (e.g., Crosse, Butler, & Lalor, 2015; Fort, Spinelli, Savariaux, Kandel, 2013; Peelle & Sommers, 2015; Rohr & Abdel Rahman, 2015; van Wassenhove, 2013). Some authors refer to this effect as visual enhancement (Peelle & Sommers, 2015), underscoring that human communication involves multisensory adaptation. Audiovisual integration in language processing is becoming, therefore, an area of growing interest.

Most of the literature on audiovisual integration in language processing has focused on the phonological level. Visual speech seems to increase the ability of a listener to correctly perceive utterances (Cotton, 1935; Sumbly & Pollack, 1954), increase the speed at which phonemes are perceived (Soto-Faraco, Navarra, & Alsius, 2004), and may even alter the perception of phonemes (McGurk & MacDonald, 1976). This multisensory gain depends on various factors, including spatial congruency, temporal coincidence, behavioral relevance, and experience (for review, see van Atteveldt, Murray, Thut, & Schroeder, 2014).

Audiovisual integration has also been studied with electrophysiological measures like event-related brain potentials (ERPs). This technique is characterized by fine-grained temporal resolution and allows investigating the neural mechanisms underlying multisensory integration at different levels. At the phonological level, the facilitation provided by audiovisual integration is reflected in shorter latencies (Alsius,

Möttönen, Sams, Soto-Faraco, & Tiippana, 2014; Baart, Stekelenburg, & Vroomen, 2014; Knowland, Mercure, Karmiloff-Smith, Dick, & Thomas, 2014; Stekelenburg & Vroomen, 2007; van Wassenhove, Grant & Poeppel, 2005) and smaller amplitudes (Hisanaga, Sekiyama, Igasaki, & Murayama, 2016; Stekelenburg & Vroomen, 2007, 2012; van Wassenhove et al., 2005) of the auditory N1 and P2 components of the ERP. Moreover, studies with functional magnetic resonance imaging and magnetic field potentials have reported that visual input about the speaker's lip positions or movements can modulate the activity of the primary auditory cortex (Calvert et al., 1997; Lakatos, Karmos, Mehta, Ulbert, & Schroeder, 2008).

Available evidence suggests that audiovisual integration also facilitates lexical access at the semantic level as shown with cross-modality priming. In this paradigm, a silent video of a speaker uttering a (prime)word is followed by the auditory-only version of the critical word. Such priming by visual speech can improve semantic categorizations (Dodd, Oerlemans, & Robinson, 1989), lexical decisions (Fort et al., 2013; Kim, Davis, & Krins, 2004), and word recognition (Buchwald, Winters, & Pisoni, 2009) of critical words. These findings support an influence of visual speech on lexical or post-lexical processes and indicate that visual and auditory speech modalities share cognitive resources (Buchwald et al., 2009).

In typical audiovisual communication, facial gestures precede the auditory input by about 150 ms (Chandrasekaran, Trubanova, Stillitano, Caplier, & Ghazanfar, 2009). A set of lexical candidates might therefore be available before the utterance can be heard (Fort et al., 2013) and, consequently, semantic processing might be easier if the visually preactivated word matches the auditory input. Further, audiovisual presentation of complex texts improves performance compared to auditory-only conditions, as shown with comprehension questionnaires (Arnold & Hill, 2001; Reisberg,

McLean, & Goldfield, 1987). In sum, the perception of the speaker's facial dynamics cannot only improve phonetic perception but also semantic comprehension.

Evidence regarding the neural correlates underlying audiovisual integration at the semantic level during sentence processing from on-line measures of brain activity, such as ERPs, is surprisingly scarce. To our knowledge, the only pertinent ERP study has been reported by Brunellière, Sanchez-García, Ikumi, and Soto-Faraco (2013). In a first experiment, these authors manipulated the semantic constraints (expectancy) of critical words within audiovisual sentences, as well as the articulatory saliency of lip movements. These variables interacted during the late part of the N400, an ERP component reflecting the access to semantic knowledge during language comprehension (Kutas & Federmeier, 2011). As compared to low visual articulatory saliency, high saliency increased the N400 amplitude for unexpected words and yielded a wide effect across the scalp. In a second experiment, Brunellière et al. (2013) compared the effect of visual articulatory saliency with respect to an audio-alone condition without manipulating semantic constraints. Words with high articulatory saliency yielded a significant N400 effect that was enhanced under audiovisual presentation relative to the audio-alone condition, which the authors interpreted in terms of late phonological effects.

The present study aimed to add further evidence to the scarce literature on audiovisual integration at the semantic level by comparing the neural processing of expected and unexpected words in spoken sentences. Sentences were presented either in a dynamic audiovisual mode, showing videos of the speaker, as compared to a still face mode, showing pictures of the speaker. This paradigm allowed exploring how the dynamics of speaker's facial movements impact the semantic processing of words during sentence comprehension. Our study therefore focused on semantic processing of connected speech while the speaker's face is seen in dynamic versus static mode.

The majority of studies on audiovisual processing of language did not consider that visual perception of face-to-face contexts is not restricted to oro-facial (i.e., mouth) speech movements. However, the perception of the eyes and their gaze direction strongly captures and directs attention (Conty, Tijus, Hugueville, Coelho, & George, 2006; von Grunau & Anston, 1995; Senju & Hasegawa, 2005) and modulates the activity of neurons in auditory cortex (van Atteveld et al., 2014). Evolutionary evidence supports the importance of eyes in human communication, like the white sclera adaptation specific to humans (Kobayashi & Kohshima, 2001; Tomasello, Hare, Lehmann, & Call, 2007). A study in macaques demonstrated enhanced activity of ventrolateral prefrontal neurons in response to combining vocalizations with pictures of direct-gaze faces (Romanski, 2012), demonstrating the role of this brain area in the integration of socialcommunicative information.

Gaze perception seems to influence social interactions and communication among humans. For instance, conversations typically begin with eye contact between individuals (Schilbach, 2015) and communicative intent is usually signalled by direct gaze (Farroni, Csibra, Simion, & Johnson, 2002; Gallagher, 2014). Hence, eyes are extremely informative both about the mental state of the interaction partner and for ascertaining what a speaker demands from a listener (Myllyneva & Hietanen, 2015). Eye contact between persons can modulate concurrent cognitive and behavioural activities, a phenomenon known as the “eye contact effect” (Senju & Johnson, 2009), which are mediated by the social brain network, including areas such as fusiform gyrus, superior temporal sulcus, medial prefrontal and orbitofrontal cortex, and amygdala. Hence, eyes are evidently “special” visual stimuli for humans.

As reviewed above, facial information can be relevant for language comprehension, and is not restricted to oro-facial movements, but also includes other cues such as eye gaze. The present ERP study explored the effects of facial dynamic

information on semantic processing by manipulating the presence of two main sources of information in the face, mouth (visual speech) and eyes (gaze). To this aim, we compared the amplitude of the semantic N400 component elicited by unexpected words within audiovisual connected speech. Expectancy of critical words within a given sentence was manipulated by a preceding context sentence. This allowed comparing exactly the same stimulus material across conditions with a maximum degree of experimental control, by merely exchanging the preceding context sentence. In parallel to the auditory material, participants were presented with two kinds of visual information, consisting in either a video of the speaker's face and upper torso (dynamic conditions) or stills of the speaker taken from these videos (static control conditions). In three experiments, we investigated the effects of visual speech and gaze on the semantic processing of connected speech on ERPs, focusing on the N400 component: In Experiment 1, participants were presented with the whole speaker's face in dynamic and static versions. In Experiments 2 and 3, the specific contributions of facial information to the observed effects were studied by concealing either the eyes or the mouth, respectively.

In Experiment 1, we expected modulations of the N400 component by dynamic information provided by the whole face. According to the literature reviewed above, visibility of lip movements should affect lexical access and semantic processing of unexpected words, leading to increased amplitudes of the N400 component (Brunellière et al., 2013). As direct eye contact has been shown to attract attention and to activate a broad network of social brain areas, resources for semantic processes might be diminished, presumably reflected in reduced N400 amplitudes. Therefore, we expected an increase of the N400 amplitude when the speaker's eyes are occluded and only visual speech is available (Experiment 2) and the N400 might be reduced when the eyes are available and the mouth is covered (Experiment 3).

6.2. Experiment 1. Whole face presentation

This experiment investigated audiovisual processing of words in spoken sentences in an ecological context, that is, perceiving the whole face of the speaker while listening to connected speech. In the video condition, participants could therefore focus on both eye gaze and visual speech available from the whole face of the speaker while concurrently listening to auditory speech.

6.2.1. Method

6.2.1.1 *Participants*

Twenty-one native German speakers participated in this experiment. One of them was excluded because of poor EEG quality. The remaining 20 individuals (15 females, 5 males; age range 20-35 [M = 27.3]) were all right-handed (Mean Oldfield scores ≥ 88) and declared normal or corrected-to-normal vision and normal hearing. Participants gave written informed consent and received monetary reimbursement. The study was approved by the ethics committee of the Humboldt-Universität at Berlin (application number 201343 R) and conducted in accordance with the declaration of Helsinki.

6.2.1.2 *Materials and procedure*

The linguistic material used in this experiment was taken from the Postdam Sentence Corpus 3 (Dambacher et al., 2012). Stimuli consisted of 144 sentence units, each containing two different context sentences and two target sentences. A context sentence defined the expectancy of a critical word. Depending on the context sentence a critical word of the exact same target sentence could be expected (cloze probability = .84 -high frequency- and .83 -low frequency-; SD = .13 in both cases) or unexpected (cloze probability = .01, SD = .02, regardless of frequency). Therefore, the material allowed comparing expected and unexpected critical words by using exactly the same

word stimuli in both conditions (for further details on the material, see Dambacher et al., 2012). All sentences were semantically correct. An example (in English translation from the original German) is given below:

1 Expected combinations:

- The man on the picture fiddled around with models of Columbus' fleet. (context 1). In his right hand he held a ship of considerable length (target 1).
- The man on the picture wore a golden crown and sat stately on a throne (context 2). In his right hand he held a scepter of considerable length (target2).

2 Unexpected combinations:

- The man on the picture fiddled around with models of Columbus' fleet (context 1). In his right hand he held a scepter of considerable length (target 2).
- The man on the picture wore a golden crown and sat stately on a throne (context 2). In his right hand he held a ship of considerable length (target 1).

Four sets of sentences were prepared for this experiment, each containing only one of the four possible sentence combinations per sentence unit. These four stimulus sets were presented to different participants in balanced fashion, such that none of the sentences were repeated to a given participant. Moreover, all sentence combinations of a given sentence unit were presented equally often across participants. Each set of sentences contained the same number of expected and unexpected critical words. According to these manipulations, we recorded four videos for each of the 144 sentence units. Sentences were spoken by a male speaker with neutral prosody, neutral emotional expression, and direct eye gaze. There was an SOA of 500 ms between the start of the video and the start of the first vocalization. Auditory speech was synchronized with visual speech.

In the dynamic condition, participants were presented with the videos together with the audio tracks of the sentences. For the static condition, static pictures of the speaker with mouth closed were shown while participants listened to the audio tracks (Figure 1). Because the audio files were taken from the video recordings, the only difference between dynamic and static conditions was the dynamics of the visual stimuli. The audio files of the sentences in all conditions were matched in acoustic intensity, with mean intensity values of 68.4 dB.

Videos and static pictures were displayed on a computer screen (1280 x 1024 pt) at a viewing distance of 80 cm. Auditory sentences were presented through a pair of speakers placed at both sides of the screen. Sound levels were kept constant for all participants. Every participant completed 144 trials (36 dynamic/unexpected, 36 dynamic/expected, 36 static/unexpected, 36 static/expected). The assignment of the sets of sentences to participants was counterbalanced. The setting of the triggers at the onset of critical words was done with GoldWave software by three independent persons. The decisions about trigger settings were based on both the visual pattern of the sound wave and the auditory onset of the initial phoneme of the critical word. The three trigger setting values were averaged to obtain an objective time-point. Since sentences in the expected and unexpected conditions were the same, trigger time-points were identical. Consequently, any differences between conditions cannot be due to differences in trigger positions or voice onsets.

6.2.1.3 EEG-recordings

The EEG was recorded from 62 electrodes placed according to the international 10-20 system. Impedances were kept below 5k Ω . The vertical electrooculogram (VEOG) was recorded from below versus above the left eye, and the horizontal electrooculogram (HEOG) was recorded from the outer canthus of each eye. Except for the electrode

below the left eye all other were placed within an elastic cap. The signals were recorded continuously with a bandpass from .1 to 100 Hz and a sampling rate of 250 Hz. The EEG recordings were initially referenced to the left mastoid (M1); offline, the EEG was rereferenced to average mastoids, and a low-pass filter of 15 Hz was applied.



Figure 1. Visual stimuli of the static condition. (1) Whole face -Experiment 1-, (2) Eyes covered – Experiment2-, (3) Mouth covered – Experiment 3-.

6.2.1.4 Data analysis

EEG epochs of 1150 ms were extracted, starting 150 ms before critical word onset. Ocular correction for blinks and eye movements was performed by Independent Component Analysis (ICA). Trials with remaining artefacts, exceeding a range of 100 μ V were semi-automatically rejected. Overall, the mean rate of rejected segments was 13%. Each experimental condition was averaged individually. The average amplitude during the first 150 ms served as pre-stimulus baseline.

Visual inspection of the ERPs confirmed the expected effects on the N400 in centro-parietal areas in all participants (Figure 2). Therefore, repeated-measures ANOVAs were performed using a region of interest (ROI) comprising electrode sites Cz, CP1, CPz, CP2, P3, Pz, P4, PO3, POz, and PO4. To reduce the number of statistical comparisons, the individual values at the electrodes within this ROI were collapsed to their mean. The analysis included the following factors: Expectancy (expected vs

unexpected), and Presentation Mode (dynamic vs static). Separate ANOVAs were performed on the average amplitudes within the following time windows, based upon visual inspection: 300-450, 450-600, 600-750 and 750-900 ms after critical word onset. Huynh-Feldt corrections were applied when appropriate.

6.2.2 Results and discussion

Figure 2 shows the ERPs to expected and unexpected words. While unexpected words yielded an N400-like negative-going modulation between 300 and 600 ms, expected words showed a parietal positivity between 300 and 900 ms. The ANOVA revealed significant effects of Expectancy between 300 and 900 ms (300-450 ms: $F(1,19) = 43.07$; $p < .001$; $\eta^2 = .694$; $\pi = 1$; 450-600 ms: $F(1,19) = 51.02$; $p < .001$; $\eta^2 = .729$; $\pi = 1$; 600-750 ms: $F(1,19) = 40.15$; $p < .001$; $\eta^2 = .679$; $\pi = 1$; 750-600 ms: $F(1,19) = 31.41$; $p < .001$; $\eta^2 = .623$; $\pi = 1$). The main effect of Presentation Mode was statistically significant between 300 and 900 ms except for the interval 600-750 ms (300-450 ms: $F(1,19) = 10.7$; $p = .004$; $\eta^2 = .362$; $\pi = .875$; 450-600 ms: $F(1,19) = 9.52$; $p = .06$; $\eta^2 = .334$; $\pi = .833$; 600-750 ms: $F(1,19) = 2.7$; $p = .114$; $\eta^2 = .126$; $\pi = .350$; 750-600 ms: $F(1,19) = 8$; $p = .01$; $\eta^2 = .298$; $p = .769$). When comparing dynamic and static modes (Figure 3) for expected words a long-lasting posterior positivity emerged specifically in the dynamic mode. For unexpected words, by contrast, ERPs in both dynamic and static modes appeared to be largely identical, displaying very similar N400 deflections between 300 and 900 ms. Supporting these impressions ANOVA of ERPs amplitudes yielded a significant interaction Expectancy by Presentation Mode (300-450 ms: $F(1,19) = 7.49$; $p = .013$; $\eta^2 = .283$; $\pi = .738$; 450-600 ms: $F(1,19) = 9.08$; $p = .007$; $\eta^2 = .323$; $\pi = .816$; 600-750 ms: $F(1,19) = 9.1$; $p = .007$; $\eta^2 = .323$; $\pi = .816$; 750-900 ms: $F(1,19) = 8.1$; $p = .01$; $\eta^2 = .299$; $\pi = .771$). To further investigate these results, and given the apparent differences between expected and unexpected critical words, likely involving two components of opposing polarities over similar regions (N400 vs late positivity),

separate ANOVAs were performed for the two conditions. Presentation Mode was therefore the only factor included in the following ANOVAs. On the one hand, Presentation Mode was not significant at all in the unexpected words between 300 and 900 ms (300-450 ms: $F(1,19) = .21$; $p = .887$; $\eta^2 = .001$; $\pi = .052$; 450-600 ms: $F(1,19) = .00$; $p = .993$; $\eta^2 = .00$; $\pi = .00$; 600-750 ms: $F(1,19) = .21$; $p = .566$; $\eta^2 = .018$; $\pi = .086$; 750-900 ms: $F(1,19) = .422$; $p = .524$; $\eta^2 = .022$; $\pi = .095$), indicating that the N400 was insensitive to this factor. On the other hand, within ERPs to expected words Presentation Mode effects were significant during the 300-900 ms interval (300-450 ms: $F(1,19) = 14.6$; $p = .001$; $\eta^2 = .953$; 450-600 ms: $F(1,19) = 13.99$; $p = .001$; $\eta^2 = .424$; $\pi = .944$; 600-750 ms: $F(1,19) = 14.5$; $p = .001$; $\eta^2 = .433$; $\pi = .951$; 750-900 ms: $F(1,19) = 12.38$; $p = .002$; $\eta^2 = .395$; $\pi = .916$), substantiating the long-lasting positivity in the dynamic condition.

Overall, and of main interest, the N400 to unexpected words was insensitive to the type of presentation since no amplitude modulation could be observed in the spoken word elicited N400 accompanied by the dynamic video presentation as compared to a static picture of the speaker. Therefore, neither mouth movements (visual speech) nor eye gaze seemed to have an impact on the N400 component, reflecting the efforts of semantic processing when an unexpected word occurs (Kutas & Federmeier, 2011). It seems therefore that activation of resources to deal with unexpected lexical information is prioritized over other types of information, such as dynamic social cues depicted in the eyes or mouth of the speaker.

Interestingly, however, when spoken words were expected, social cues seem to play a relevant role. Dynamic cues of the speaker's face likely elicited a long-lasting late centroparietal positivity. Although the dynamics of the stimuli presented during the baseline differed among conditions, it cannot explain the emergence of this component. In this case, the effect of different baselines should have impacted the N400 as well, but

this was not at all the case. Therefore, the late posterior positive component may reflect an increase in motivated attention to the dynamic relative to the static face. Such an interpretation was suggested for comparable positivities in a study by Schindler, Wegrzyn, Steppacher, and Kissler (2015; c.f. General Discussion), which presumably occurs to words emitted by a dynamic face. Alternatively, the posterior positivity observed here might indicate that during easy-to-process verbal conditions, that is in case of expected words, the participants had larger resources available for attentively inspecting the video (Rohr & Abdel Rahman, 2015).

Experiments 2 and 3 were designed to determine whether the increased posterior positivity during dynamic as compared to static visual face input while listening to expected words are specifically related to eye gaze, dynamic mouth information (visual speech), or to a combination of both. In addition, we wanted to test whether the stability of the N400 holds after removing information from the eyes or mouth.

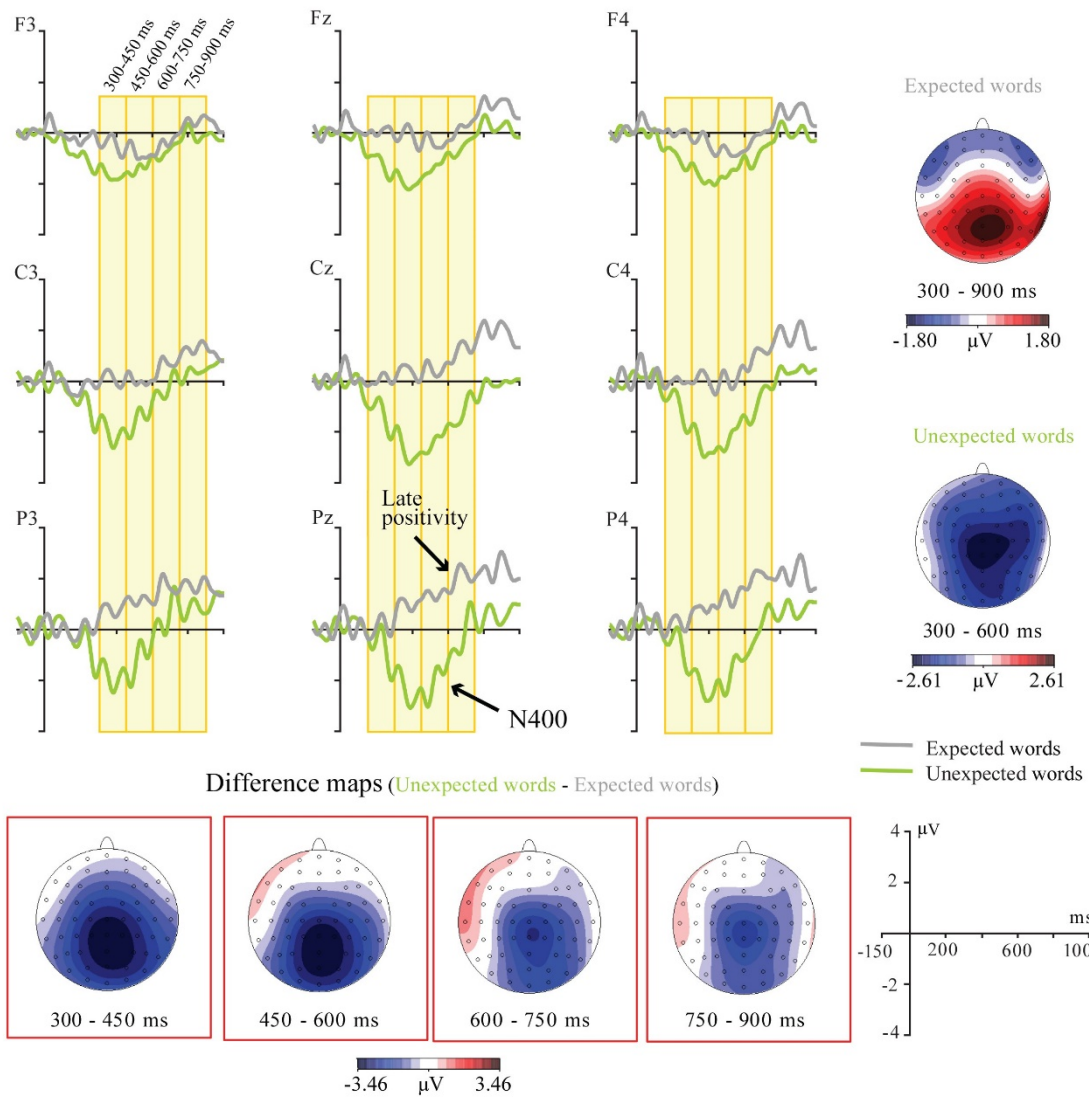


Figure 2 - ERPs to expected (grey) and unexpected words (green) in the whole face condition (Experiment 1). The ERP topographies for each condition correspond to a late posterior positivity for expected words (300-900 ms) and an N400 for unexpected words (300-600 ms). Therefore, each condition yielded a different component. The difference maps depict an N400 effect.

WHOLE FACE PRESENTED / EXPERIMENT 1

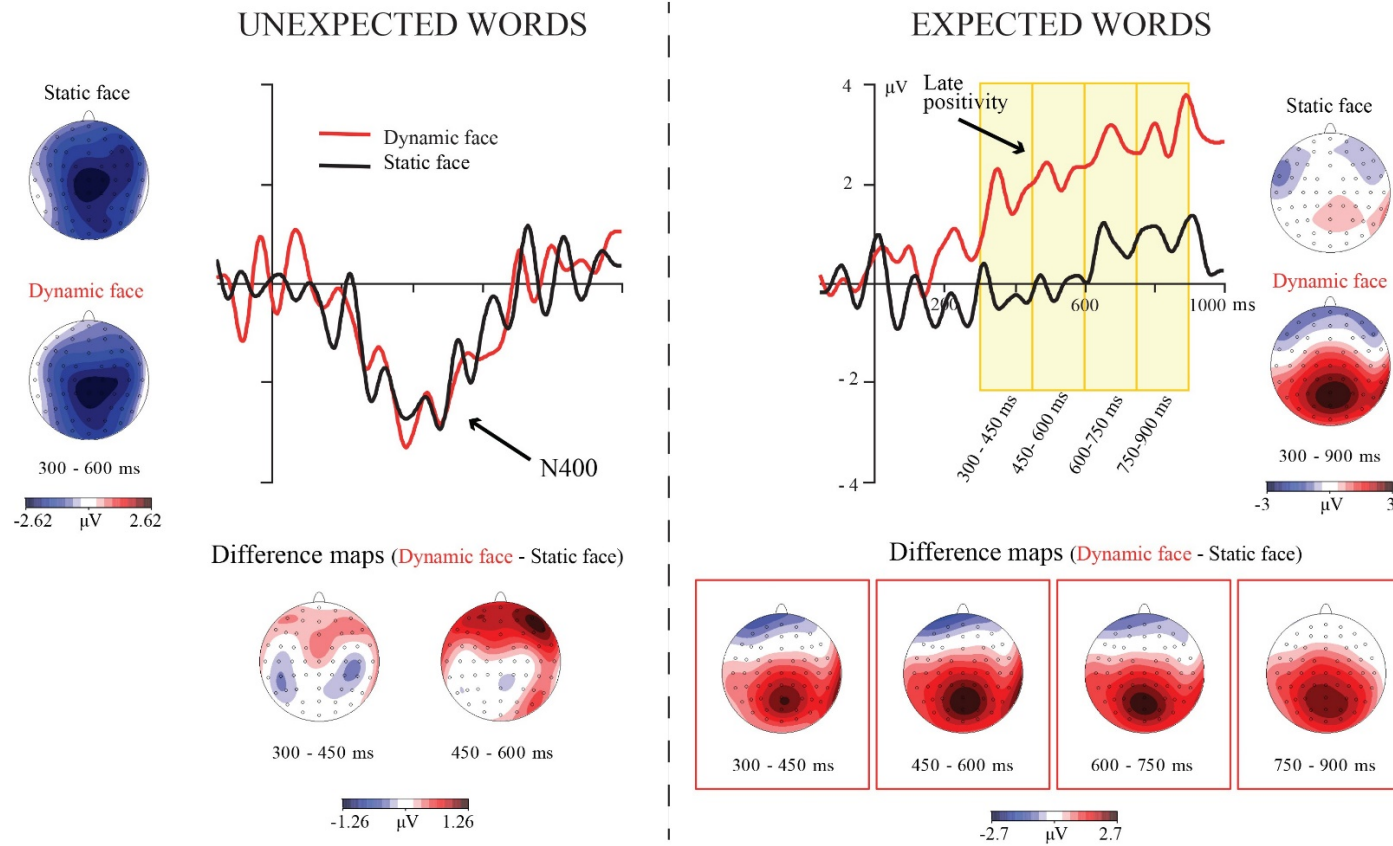


Figure 3 - Effects to Presentation Mode on expected and unexpected words in the whole face condition (Experiment 1). ERPs of the ROI electrodes are pooled. The ERP topographies represent each component individually for each presentation mode. The difference maps represent the Presentation Mode effect (dynamic minus static) for unexpected (left) and expected words (right).

6.3 Experiment 2 - Eyes covered

The aim of this experiment was to explore the influence of dynamic mouth movements (visual speech) on semantic processing of connected speech comprehension. The procedure of Experiment 2 was the same as in Experiment 1, except that the eyes of the speaker were covered (Figure 1).

6.3.1. Method

6.3.1.1 *Participants*

Twenty native German speakers (9 females, 11 males; age range 18-28 [M = 25.04]), different from those in Experiment 1, participated in this experiment. All declared to have normal or corrected-to-normal vision, normal hearing, and were righthanded (mean Oldfield score +79). Participants gave written informed consent and received monetary reimbursement.

6.3.1.2 *Materials and procedure*

Stimulus materials and their presentation were identical to Experiment 1, except that a skin-coloured opaque bar covering the speaker's eyes was digitally added to both videos and pictures.

6.3.1.3 *EEG recordings and data analysis*

The EEG-recording settings were as described for Experiment 1. Due to the presence of artefacts, on average 11.5% of the recorded EEG segments had to be excluded from data analysis.

EYES COVERED / EXPERIMENT 2

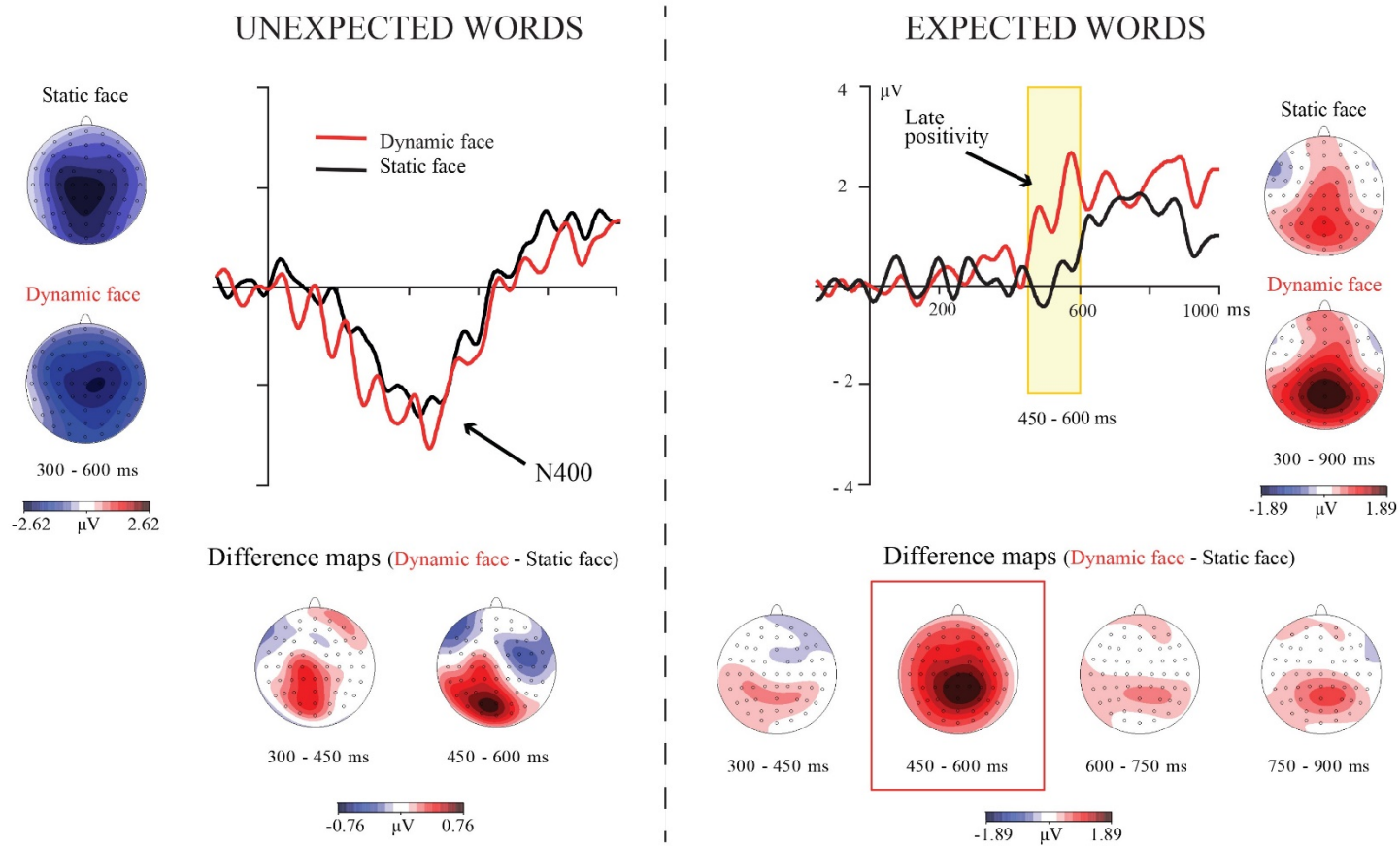


Figure 4 - Effect of Presentation Mode on expected and unexpected words in the eyes covered condition (Experiment 2). ERPs of the ROI electrodes are pooled. The ERP topographies represent each component individually for each presentation mode. The difference maps represent the Presentation Mode effect (dynamic minus static) for unexpected (left) and expected words (right).

6.3.2 Results and discussion

A large N400 was obtained in the ERPs to unexpected words (Figure 4, left), very similar to the results of Experiment 1. In turn, for the expected words (Figure 4, right), the long-lasting positivity in the dynamic mode was again observed, though apparently smaller than in Experiment 1. The main ANOVA, including both Expectancy and Presentation Mode as factors, showed significant effects of Expectancy between 300 and 750 ms (300-450ms: $F(1,19) = 57.43$; $p < .001$; $\eta^2 = .751$; $\pi = 1$; 450-600 ms: $F(1,19) = 39.72$; $p < .001$; $\eta^2 = .676$; $\pi = 39.7$; 600-750 ms: $F(1,19) = 12.66$; $p = .002$; $\eta^2 = .4$; $\pi = .921$), and as a trend between 750 and 900 ms ($F(1,19) = 3.31$; $p = .084$; $\eta^2 = .149$; $\pi = .409$). Presentation Mode had significant effects between 450 and 600 ms ($F(1,19) = 11.72$; $p = .03$; $\eta^2 = .382$; $\pi = .901$), but not in the other time windows analyzed (300-450 ms: $F(1,19) = 1.37$; $p = .255$; $\eta^2 = .068$; $\pi = .2$; 600-750 ms: $F(1,19) = .75$; $p = .395$; $\eta^2 = .038$; $\pi = .131$; 750-900 ms: $F(1,19) = 2.02$; $p = .171$; $\eta^2 = .096$; $\pi = .272$). The Expectancy by Presentation Mode interaction reached a trend for the interval 450-600 ms ($F(1,19) = 4.14$; $p = .056$; $\eta^2 = .179$; $\pi = .489$), and no other time segment reached or approached significance (300-450ms: $F(1,19) = .25$; $p = .62$; $\eta^2 = .013$; $\pi = .077$; 600-750 ms: $F(1,19) = .27$; $p = .609$; $\eta^2 = .014$; $\pi = .079$; 750-900 ms: $F(1,19) = .01$; $p = .912$; $\eta^2 = .001$; $\pi = .051$). For the same reasons as in Experiment 1, ANOVAs were performed for expected and unexpected words separately. Since the interaction Expectancy by Presentation Mode was a very strong trend between 450 and 600 ms, and in order to focus on a pure measure of the late positivity, separate analyses were conducted on the late posterior positivity for expected words. The ANOVA for unexpected words revealed no differences in the N400 between dynamic and static modes (300-450 ms: $F(1,19) = .09$; $p = .757$; $\eta^2 = .005$; $\pi = .06$; 450-600 ms: $F(1,19) = .33$; $p = .572$; $\eta^2 = .017$; $\pi = .085$; 600-750 ms: $F(1,19) = .02$; $p = .88$; $\eta^2 = .001$; $\pi = .052$; 750-900 ms: $F(1,19) = .91$; $p = .35$; $\eta^2 = .0146$; $\pi = .149$). Both conditions also showed the same scalp distribution (Figure 4). In the

ANOVA for expected words Presentation Mode was significant as a main effect in the 450-600 ms window ($F(1,19) = 15.14$; $p = .001$; $\eta^2 = .444$; $\pi = .958$) but failed significance in the other time windows analyzed (300-450 ms: $F(1,19) = 1.2$; $p = .286$; $\eta^2 = .06$; $\pi = .181$; 600-750 ms: $F(1,19) = .8$; $p = .381$; $\eta^2 = .041$; $\pi = .136$; 750-900 ms: $F(1,19) = 1.26$; $p = .275$; $\eta^2 = .062$; $\pi = .187$).

In sum, a late posterior positive component for expected words in dynamic conditions appeared when eyes of the speaker were covered, though attenuated in amplitude and temporally more restricted as compared to Experiment 1, where the whole face was visible. This result appeared obscured in the main ANOVA including both expected and unexpected words, maybe because of the presence of components with opposite polarities for the different Expectancy conditions (N400 and late posterior positivity). Visibility of the eyes seems therefore to be one of the elements contributing to the effects obtained in Experiment 1. However, since the late posterior positivity was again elicited, the visibility of the mouth (or other parts of the face) might also be relevant for this effect. To directly test this possibility, we conducted Experiment 3, where the mouth of the speaker was covered.

6.4. Experiment 3. Mouth covered

By occluding the mouth region (Figure 1), Experiment 3 investigated whether information other than lip movements -leaving the eyes as most important facial features visible- contributes to the effect of dynamic versus static presentation mode, observed in Experiment 1.

6.4.1 Method

6.4.1.1 Participants

Twenty native German speakers, other than those of Experiments 1 or 2, participated in this experiment (13 females, 7 males; age range 18-34 [M = 25.6]). All declared to have normal or corrected-to-normal vision, normal hearing, and were righthanded (Mean Oldfield scores >75). Participants gave written informed consent and received reimbursement for their participation.

6.4.1.2 *Materials and procedure*

Materials and procedure were the same as in Experiment 1 except that a skin-coloured opaque bar covering the speaker's mouth was added to both videos and pictures.

6.4.1.3 *EEG-recordings and data analysis*

The EEG-recording settings were as described for Experiment 1. Due to the presence of artefacts, on average 7.4% of the recorded EEG segments had to be excluded from data analysis.

6.4.2 Results and discussion

Again, a large N400 was obtained in the ERPs to unexpected words (Figure 5, right), highly resembling the corresponding results of Experiments 1 and 2. For the expected words (Figure 5, left), the long-lasting posterior positivity in the dynamic mode emerged again, smaller, however, than in Experiment 1. The main ANOVA, including the factors Expectancy and Presentation Mode, showed significant effects of Expectancy between 300 and 750 ms (300-450ms: $F(1,19) = 26.08$; $p < .001$; $\eta^2 = .57$; $\pi = .998$; 450-600 ms: $F(1,19) = 34.03$; $p < .001$; $\eta^2 = .642$; $\pi = 1$; 600-750 ms: $F(1,19) = 14.2$; $p = .001$; $\eta^2 = .428$; $\pi = .947$) but not between 750 and 900 ms ($F(1,19) = 2.93$; $p = .103$; $\eta^2 = .134$; $\pi = .370$). The Presentation Mode effect was statistically significant between 450 and 750 ms (450-600 ms: $F(1,19) = 1.6$; $p = .221$; $\eta^2 = .078$; $\pi = .225$; 600-750 ms: $F(1,19) = 5.76$; $p = .027$; $\eta^2 = .233$; $\pi = .625$). However, it did not reach statistical significance between

300 and 400 ms ($F(1,19) = 1.35$; $p = .259$; $\eta^2 = .066$; $\pi = .197$), and between 750 and 900 ms ($F(1,19) = 1.72$; $p = .204$; $\eta^2 = .083$; $\pi = .239$). The Expectancy by Presentation Mode interaction did not yield significant effects (300-450 ms: $F(1,19) = .31$; $p = .584$; $\eta^2 = .016$; $\pi = .083$; 450-600 ms: $F(1,19) = 1.16$; $p = .293$; $\eta^2 = .058$; $\pi = .177$; 600-750 ms: $F(1,19) = .68$; $p = .419$; $\eta^2 = .035$; $\pi = .123$; 750-900 ms: $F(1,19) = .00$; $p = .951$; $\eta^2 < .001$; $\pi = .05$).

As before, separate ANOVAs for expected and unexpected words were performed. Although the interaction of Expectancy by Presentation Mode failed significance in the main ANOVA, both Expectancy conditions were analysed separately to assure that the co-occurrence of an N400 for unexpected words would not affect the detection of a simultaneous posterior positivity for expected words. Thus, consistent analyses were performed throughout all three experiments. The ANOVA for unexpected words revealed no differences in the N400 between dynamic and static presentation modes (300-450 ms: $F(1,19) = .42$; $p = .84$; $\eta^2 = .002$; $\pi = .054$; 450-600 ms: $F(1,19) = .02$; $p = .966$; $\eta^2 = .00$; $\pi = .05$; 600-750 ms: $F(1,19) = .57$; $p = .458$; $\eta^2 = .029$; $\pi = .111$; 750-900 ms: $F(1,19) = .37$; $p = .547$; $\eta^2 = .019$; $\pi = .09$). In contrast, the ANOVA to expected words revealed a significant effect of Presentation Mode between 600 and 750 ms, ($F(1,19) = 4.84$; $p = .04$; $\eta^2 = .203$; $\pi = .551$) but not in the other time windows (300-450 ms: $F(1,19) = 1.20$; $p = .287$; $\eta^2 = .059$; $\pi = .18$; 450-600 ms: $F(1,19) = 3.14$; $p = .09$; $\eta^2 = .142$; $\pi = .391$; 750-900 ms: $F(1,19) = .37$; $p = .547$; $\eta^2 = .019$; $\pi = .09$).

Summarizing Experiment 3, a late posterior positivity for expected words in dynamic mode still appeared when the mouth was covered, though apparently weaker and temporally more restricted as compared to Experiment 1 (whole face) but similar to that in Experiment 2 (eyes covered). Therefore, lip movements (retained in the videos) seem to also contribute to the effects observed in Experiment 1.

MOUTH COVERED / EXPERIMENT 3

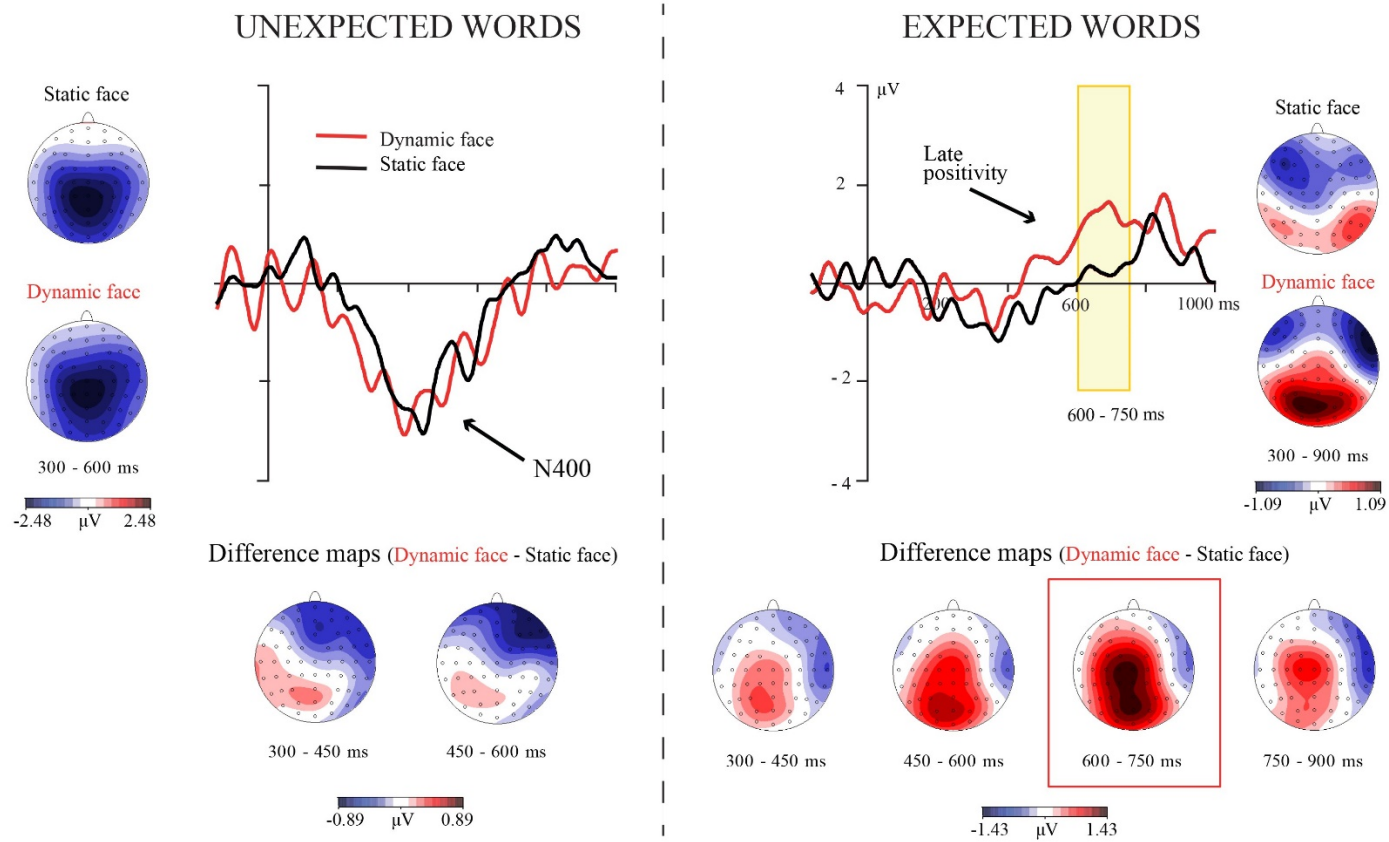


Figure 5 - Effect of Presentation Mode on expected and unexpected words in the mouth covered condition (Experiment 3). ERPs of the ROI electrodes are pooled. The ERP topographies represent each component individually for each presentation mode. The difference maps represent the Presentation Mode effect (dynamic minus static) for unexpected (left) and expected words (right).

On the other hand, the N400 in response to unexpected words was again unaffected by the dynamic or static presentation mode of the speaker's face, very similar to the results of Experiments 1 and 2. Hence, the N400 to unexpected words does not seem to be modulated by any of the facial cues manipulated here. This will be discussed in more detail below.

6.5 Comparison of Experiments 1, 2, and 3

6.5.1 Data analysis

In order to directly compare the potential impact of different face areas visible during speech processing, we conducted analyses of the effects of type of presentation and expectancy of words across all three facial feature presentation conditions: whole face (Exp.1), eyes covered (Exp. 2), and mouth covered (Exp. 3). To this aim, a mixed ANOVA was first performed including the factors Facial Feature (Experiment) as group factor and Expectancy and Presentation Mode as within-subject factors. To further compare the N400 and the late posterior positivity across facial features (i.e., experiments) devoid of the conceivable confounds caused by the inclusion of two components of opposite polarity over similar regions possibly inducing type II errors, separate mixed ANOVAs were performed for the expected and unexpected conditions, with Facial Feature as group factor and Presentation Mode as within-subject factor. Bonferroni-corrected posthoc pairwise comparisons were applied to significant interactions; Huynh-Feldt corrections were applied where appropriate.

6.5.2 Results and discussion

The main ANOVA on ERPs including the factors Facial Feature, Expectancy and Presentation Mode showed significant main effects of Expectancy between 300 and 900 ms (300-450 ms: $F(1,57) = 121.41$; $p < .001$; $\eta^2 = .681$; $\pi = 1$; 450-600 ms: $F(1,57) = 124.31$; $p < .001$; $\eta^2 = .686$; $\pi = 1$; 600-750 ms: $F(1,57) = 59.25$; $p < .001$; $\eta^2 = .51$; $\pi = 1$;

750-900 ms: $F(1,57) = 23.53$; $p < .001$; $\eta^2 = .292$; $\pi = .998$). The interaction of Expectancy with Facial Feature reached statistical significance between 300 and 450 ms ($F(2,57) = 98.36$; $p = .041$; $\eta^2 = .106$; $\pi = .6134$) and trends between 450 and 600 ms ($F(2,57) = 2.48$; $p = .093$; $\eta^2 = .08$; $\pi = .479$) and between 750 and 900 ms ($F(2,57) = 2.67$; $p = .078$; $\eta^2 = .086$; $\pi = .51$), but it did not even approach statistical significance in the 600-600 ms time window ($F(1,57) = 1.54$; $p = .223$; $\eta^2 = .051$; $\pi = .314$). Presentation Mode reached significance between 300 and 900 ms (300-450 ms: $F(1,57) = 148.46$; $p = .001$; $\eta^2 = .165$; $\pi = .909$; 450-600 ms: $F(1,57) = 19.45$; $p < .001$; $\eta^2 = .254$; $\pi = .991$; 600-750 ms: $F(1,57) = 7.96$; $p = .007$; $\eta^2 = .123$; $\pi = .792$; 750-900 ms: $F(1,57) = 10.55$; $p = .002$; $\eta^2 = .156$; $\pi = .891$), but no interval showed significant effects for the Presentation Mode by Facial Feature interaction (300-450 ms: $F(2,57) = 27.58$; $p = .133$; $\eta^2 = .068$; $\pi = .412$; 450-600 ms: $F(2,57) = 1.17$; $p = .316$; $\eta^2 = .04$; $\pi = .248$; 600-750 ms: $F(2,57) = .7$; $p = .5$; $\eta^2 = .024$; $\pi = .163$; 750-900 ms: $F(2,57) = .84$; $p = .435$; $\eta^2 = .029$; $\pi = .188$). The ANOVA also yielded a significant interaction Expectancy by Presentation Mode between 300 and 750 ms (300-450 ms: $F(2,57) = 5.07$; $p = .028$; $\eta^2 = .82$; $\pi = .601$; 450-600 ms: $F(2,57) = 12.38$; $p = .001$; $\eta^2 = .179$; $\pi = .933$; 600-750 ms: $F(2,57) = 6.54$; $p = .013$; $\eta^2 = .103$; $\pi = .711$), but the interval 750-900 ms did not reach statistical significance ($F(2,57) = 1.82$; $p = .182$; $\eta^2 = .031$; $\pi = .264$). The Expectancy by Presentation Mode by Facial Feature interaction did not reach significance in any interval (300-450 ms: $F(2,57) = 1.84$ $p = .167$; $\eta^2 = .061$; $\pi = .370$; 450-600 ms: $F(2,57) = .903$; $p = .411$; $\eta^2 = .031$; $\pi = .198$; 600-750 ms: $F(2,57) = 1.95$; $p = .151$; $\eta^2 = .064$; $\pi = .389$; 750-900 ms: $F(2,57) = 1.42$; $p = .249$; $\eta^2 = .048$; $\pi = .293$).

The significance of main effects of Presentation Mode clearly conflicts with visual inspection of the data as well as with separate ANOVAs performed for the three Experiments individually, which systematically showed that unexpected words were blind to presentation mode. On the other hand, the absence of Expectancy by

Presentation Mode by Facial Feature interaction would also be at odds with main ANOVAs performed for the three Experiments in sequence, as the latter indicated that no significant effects were observed for Expectancy by Presentation Mode in Experiment 3 and informed about a trend in Experiment 2. All these features endorse that mixing expected and unexpected words in the same analyses is being prone to statistical inaccuracies probably as a consequence of conflating two different components of opposite polarities over similar scalp areas (cf. Brouwer & Crocker, 2017; Luck, 2014) and, therefore, that separate ANOVAs are the most appropriate approach to analyse the present results.

The separate ANOVA to expected words revealed significant main effects of Presentation Mode between 300 and 900 ms (300-450 ms: $F(1,57) = 13.33$; $p = .001$; $\eta^2 = .190$; $\pi = .948$; 450-600 ms: $F(1,57) = 29.55$; $p < .001$; $\eta^2 = .341$; $\pi = .1$; 600-750 ms: $F(1,57) = 16.5$; $p < .001$; $\eta^2 = .225$; $p = .979$; 750-900 ms: $F(1,57) = 11.54$; $p = .001$; $\eta^2 = .168$; $\pi = .916$). These results confirm the presence of the long-lasting late posterior positivity for dynamic as compared to static modes across the three experiments. The interaction of Presentation Mode and Facial Feature was significant in the time window 300-450 ms ($F(2,57) = 3.49$; $p = .037$; $\eta^2 = .109$; $\pi = .631$), and re-appeared as trends between 600 and 900 ms (600-750 ms: $F(1,19) = 2.43$; $p = .096$; $\eta^2 = .079$; $\pi = .472$; 750-900 ms: $F(1,19) = 2.46$; $p = .094$; $\eta^2 = .08$; $\pi = .476$).

Post-hoc pairwise comparisons for the 300 and 450 ms interval revealed that the posterior positivity in the dynamic mode was significantly larger for Experiment 1 than Experiment 3 ($\Delta = 2.106$ mV, $p = .004$) (Figure 6). This difference was present also in the time window 600-750 ms though only as a trend ($\Delta = 1.37$ μ V, $p = .084$) but was significant again later between 750 and 900 ms ($\Delta = 1.7$ μ V, $p = .008$). No other significant comparison was found.

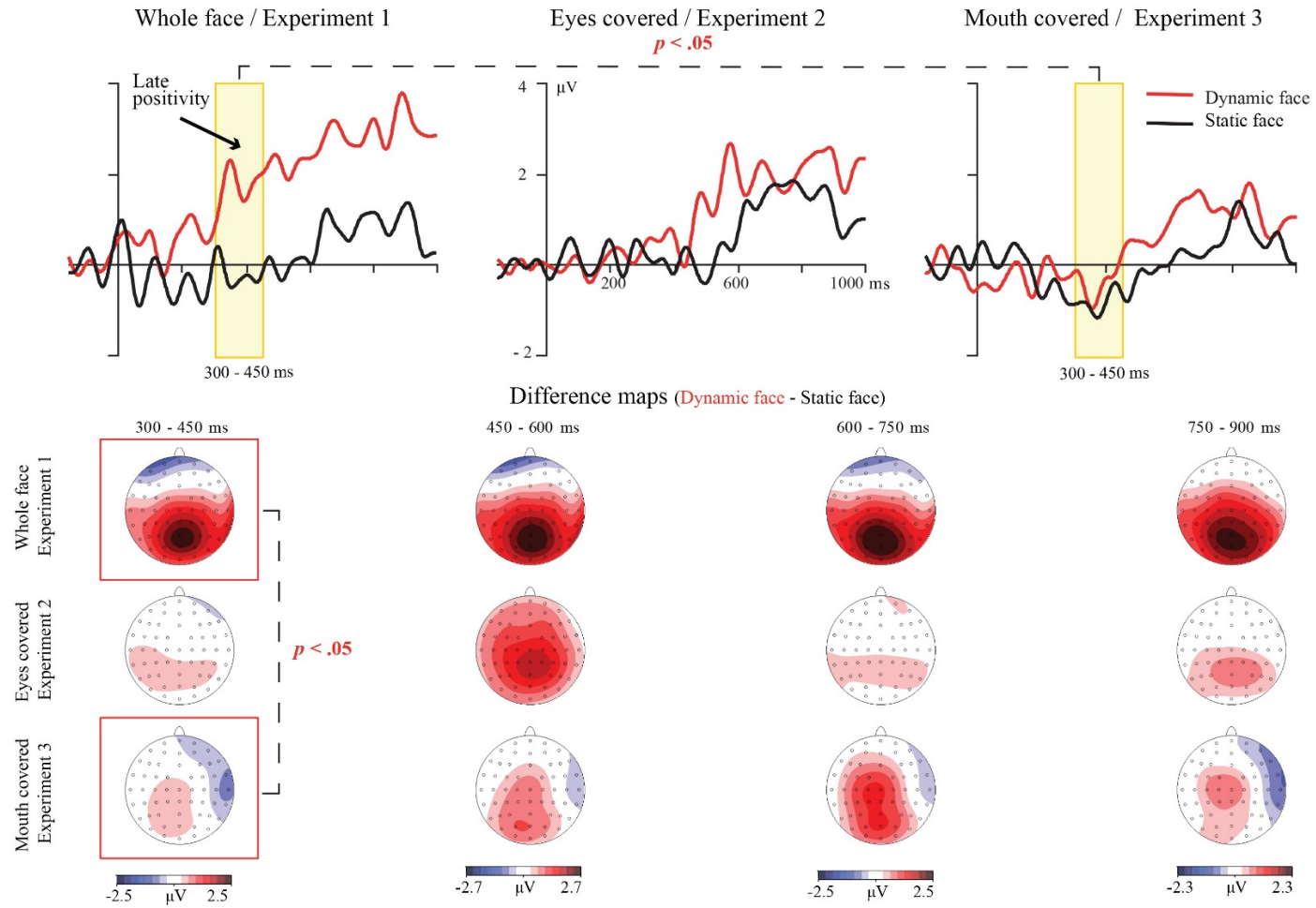


Figure 6 - Effect of Presentation Mode on expected words in each experiment. ERPs of the ROI electrodes are pooled. The difference maps represent the Presentation Mode effect (dynamic minus static) for each Facial Feature.

The ANOVA of ERP amplitudes to unexpected words did not yield any significant differences for Presentation Mode (300-450 ms: $F(1,57) = .04$; $p = .828$; $\eta^2 = .001$; $\pi = .055$; 450-600 ms: $F(1,57) = .123$; $p = .727$; $\eta^2 = .002$; $\pi = .064$; 600-750 ms: $F(1,57) = .00$; $p = .944$; $\eta^2 = .00$; $\pi = .051$; 750-900 ms: $F(1,57) = 1.53$; $p = .22$; $\eta^2 = .026$; $\pi = .23$), or for the interaction of Facial Feature and Presentation Mode (300-450 ms: $F(1,57) = .05$; $p = .942$; $\eta^2 = .002$; $\pi = .059$; 450-600 ms: $F(1,57) = .1$; $p = .905$; $\eta^2 = .004$; $\pi = .065$; 600-750 ms: $F(1,57) = .53$; $p = .589$; $\eta^2 = .018$; $\pi = .134$; 750-900 ms: $F(1,57) = .048$; $p = .953$; $\eta^2 = .002$; $\pi = .057$).

In sum, the long-lasting late posterior positivity for expected words appeared whenever the stimulus was presented in a dynamic context. Interestingly, this positivity was significantly reduced when the mouth was covered. Statistical analyses showed a significant interaction in the 300-450 ms window, while post-hoc analyses of this segment were significant only when comparing Experiments 1 (whole face) and 3 (mouth covered). In contrast, the N400 amplitude in ERPs to unexpected words was robust and insensitive against all our manipulations; it was of similar amplitude regardless of the dynamic or static presentation mode of the face and whether the face was shown at full view or whether mouth or eyes of the speaker were occluded.

6.6 General Discussion

In the present study, we investigated whether dynamic features of a speaker's face can facilitate the semantic processing of connected speech, as compared to a static condition. We recorded ERPs to expected and unexpected words, embedded in spoken sentences, in two different conditions. In one condition, the spoken utterances appeared together with a video of the speaker; in the other condition, a static picture of the face was shown. Importantly, the same critical words embedded in the same sentences were either expected or unexpected, depending on a preceding context

sentence (cf. Dambacher et al., 2012). This manipulation ruled out any confounds due to different (acoustic) properties of the stimulus material. As expected, a large N400 component appeared to the unexpected compared to expected critical words (Kutas & Federmeier, 2011). Contrary to our predictions, this ERP deflection was not modulated at all by dynamic versus static presentation modes in any of the three experiments. A consistent finding across all three experiments, however, was a long-lasting posterior positivity in the condition with expected words in the dynamic relative to the static condition; such an effect was not seen in the condition with unexpected critical words. Experiments 2 and 3 were conducted to disentangle the contribution of different facial features of the speaker, which is eyes and mouth, to these effects.

6.6.1 No modulation of the N400

As mentioned, presentation mode did not have any impact on the semantic processing of sentences, reflected in the N400. If we had focused on the N400 effect, that is, the difference between unexpected and expected words, differences between dynamic and static conditions in this ERP fluctuation would have emerged, but merely as a consequence of the late posterior positivity in the expected word condition (Figure 2). For this reason, we focused on the N400 component. According to our results, online semantic word processing in sentences seems unaffected by the perception of facial dynamics (visual speech and eye gaze). Articulatory visual saliency of speaker lip movements has been shown to impact the N400 in dynamic situations (Brunellière et al., 2013; van Wassenhove et al., 2005). We did not control the articulatory visual saliency of our critical words because our main manipulation was of a different kind. In this regard, our dynamic condition might be considered as more salient than the static one, but no difference in the N400 was present between these two situations.

Other factors might be in play in accounting for our results. In the light of limited resources, the human cognitive system focuses on highly relevant stimuli while ignoring other information via selective attention (Lakatos et al., 2008; Li et al., 2016; Schroeder & Lakatos, 2009). Unexpected words might make listeners devote more resources to the semantic processing of the auditory stimulus and ignore visual stimuli; in this case, effects may be similar irrespective of the dynamic versus static information in the face. On the contrary, listening to expected words does not require much effort and might liberate resources otherwise devoted to semantic processing, permitting attention to be directed to the visual information in the face. According to our results, only when semantic processing is not cognitively demanding (expected words), there is an influence of visual dynamic information provided in parallel to the auditory input.

It should also be considered that facilitating effects of multisensory integration might be weak or absent when the input coming from both sensory streams is unambiguous and can be perceived clearly (Colonius & Diederich, 2004; Hong & Shim, 2016; Stanford, Quessy, & Stein, 2005). A few studies demonstrated visual speech to be advantageous over phonological and lexical processes when using noisy contexts (Buchwald et al., 2009; Fort, Spinelli, Savariaux, & Kandel, 2010; Sumbly & Pollack, 1954). Under noise-free situations, auditory information alone may be enough to complete a lexical decision task, rendering both dynamic and static modes redundant (Fort et al., 2010; 2013). As the present experiment used clearly audible spoken sentences, audiovisual integration might not have been required to semantically process the unexpected words.

6.6.2 Posterior positivity to expected words in dynamic presentation

The long-lasting late posterior positivity to expected words in the dynamic relative to the static condition was surprising because there seem to be no previous reports of

6such an effect. Its amplitude may relate to both visual speech and direct dynamic gaze perception during a simulated communicative situation. In fact, we observed the largest and longest (300e900 ms) effect when the whole face was visible (Exp. 1). A visual inspection of Figure 6 revealed apparent differences between the three experiments in the amplitude of the late posterior positivity, being most pronounced when the whole face accompanied speech in dynamic motion. Covering the eyes or the mouth seemed to attenuate this modulation, though only the post-hoc comparison between Experiments 1 and 3 (mouth-covered) yielded a significant reduction of the effect relative to the whole face.

Our late posterior positivity is similar to the ERP waves consistently reported by Schindler and colleagues in the frame of social contexts (Schindler et al., 2015; Schindler & Kissler, 2016; 2017). They asked participants to describe themselves on a video to be watched by another participant next door. Immediately afterwards, participants were presented a feedback consisting of evaluative adjectives on a screen (e.g., “happy”, “weak”). These adjectives were claimed to either stem from the other participant or to be random generated by a computer. This manipulation resulted in a continuous long-lasting posterior positivity, interpreted as a P3 component followed by an LPP (late positive potential). Interestingly, the observed long-lasting posterior positivity was larger when participants were informed that feedback was given by a human sender rather than by a computer. This increased posterior positivity seems to resemble our effect of dynamic versus static presentation. It is important to note, however, that Schindler and colleagues did not use face stimuli, and therefore their results cannot be related to specific facial features. Schindler and colleagues suggested their results as an influence of sender information on language processing due to different communicative contexts and interpreted them as effects of higher motivated attention directed to a human sender compared to the computer. Similarly, communicative situations, in which

a talking face is presented, have recently been found to enhance (emotional) word processing (Rohr & Abdel Rahman, 2015). In our study, the social context of the dynamic mode was richer than the static mode. Seeing the whole face of a speaker in motion appears to be the condition that most resembles a natural communicative context.

Schindler and colleagues framed their data within the motivated attention model (Lang, Bradley, & Cuthbert, 1997), adding that context manipulations and not only the emotional content could amplify the motivational relevance of written words. Our findings are consistent with this idea, indicating that motivated attention can be manipulated by contextual factors, possibly enhancing the late processing of words. Further, they extend the effect to connected speech in a multisensory context, similar to face-to-face communication.

The posterior positivity diminished when covering the mouth of the speaker, but not significantly when covering the eyes. In social interactions, direct gaze is important because it allows the beholder to make communicative inferences (Gallagher, 2014). It seems necessary to underline, however, that the characteristics of our stimuli prevent us from firmly attributing the late posterior positivity effect to the importance of the mouth over gaze. The main reason is that on the videos the speaker's mouth was more dynamic than his eyes, which gazed at the participant rather constantly. The difference between covering the eyes and the mouth might not be related to any particular facial feature, but mainly to differences on overall dynamics and perception of motion. More research is necessary to confirm our results. It would be useful to compare specific contributions of eyes and mouth motions in similar dynamic contexts.

Possibly, verbal communication cues from the mouth dominate over the social cues from eye gaze. In fact, mouth dynamics are directly related to the auditory stimuli; hence the interplay and coherence between mouth movements and utterances may

enhance language comprehension and be advantageous in communication contexts. In line with this thought, Western people (our sample) relative to Eastern seem to focus their attention on the mouth of the speaker more than on her gaze during audiovisual speech perception (Hisanaga et al., 2016). Consequently, dynamic presentation of both speaker's eyes and mouth importantly contribute to modulate the processing of connected speech, with a larger contribution of the mouth.

6.7 Conclusions

The main finding of the present study is the higher attentional processing to contexts that resemble most strongly natural communicative situations, as long as semantic speech processing is not very demanding. Contrary to our predictions, we could not find any modulation of the N400 semantic effect by the concomitant dynamic facial information. The speaker's dynamic facial features did not affect semantic processing. When semantic comprehension is more demanding (i.e., when an unpredicted or unexpected word is presented), visual cues are not critical or disregarded for language processing. By contrast, material that is predictable in a linguistic stream generates, when accompanied by the dynamic face of the speaker, a long-lasting late posterior positivity. This positivity is reminiscent of the communicative effect described by Schindler and colleagues (Schindler et al., 2015; Schindler & Kissler, 2016; 2017), interpreted as an increase of motivated attention in richer social contexts. The present study has provided new information about the interaction of audiovisual social-contexts and word processing of connected speech. Hence, it is a step forward towards the study of language comprehension in real-life situations.

7. CHAPTER 4. STUDY TWO

7.1. Introduction

Human language is social by nature. During inter-personal communication interlocutors usually face each other and there is multimodal exchange of information. Most of the experiments on (neuro)linguistics have not paid attention to the visual effects of social stimuli on linguistic comprehension (Dale, Fusaroli, Duran & Richardson 2013; Munster & Knoeferle, 2018). However, the number of studies interested in social factors during language processing is rapidly rising (e.g. Dale et al., 2013; Knoeferle, 2016; Münster & Knoeferle, 2018; Rohr & Abdel-Rahman, 2015, 2018; Schindler et al., 2015). Following this line of research, the present paper uses electrophysiological measures to investigate whether processing the semantic and syntactic domains in connected speech are affected by the presence of the speaker's face as a minimal visuo-social factor.

In face-to-face communication, language is a multimodal process involving both the linguistic information contained in the auditory stream and the visual input received from the speaker's facial speech movements, gaze, or facial expressions (Hernández-Gutiérrez et al., 2018; Peelle & Sommers, 2015; Rohr & Abdel Rahman, 2015; van Atteveldt et al., 2014; Van Wassenhove, 2013). Auditory and visual streams converge into a situational model of language comprehension (Hagoort, 2017). In this context, two critical cues can be extracted from a face. On the one hand, a linguistic-related stream comes from the articulatory mouth movements, typically known as visual speech (Buchwald et al., 2009; Crosse, Butler & Laor, 2015, van Wassenhove et al., 2015). On the other hand, a face-to-face encounter provides *stable* (invariant) social information about the speaker (e.g., gender, age, attractiveness, identity), as well as *dynamic* social information via changeable attributes like gaze direction or facial expressions (Haxby, Hoffman & Gobbini, 2000). In this sense, mentalizing is critical in human communication,

enabling the listener to decode mental states and communicative intentions from the speaker based on the perception of his/her gaze (Kampe, Frith & Frith, 2003; Myllyneva & Hietanen, 2015; Senju & Johnson 2009). Moreover, gaze direction conveys powerful social cues related to the attentional focus (Conty et al., 2006, Irwin, 2004, Senju & Hasegawa, 2005, Senju & Johnson, 2009). In face-to-face interactions, direct gaze perception triggers a feeling of being attended while special attention is paid to the speaker's face (Vertegaal, Slagter, Van der Veer & Nijholt, 2001). Therefore, eyes are special stimuli capturing and allocating attention (Conty et al., 2006; Risko, Laidlaw, Freeth, Foulsham & Kingston, 2012; Senju & Hasegawa, 2005; von Grünau & Anston, 1995). Indeed, there is also a strong attentional bias to faces compared to other stimuli (Bindemann, Burton, Langton, Schweinberger & Doherty, 2007; Langton, Law, Burton & Schweinberger, 2008; Ro, Russell & Lavie, 2001; Theeuwes & Van der Stigchel, 2006).

Neuroanatomical studies report that speech processing and social cognition share brain networks, particularly in the superior temporal sulcus (STS), involved in the multimodal processing of language and social meaning (Redcay, 2008). In line with this claim, Carlin and Calder (2013) and McGettigan et al., (2017) confirmed the role of the STS in the processing of social gaze. On the other hand, brain structures associated with Theory of Mind (TOM) (e.g. dorsomedial prefrontal cortex -dmPFC- and temporo-parietal junction -TPJ-) have been repeatedly found to be involved in the processing of faces. Interestingly, regions supporting TOM exhibited more activity in a simulated live-speech task (more like a real communicative context) compared to a recorded-speech task (Rice & Redcay, 2016). This result was explained as the engagement of the TOM network in social interaction. In turn, the Medial Temporal Gyrus -MTG-, not only has a role in integrating information from faces, gaze direction, and speech during social communication, but also in grasping others' intentions (Adams et al., 2010; Brunet,

Sarfati, Hardy-Baylé, & Decety, 2000; Cecchini, Aceto, Altavilla, Palumbo & Lai, 2013; Holler et al., 2014a; Segaert, Menenti, Weber, Petersson & Hagoort, 2012).

Behavioural studies found that facial features, particularly the speaker's gaze, play facilitate language comprehension, either at lexico-semantic stages (Holler et al., 2014b; Richardson & Dale, 2005) or at the syntactic level -e.g. referents disambiguation (Hanna & Brennan, 2007), thematic role assignment and syntactic structuring (Knoeferle & Kreysa, 2012)-

While there is extensive behavioural and neuroimaging evidence of the visual integration of the speaker's face in communicative situations, results from online comprehension measures are scarce. A fine-grained study in the temporal domain may be suitably done with event-related-potentials (ERP). Well-known ERP language-related indices are the N400, the LAN, and the P600 components in the ERP.

Previous electrophysiological research demonstrated that during language comprehension listeners take into consideration the social context and their knowledge about the speaker (Bornkessel-Schlesewsky, Krauspenhaar & Schlewsky, 2013; Jouralev et al., 2018; Rueschemeyer, Gardner & Stoner, 2014; Van Berkum, Van den Brink, Tesink, Kos, Hagoort, 2008). In this regard, an N400 effect has been reported to inconsistencies between a voice and the content of the message, like listening to the sentence "Every evening I drink some *wine* before I go to sleep" when uttered with voice of a child (Van Berkum et al., 2008). In another study, larger N400 effects were found to false political statements when the speaker was a politician compared to other speakers, but no difference was found for non-political statements (Bornkessel-Schlesewsky et al., 2013). Moreover, language processing is also affected by the communicative context, which can be triggered just by believing that a real person is communicating with us through a computer (Schindler et al., 2015; Schindler & Kissler, 2016, 2017). This

communicative effect was reflected in a late posterior positivity (LPP) to emotional words uttered by a real person, compared to an artificial sender, and was interpreted as an increase of motivated attention. In a previous study we found a similar effect in an audiovisual context when congruent sentences were accompanied by a video of the speaker compared to his still face (Hernández-Gutiérrez et al., 2018). In the present study, we will focus on whether a still face is sufficient to elicit social effects on language processing. Hence, we will study language in a *minimal social context*.

No study to date has investigated the impact of the mere presence of the speaker's face on speech comprehension with online measures. Here, we situate language in this minimal social context to investigate with ERP the influence of simply seeing the speaker's still face displaying a direct gaze in real-time language processing. We separately manipulated the morphosyntactic agreement and the semantic congruency of target words embedded in natural spoken sentences to manipulate the syntactic and semantic domains, respectively. Participants listened to the sentences while viewing the still face of the putative speaker or – as a control - a scrambled face. In the semantic Experiment 1 we focused on the N400 component (and P600, if present), whereas in the syntactic Experiment 2, the LAN and P600 were explored.

Within this minimal social context, we expected attentional effects on semantic processing, increasing attention to the linguistic message when the speaker's face is perceived (relative to scrambled stimulus) because of its relationship to and relevance for the communicative process. Attention can affect semantic processing, and thus it has been found to enhance the N400 semantic effect when words are attended (McCarthy & Nobre, 1993). Further, experiments with explicit semantic judgements usually show larger N400 amplitudes (Van Petten, 2014b). Accordingly, we expected participants to allocate more attentional resources to the linguistic stream when the face of the speaker is observable, resulting in larger N400 effects. It is likely that situating

language in a minimal social context leads to a deeper linguistic processing due to self-reference mechanisms and the perceived communicative intent (Wang, Bastiaansen, Yan & Hagoort, 2011), as a visible person would be experienced as (intentionally) speaking to the participant. In this case deeper processing (Craik & Lockhart, 1972; Wang et al., 2011) might facilitate more detailed linguistic analysis, which appears to enhance the N400 semantic effect in auditory sentences (Wang et al., 2011).

Syntactic processing has been traditionally considered informationally encapsulated and consequently not affected by non-linguistic stimuli (Friederici, 2002, Hauser, Chomsky & Fitch, 2000); however, there are numerous ERP findings questioning this claim (Casado et al., 2018; Martín-Loeches et al., 2006; Martín-Loeches et al., 2012). Besides, there is behavioural evidence on the relationship between gaze and syntactic processing (Hanna & Brennan, 2007; Knoeferle & Kreysa, 2012). Therefore, we predicted that also the LAN and P600 effects may be enhanced by the minimal social context manipulation employed here.

7.2. Experiment 1. Semantic domain

7.2.1 Methods

7.2.1.1 Participants

Twenty-eight native Spanish speakers participated in this experiment (14 females; age range 18 – 24; $M = 21.3$ years). They all were right handed (Mean Oldfield scores: +75) and declared normal or corrected to normal vision and hearing, and absence of neurological disorders. Participants gave written informed consent and were reimbursed for participating in the experiment. The study was approved by the ethics committee of the Hospital Clínico San Carlos, Madrid, Spain, and performed in accordance with the Declaration of Helsinki.

7.2.1.2 Materials and procedure

The linguistic stimuli consisted of 480 sentences in Spanish with three different structures. In addition, a semantically incongruent version of each sentence was created. To do this, critical words (bold-faced below) were pseudo-randomly scrambled and shuffled between sentences. In written stimuli, these kinds of semantic manipulations have been typically related to N400 effects (e.g. Martín-Loeches et al., 2012). A congruent and incongruent example of each type of sentence is given below (English translation in brackets).

Structure 1(n=300): [Det]-[N]-[**Adj**]-[V]-[Prep]-[N]

- Congruent sentence: *El pañuelo **bordado** era de mi abuela* (The **embroided** cushion belonged to my grandmother)
- Incongruent sentence: *El pañuelo **asado** era de mi abuela* (The **roasted** cushion belonged to my grandmother)

Structure 2 (n=90): [Det]-[N]- [V]-[Det]-[**N**]- [Adj]

- Congruent sentence: *Los turistas habían fotografiado los **glaciares** árticos.* (The tourists had photographed the arctic **glaciers**)
- Incongruent sentence: *Los turistas habían fotografiado los **pensamientos** árticos* (The tourists had photographed the arctic **thoughts**)

Structure 3 (n=90): [Det]-[N]- [V] -[Prep]-[Det]-[**N**]-[Prep]-[Det]-[N]

- Congruent sentence: *Las hojas son recogidas durante el **otoño** por los barrenderos* (The leaves are picked by the sweepers during the **autumn**)
- Incongruent sentence: *Las hojas son recogidas durante el **escritor** por los barrenderos.* (The leaves are picked by the sweepers during the **writer**)

The whole set of 960 sentences (correct plus incorrect versions) were recorded with neutral prosody by a female and a male speaker. One additional male and female voice was created by manipulating the fundamental frequency (F_0) with Praat software. These voices were created by increasing the F_0 of the male voice by 10% and reducing the female voice by 10%. This manipulation resulted in two different male and female voices each, per sentence. We decided not to use four different speakers in order to minimize speech variability. All audio files were matched in acoustic intensity with Audacity software. Three independent researchers set the triggers at the onset of each target words with GoldWave software considering the auditory and visual patterns of the sound waves. Then, the three triggers per word were averaged to obtain objective time-points. This procedure had been successful employed in previous work (Hernandez-Gutierrez et al, 2018). The length of target words varied between two and five syllables, and linguistic characteristics like word frequency, concreteness, imageability, familiarity and emotional content were for controlled by presenting every word on each voice across all experimental conditions. The cloze probability was calculated for congruent and incongruent target words with a questionnaire completed by individuals who did not participate in the experiment. Congruent target words were predicted 8.4% of the times while the percentage was 0% for the incongruent ones.

Every auditory sentence was accompanied by the visual presentation of either a still picture of the speaker's face (social condition) or a scrambled face (control condition) - Figure 7-. Two male and two female faces were taken from the Humboldt database. The scrambled version of the faces was created with Matlab Software using a 30 x 40 matrix. Therefore, the control stimuli kept most physical characteristics intact, but no facial features were identifiable. Each face was assigned to one of the voices (matching gender), and the correspondence was kept consistent throughout the experiment.

The experiment was performed in an electrically shielded cabin. Participants were seated in a comfortable chair facing a computer screen (1280 x 1024 pt) at a viewing distance of 60 cm. The auditory stimuli were presented through a pair of shielded speakers placed at both sides of the screen. Sound pressure level was the same for all participants, who first confirmed that the loudness of the voice was comfortable. Every participant listened to 240 sentences evenly distributed to four conditions: 60 congruent and 60 incongruent sentences seeing the speaker, and the same proportion seeing the scrambled face. Each sentence was presented to a given participant only once. The experiment was performed in two blocks of 120 sentences each according to the type of picture. Congruent and incongruent sentences were mixed. The order of the blocks was counterbalanced across subjects and one pause was included within each block after 60 sentences. We designed enough presentation sets of 240 sentences to cover all the possible combinations between sentences, semantic congruency and visual stimuli; please note that participants were presented only 240 out of the total 480 sentences, because the participants in the present experiment also participated in Experiment 2, where they received the other 240 sentences, thus avoiding repetition effects. Two participants were assigned to each set of sentences, and the presentation of the sentences within each set was randomized. At the end of the experiment every sentence had been spoken in all 4 voices, but a given participant heard a given sentence only in one of the voices, hence differences in the results cannot be due to particular linguistic characteristics of the sentences or the voices. Participants were asked to try not to blink while the sentences were presented. Experiment 1 took 25 minutes to be completed and was separated from Experiment 2 by a 10-min break. Both experiments were counterbalanced in order.

Participants were informed that they would listen to sentences while seeing the face of the person speaking to them. They decided after each sentence whether it made

sense by pressing one of two different buttons on a response box. The button-decision assignments as well as the response hand were counterbalanced across participants. At the beginning of each trial the speaker's face appeared in the center of the screen and after 500 ms the audio started. The face was present until the auditory sentence finished, when, after 1 s, a question mark ("?") appeared in the center of the screen that prompted the response.

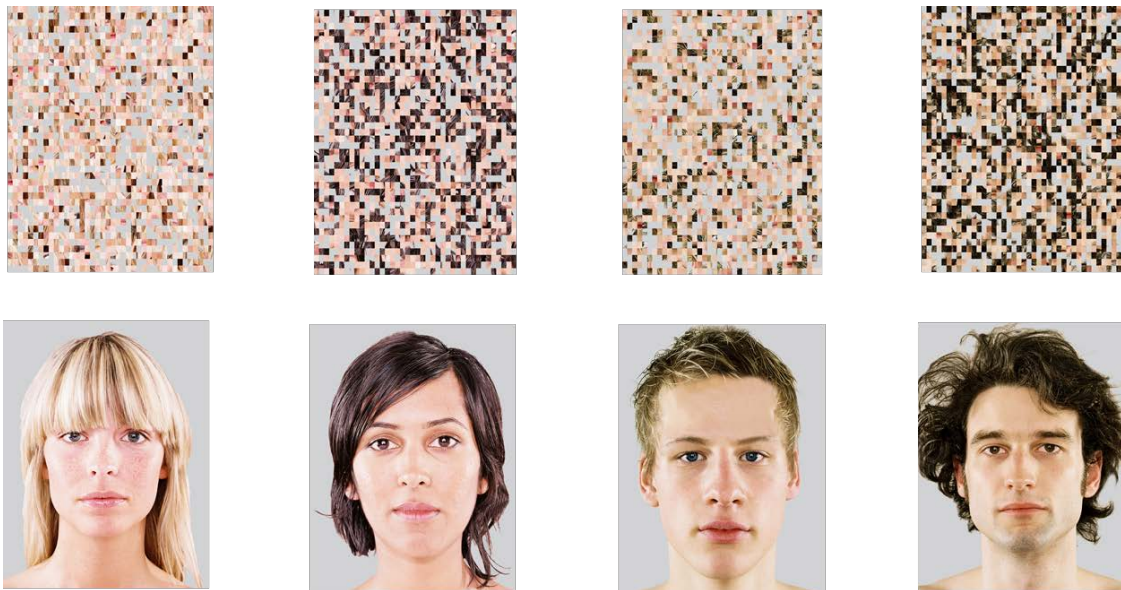


Figure 7 – Visual stimuli. Pictures of the speakers (bottom) and their scrambled versions (top).

7.2.1.3 EEG recording and data analysis

The EEG was recorded from 59 cephalic electrodes placed within an elastic cap according to the international 10-20 system. Impedances were kept below 5 k Ω . Vertical (VEOG) and horizontal (HEOG) bipolar ocular electrodes (EOGs) were used to record blinks and horizontal eye movements. One electrode each was placed on the mastoids, the right one serving as initial reference. Raw data were sampled at 250 Hz and recorded with a band-pass from 0.01 to 100 Hz.

The EEG was re-referenced offline to average mastoids and filtered at 0.1 to 15 Hz. EEG epochs of 1600 ms were segmented from the continuous EEG data, starting 200 ms before the onsets of the critical words. The correction of the ocular artifacts (blinks and horizontal eye movements) was performed by means of Independent Component Analysis (ICA). The rejection of the remaining artifacts was semi-automatically performed, removing trials exceeding a range of 100 μ V. Overall, the mean rate of rejected segments was 13%. ERPs were computed only for trials followed by correct responses.

Repeated-measures ANOVAs were performed including factors Electrode (59 levels), Semantic Congruency (congruent vs incongruent), and Face Presence (presence vs absence). Based upon visual inspection of both the difference waveforms and the topographies of the effect, the statistical analysis included the following time windows after the critical word onset: 300-600 ms for the N400, and 700-850, 850-1000, 1000-1150, and 1150-1300 ms for the P600.

A 200 ms post-stimulus baseline was applied to the N400. This sort of baseline has been previously used by others (e.g. Hutzler et al., 2007; Lau, Namyst, Fogel & Delgado, 2016; Camblin, Gordon & Swaab, 2007). With a typical pre-stimulus baseline (say, -200 ms), the experimental manipulations might not explain every difference on the N400 amplitude because the ERP in both congruent and incongruent conditions diverged before and after the critical word onset (for a similar explanation see Camblin et al., 2007). Recently, Brouwer and Crocker (2017) examined the overlapping effect of the N400 and P600 components when measuring their respective amplitudes. They argued that the amplitude of the P600 is negatively related to the amplitude of the preceding N400 because both components partly overlap in topography and latency. For that reason, we followed Brouwer and Crocker's suggestion to measure the P600 amplitude by applying a baseline during the time window of the N400 component (200-

700 ms, see also Hagoort, 2003). By doing this we are confident that experimental manipulations account for P600 modulations regardless of any difference on the N400 between conditions. -Appendix 2 include alternative P600 ANOVA results with the 0-200 baseline-

7.2.2 Results and discussion

The mean error rate in the semantic congruency task was 11.38%. An ANOVA including the repeated measures factors Semantic Congruency and Face Presence revealed a significant effect of Semantic Congruency ($F(1,27) = 10.85; p = .002$). Incongruent sentences showed a higher error rate (14.98%) compared to congruent sentences (7.82%). Neither Face Presence ($F(1,27) = 0.11; p = .743$) nor the interaction of Semantic Congruency by Face Presence ($F(1,27) = 0.28; p = .598$) yielded significant results.

Regarding reaction times, ANOVA revealed significant main effects of Semantic Congruency ($F(1,27) = 1.67; p = .006$) and Face Presence ($F(1,27) = 3.64; p = .043$). Congruent sentences ($M = 366.09$ ms) were associated to shorter reactions times compared to incongruent sentences ($M = 378.14$ ms), and for the speaker's face condition reaction times were significantly shorter ($M = 367.16$ ms) compared to the scrambled face condition ($M = 376.97$ ms). The interaction of Semantic Congruency and Face Presence was not significant ($F(1,27) = 1.36; p = .244$).

Figure 8 shows grand-average ERPs to congruent and incongruent words at six selected electrodes. The N400 effect exhibits a broad scalp distribution, which may be related to the use of auditory language stimulation (e.g. Hagoort & Brown, 2000; Li, Hagoort & Yang, 2008; Wang et al., 2011). An ANOVA was computed in the time window between 300 and 600 ms, yielding a significant effect of Congruency ($F(1,27) = 23.5; p < .001; \eta^2 = .465; \pi = .997$). The interaction of Congruency with Electrode was also statistically significant ($F(58, 1566) = 3.97; p = .004; \eta^2 = .128; \pi = .904$). Face Presence did not yield significant effects in this interval ($F(1,27) = 0.40; p = .528; \eta^2 = .015; \pi = .095$) neither as

a main effect nor in interaction with Electrode ($F(58, 1566) = 0.67$; $p = .588$; $\eta^2 = .024$; $\pi = .195$). Finally, Congruency by Face Presence showed a significant interaction ($F(1,27) = 4.59$; $p = .041$; $\eta^2 = .146$; $\pi = .543$). Seeing the speaker's face apparently has an impact on semantic processing.

As to the P600, Congruency as main effect yielded significant results across the whole analyzed interval (700-850 ms: $F(1,27) = 8.64$; $p = .007$; $\eta^2 = .243$; $\pi = .809$; 850-1000 ms: $F(1,27) = 8.42$; $p = .007$; $\eta^2 = .238$; $\pi = .799$; 1000-1150 ms: $F(1,27) = 12.51$; $p = .001$; $\eta^2 = .317$; $\pi = .926$; 1150-1300 ms: $F(1,27) = 9.54$; $p = .005$; $\eta^2 = .259$; $\pi = .842$). The interaction Congruency by Electrode yielded significant results in the same interval (700-850 ms: $F(58, 1566) = 10.96$; $p < .001$; $\eta^2 = .289$; $\pi = 1$; 850-1000 ms: $F(58, 1566) = 10.28$; $p < .001$; $\eta^2 = .276$; $\pi = .999$; 1000-1150 ms: $F(58, 1566) = 11.83$; $p < .001$; $\eta^2 = .305$; $\pi = 1$; 1150-1300 ms: $F(58, 1566) = 6.03$; $p = .001$; $\eta^2 = .183$; $\pi = .964$). In contrast to the N400, the P600 effect was insensitive to the presentation of the speaker's face, and the interaction Congruency by Face Presence was not significant in any of these windows (700-850 ms: $F(1,27) = 0.96$; $p = .412$; $\eta^2 = .289$; $\pi = 1$; 850-1000 ms: $F(1,27) = 0.18$; $p = .67$; $\eta^2 = .007$; $\pi = .070$; 1000-1150 ms: $F(1,27) = 0.53$; $p = .47$; $\eta^2 = .019$; $\pi = .109$; 1150-1300 ms: $F(1,27) = 0.22$; $p = .638$; $\eta^2 = .008$; $\pi = .075$). The same applied to the three-way interaction Electrode by Congruency by Face Presence (700-850 ms: $F(58, 1566) = .383$; $p = .788$; $\eta^2 = .014$; $\pi = .127$; 850-1000 ms: $F(58, 1566) = 1.03$; $p = .383$; $\eta^2 = .037$; $\pi = .278$; 1000-1150 ms: $F(58, 1566) = 0.51$; $p = .67$; $\eta^2 = .019$; $\pi = .152$; 1150-1300 ms: $F(58, 1566) = 1.21$; $p = .309$; $\eta^2 = .043$; $\pi = .357$).

Interestingly, a main effect of Face Presence was not significant between 700 and 1000 ms (700-850 ms: $F(1,27) = 1.34$; $p = .256$; $\eta^2 = .048$; $\pi = .201$; 850-1000 ms: $F(1,27) = 2.89$; $p = .1$; $\eta^2 = .097$; $\pi = .375$), but it was from 1000 to 1300 ms (1000-1150 ms: $F(1,27) = 8.46$; $p = .007$; $\eta^2 = .239$; $\pi = .801$; 1150-1300 ms: $F(1,27) = 4.47$; $p = .044$; $\eta^2 = .142$; $\pi = .532$). The ANOVA also revealed a significant interaction of Face Presence

by Electrode between 700 and 850 ms (700-850 ms: $F(58, 1566) = 2.54$; $p = .049$; $\eta^2 = .086$; $\pi = .676$), but not for the remaining windows (850-1000 ms: $F(58, 1566) = 2.18$; $p = .083$; $\eta^2 = .075$; $\pi = .594$; 1000-1150 ms: $F(58, 1566) = 1.69$; $p = .163$; $\eta^2 = .059$; $\pi = .474$; 1150-1300 ms: $F(58, 1566) = 1.67$; $p = .17$; $\eta^2 = .058$; $\pi = .441$). Figure 9 shows the grand average to the speaker's face compared to the control condition. The effect exhibits a centro-parietal distribution with negative polarity that is larger to the speaker's face.

Summarizing, in Experiment 1 the semantic N400 effect was sensitive to the type of visual stimuli presented. In line with our hypothesis, the N400 effect was larger when the auditory sentence was associated with a speaker's face as compared to a scrambled image. This result could be explained by attentional processing effects because in the communicative visual context attention may be boosted by the presence of a putative speaker, which could impact semantic processing (McCarthy & Nobre, 1993, Van Petten, 2014b), while mentalizing processes may increase the linguistic depth of processing (Wang et al, 2011).

The main effect to the speaker's face was unexpected. This negativity resembles a Late Posterior Negativity (LPN) effect (Johansson & Mecklinger, 2003; Mecklinger, Rosburg & Johansson, 2016). Results of Experiment 2 will be useful to explain this effect and will probe its consistency. Experiment 2 will also help to verify whether syntactic processing is also sensible to this minimal social context manipulation.

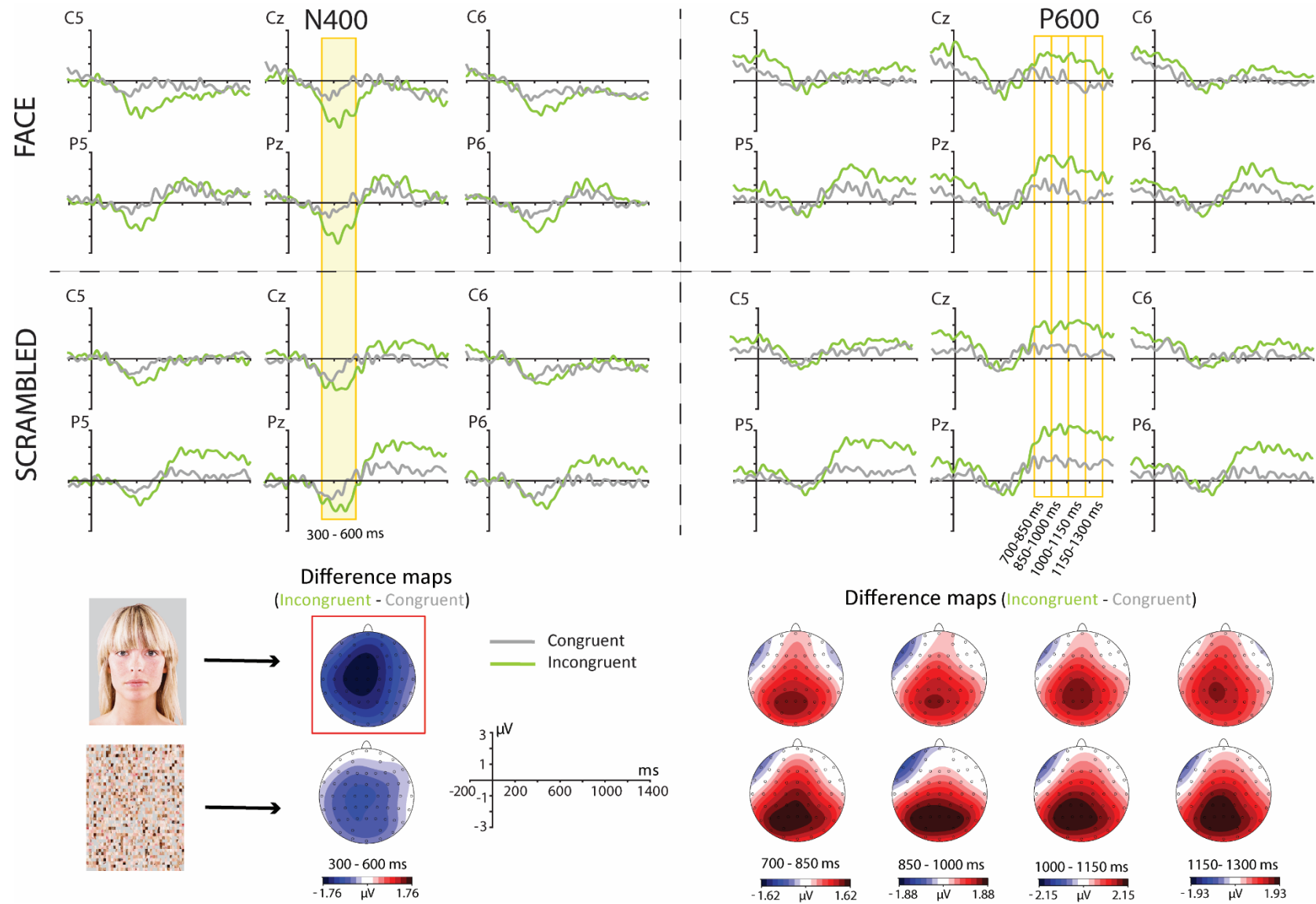


Figure 8. Effect of Congruency for the speaker's face and the scrambled face condition. Different baselines were applied for the N400 (0-200 ms) and the P600 (200-700 ms), therefore ERP waves are plotted separately for each component. The difference maps represent the Congruency effect (incongruent minus congruent) for each visual condition.

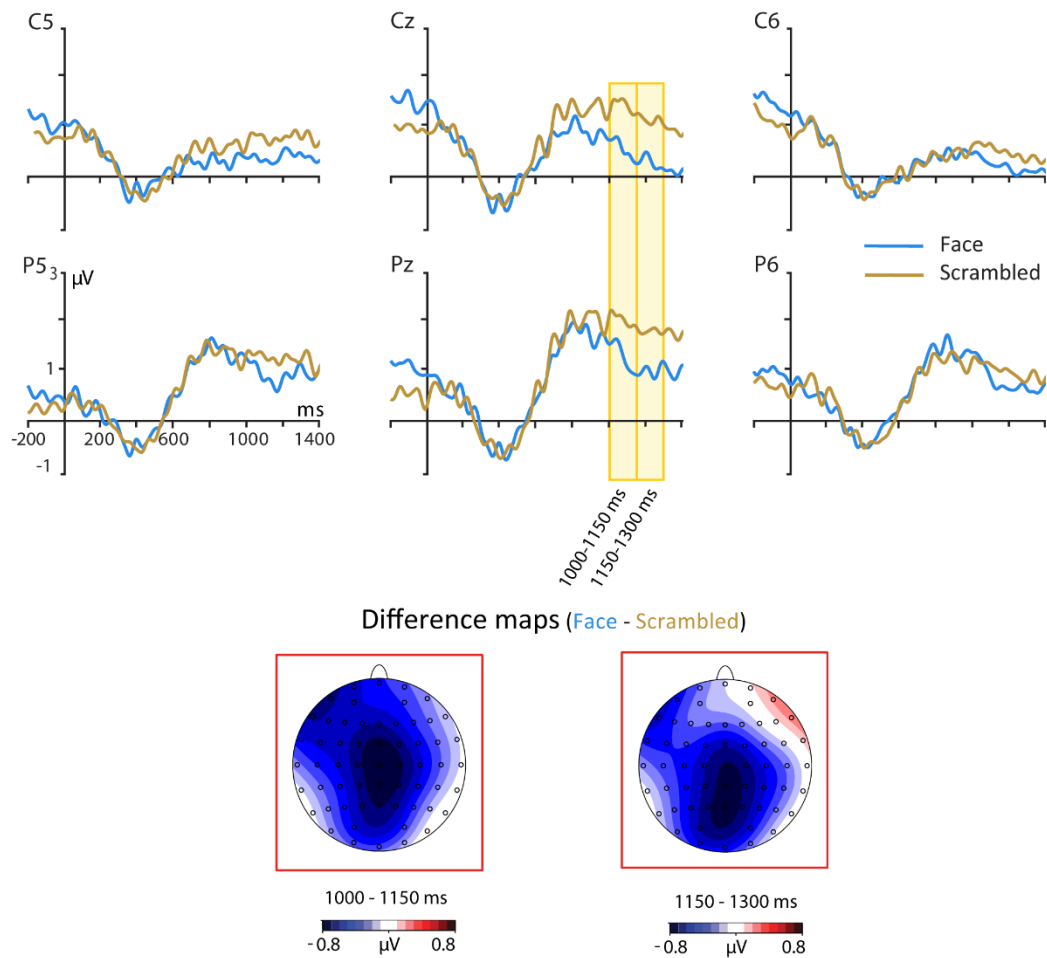


Figure 9. Main effect of Face Presence. The topographies represent the Late Posterior Negativity (LPN) effect (face minus scrambled face). ERPs are plotted with a 200-700 ms baseline.

7.3 Experiment 2. Syntactic domain

7.3.1 Methods

7.3.1.1 Participants

Participants were the same as in Experiment 1. The order of the experiments was counterbalanced, therefore half of the participants completed Experiment 2 before Experiment 1.

7.3.1.2 Materials and procedure

The same 480 sentences used in Experiment 1 were modified to include a morphosyntactic violation of gender or number in the critical word. Depending on the

structure of the sentence, there could be a noun-adjective mismatch (Structure 1) or a determiner-noun mismatch (Structures 2 and 3). Both types of morphosyntactic errors typically elicit LAN and P600 components. An example of the sentences by type of structure is given below (English translation is given in brackets).

Structure 1 (n = 300): [Det]-[N]-[Adj]-[V]-[Prep]-[N]

- Correct sentence: *El pañuelo_{Masc/Sing} **bordado** _{Masc/Sing} era de mi abuela* (The **embroided** _{Masc/Sing} cushion _{Masc/Sing} belonged to my grandmother)
- Incorrect sentence: *El pañuelo _{Masc/Sing} **bordada** _{Fem/Sing} era de mi abuela* (The **embroided** _{Fem/Sing} cushion _{Masc/Sing} belonged to my grandmother)

Structure 2 (n = 90): [Det]-[N]- [V]-[Det]-[N]- [Adj]

- Correct sentence: *Los turistas habían fotografiado los _{Masc/Plur} **glaciares** _{Masc/Plur} árticos.* (The tourists had photographed the _{Masc/Plur} arctic **glaciers** _{Masc/Plur})
- Incorrect sentence: *Los turistas habían fotografiado los _{Masc/Plur} **glaciar** _{Masc/Sing} árticos* (The tourists had photographed the _{Masc/Plur} arctic **glacier** _{Masc/Sing})

Structure 3 (n=90): [Det]-[N]- [V] -[Prep]-[Det]-[N]-[Prep]-[Det]-[N]

- Correct sentence: *Las hojas son recogidas durante el _{Masc/Sing} **otoño** _{Masc/Sing} por los barrenderos* (The leaves are picked by the sweepers during the _{Masc/Sing} **autumn** _{Masc/Sing})
- Inorrect sentence: *Las hojas son recogidas durante el _{Masc/Sing} **otoños** _{Masc/Plur} por los barrenderos.* (The leaves are picked by the sweepers during the _{Masc/Sing} **autumns** _{Masc/Plur})

Participants listened to 240 sentences, different to the ones presented for a specific participant in Experiment 1, so that at the end of the whole study every participant had

heard all 480 sentences once. For this experiment, given that the critical information for morphosyntactic violations relates to the gender/number markers, triggers were set on critical words at the offset of the lexeme, just before the gender/number declension.

The procedure was similar to Experiment 1, but participants performed a morphosyntactic correctness task after the presentation of each sentence.

7.3.1.3 EEG recordings and data analysis

The characteristics of the EEG recordings were identical to Experiment 1.

The data analysis procedures, except for component parametrization, were the same as for Experiment 1. Overall, the mean rate of rejected epochs was 11%. The same type of ANOVA was employed as for Experiment 1 and applied to the following time segments after morphosyntactic declension onset: 250-400 ms for the LAN and 500-650, 650-800 and 800-950 ms for the P600. Since in Experiment 1, Face Presence had been significant between 1000-1150 and 1150-1300 ms, we performed ANOVAs at these time windows in Experiment 2 as well. A post-stimulus baseline of 150 ms was applied. In this experiment we did not apply a different baseline for the P600 because no spatial overlap exists between this component and the LAN.

7.3.2 Results and discussion

The mean error rate in the morphosyntactic correctness task was 5.39%. The results of the ANOVA including the factors Morphosyntactic Correctness and Face Presence revealed a significant effect of Morphosyntactic Correctness ($F(1,27) = 8.09$; $p = .008$). Incorrect sentences related to a higher error rate (6.26%) compared to correct ones (4.51%). The factor Face Presence ($F(1,27) = 0.11$; $p = .74$) and the interaction of Morphosyntactic Correctness by Face Presence ($F(1,27) = 1.65$; $p = .209$) did not show significant effects

The ANOVA of the reaction times revealed significant main effects of both Morphosyntactic Correctness ($F(1,27) = 63.63; p < .001$) and Face Presence ($F(1,27) = 43.28; p = .043$). Correct sentences ($M = 379.03$ ms) were associated with longer reaction times than incorrect sentences ($M = 341.08$ ms), and reaction times for sentences accompanied by the speaker's face were significantly shorter ($M = 343.53$ ms) as compared to the scrambled face condition ($M = 377.31$ ms). The interaction of Morphosyntactic Correctness and Face Presence was not significant ($F(1,27) = 0.023; p = .878$).

Figure 10 shows the ERP waveforms to the morphosyntactic manipulation on each visual condition. Morphosyntactic violations elicited a LAN distributed at left fronto-temporal sites between 200-450 ms, followed by a prominent P600 between 400 and 1100 ms at centro-parietal sites. In the LAN interval, the ANOVA only revealed a significant interaction Morphosyntactic Correctness by Electrode in the 250-400 ms segment ($F(1,27) = 7.08; p < .001; \eta^2 = .208; \pi = .994$). Neither the main effect of Face Presence ($F(1,27) = 0.58; p = .45; \eta^2 = .021; \pi = .115$) nor of Morphosyntactic Correctness ($F(1,27) = 0.11; p = .450; \eta^2 = .004; \pi = .062$) reached statistical significance, as was the case for the interactions Face Presence by Electrode ($F(1,27) = 0.35; p = .803; \eta^2 = .013; \pi = .118$) and Face Presence by Morphosyntactic Correctness ($F(1,27) = 0.13; p = .718; \eta^2 = .005; \pi = .064$). The three-way interaction with Electrode was not significant ($F(1,27) = 0.79; p = .532; \eta^2 = .029; \pi = .25$). Therefore, the LAN did not seem to be affected at all by the visual social context.

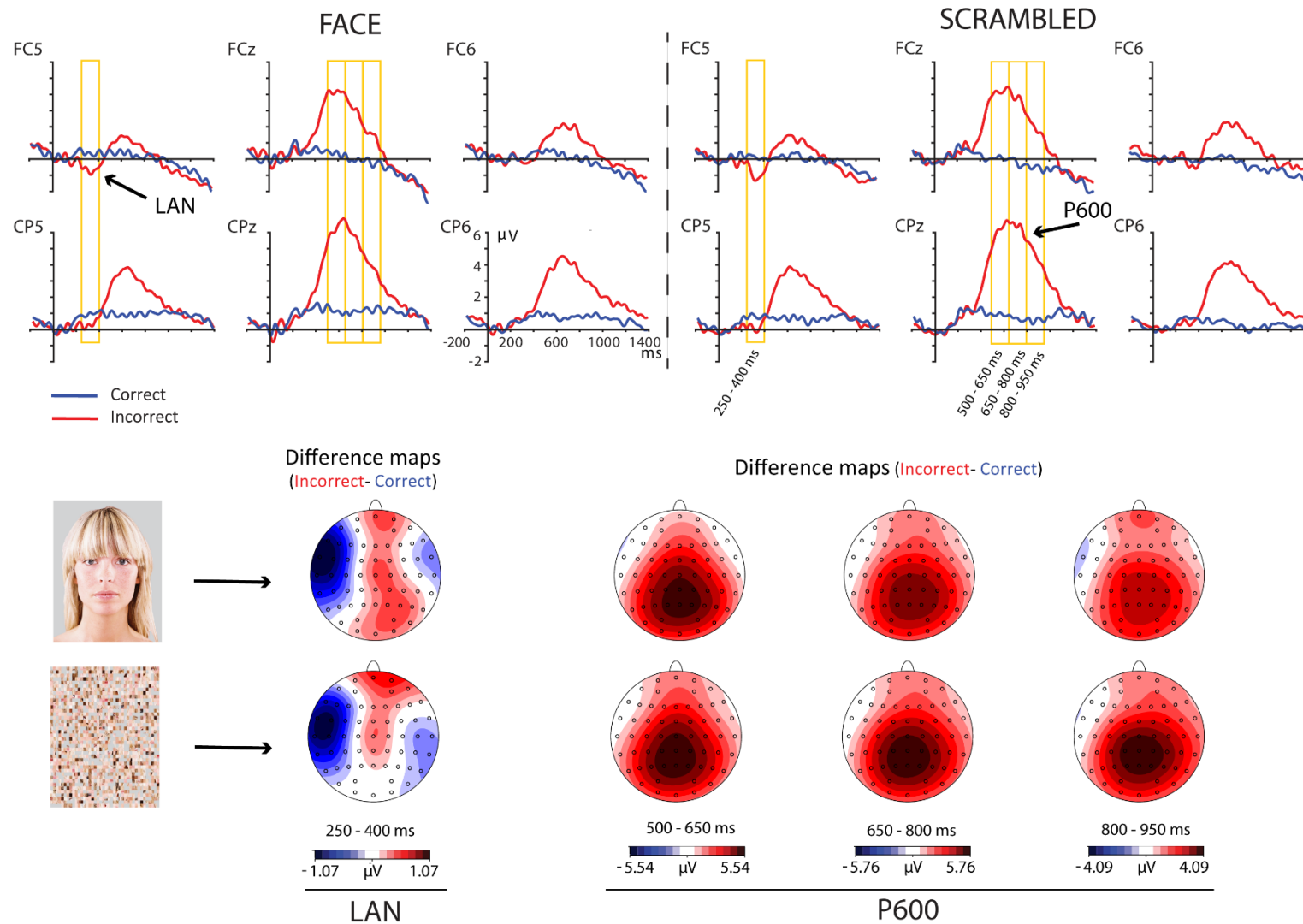


Figure 10. Effect of Morphosyntactic Correctness. ERPs are plotted separately for each visual context. The difference maps (incorrect minus correct) represent the topographies of the LAN and the P600 effect.

Apart from the LAN, morphosyntactic violations also generated a P600 component, which yielded strong effects of Morphosyntactic Correctness (500-650 ms: $F(1,27) = 61.11$; $p < .001$; $\eta^2 = .69$; $\pi = 1$; 650-800 ms: $F(1,27) = 72.73$; $p < .001$; $\eta^2 = .72$; $\pi = 1$; and 800-950 ms: $F(1,27) = 37.09$; $p < .001$; $\eta^2 = .579$; $\pi = 1$). This factor also interacted with Electrode along the same period (500-650: $F(1,27) = 43.7$; $p < .001$; $\eta^2 = .61$; $\pi = 1$; 650-800: $F(1,27) = 34.22$; $p < .001$; $\eta^2 = .559$; $\pi = 1$; and 800-950 ms: $F(1,27) = 18.1$; $p < .001$; $\eta^2 = .579$; $\pi = 1$). Face Presence alone did not induce any significant ERP differences in the P600 intervals between 500 and 950 ms as a main effect nor in interaction with electrode ($F_s < 1.3$). Importantly, the P600 effect was not modulated by the speaker's face, since the interaction Face Presence by Morphosyntactic Correctness was not significant (500-650: $F(1,27) = 0.38$; $p = .541$; $\eta^2 = .014$; $\pi = .092$; 650-800: $F(1,27) = 0.65$; $p = .42$; $\eta^2 = .024$; $\pi = .122$; and 800-950 ms: $F(1,27) = 1.32$; $p = .26$; $\eta^2 = .047$; $\pi = .199$). The three-way interaction Face Presence by Morphosyntactic Correctness by Electrode was again non-significant (500-650: $F(1,27) = 0.75$; $p = .526$; $\eta^2 = .027$; $\pi = .205$; 650-800: $F(1,27) = 0.42$; $p = .724$; $\eta^2 = .015$; $\pi = .128$; and 800-950 ms: $F(1,27) = 0.86$; $p = .454$; $\eta^2 = .031$; $\pi = .22$).

Finally, the extended ANOVAs exploring Face Presence in the two windows between 1000 and 1300 ms did not yield any significant main effect (1000-1150 ms: $F(1,27) = 0.04$; $p = .949$; $\eta^2 < .001$; $\pi = .05$; 1150-1300 ms: $F(1,27) = 0.81$; $p = .778$; $\eta^2 = .003$; $\pi = .059$), nor in interaction with Electrode (1000-1150 ms: $F(1,27) = 1.47$; $p = .215$; $\eta^2 = .052$; $\pi = .446$; 1150-1300 ms: $F(1,27) = 1.46$; $p = .209$; $\eta^2 = .051$; $\pi = .488$).

Overall, the brain processes underlying morphosyntactic processing were not significantly affected by the minimal social context. On the one hand, the LAN effect showed almost identical amplitude and distribution in both visual contexts. On the other hand, the P600 effect was visually larger in the control condition, but statistics did not support the difference. Interestingly, there was no main effect of the speaker's face in

this experiment. This suggests that the negativity found in Experiment 1 to the speaker's face is probably dependent of the experimental task. This result will be addressed in the *General discussion* section.

7.4 General discussion

The current study aimed to investigate how the mere presence of a speaker's still face may influence semantic and morphosyntactic processing in connected speech. We explored these manipulated effects by means of the linguistic-related ERP modulations (N400, LAN and P600). To this end, two independent experiments were performed. In spite of the problems associated to the use of natural speech language stimuli, which implies differences in word length and jittering of the ERP (Alday, Schlesewsky, & Bornkessel-Schlesewsky 2017), we obtained all the ERP components to be expected in the conditions created.

The presence of the speaker's face appeared to have a clear impact on semantic processing. Experiment 1 showed an interaction of visual context and semantic comprehension in the latency of the N400, its amplitude being higher when language is situated in a minimal social context. This finding is in accordance with our hypothesis and harmonizes with previous studies reporting larger N400 when attention is explicitly oriented to the linguistic stimuli (McCarthy & Nobre, 1993) and when the depth of processing is enhanced (Wang et al., 2011). Accordingly, participants seem to attend more to the critical words when situated in a minimal communicative context and the self-reference processing may also lead to a deeper processing of the linguistic stimuli. Our experiment simulates a face-to-face context and indicates that semantic comprehension is not only affected when participants receive information from the speaker that is semantically incongruent relative to the linguistic message (e.g. gaze shifts or previous knowledge about the speaker that are incongruent with the content

of the sentences), but also when the incoherent information is processed in presence of the speaker's face.

The effect of the speaker's face may be due to the interplay of different factors. First, faces -and particularly the eyes- are unlike any other visual stimulus because of their capacity to capture larger amounts of attentional resources (Conty et al., 2006; von Grönau & Anston, 1995; Senju & Hasegawa, 2005; Theeuwes & Van der Stigchel, 2006, Langton et al., 2008). Further, it can be argued that in a communicative context, the listener's motivated attention to the speaker is increased (Schlinder et al; 2015; Schlinder & Kissler, 2016, 2017; Hernández-Gutiérrez et al., 2018), which in turn would lead to a deeper processing of the message (Craik & Lockhart, 1972, Wang et al., 2011). On the other hand, seeing a face with direct gaze -as was the case here- has been related to the activation of social brain circuits (Adams et al., 2010; Brunet, Sarfati, Hardy-Baylé, & Decety, 2000), some of which also take part in the comprehension of language (e.g., Redcay, 2008; Cechini et al., 2013). Therefore, the activation of social brain networks may strengthen attention to the linguistic message. Results of the present study may seem difficult to reconcile at first sight with those of *Study One*, where the N400 was insensitive to the facial dynamics. However, in that study language processing was always situated in a social context, either dynamic or static. On the contrary, only one condition of *Study Two* situates language processing in a social context. Hence, the social context may be more influential to the N400 effect than the realism of the communicative situation.

In the morphosyntactic task, in contrast, we did not observe LAN or P600 modulations by the presence of the speaker's face. It seems that the minimal social context manipulated here was not enough to affect the neural processes involved in morphosyntactic processing. While there is evidence that extralinguistic factors can affect syntactic and morphosyntactic processes (Casado et al., 2018; Espuny et al.,

2018b; Martín-Loeches et al., 2012) syntactocentric views of language (e.g., Friederici, 2002; Hauser, Chomsky & Fitch, 2002) would consider these processes as encapsulated and difficult to be influenced. Speaker's gaze, however, has been reported to interact with the processing of syntactic structures, as a function of the coordination between both the linguistic and the visual streams (Knoeferle & Kreysa, 2012). It is possible that our paradigm did not meet the requirements to yield a significant visual effect on syntactic processing. Seeing the speaker's still face with direct gaze may not be a suitable visual stimulus to influence the syntactic processes of the brain. In this regard, it is worthy of mention our finding that reaction times for sentences accompanied by the speaker's face were significantly shorter than in the scrambled face condition in the second experiment. This finding indicates, interestingly, overall effects of the presence of a face in a syntactic task, even if the ERP fluctuations studied here have not been able to grasp them. In future studies, however, it would be interesting to manipulate gaze movements.

Regardless of the linguistic manipulation, a late posterior negativity arose between 1000 and 1300 ms in the presence of a face (Figure 9). Interestingly, this ERP modulation only emerged in Experiment 1. In this case participants had to perform a semantic congruence task, contrasting with the morphosyntactic correctness task in Experiment 2. It is to note that both experiments had the same stimulation procedures as well as exactly the same visual and linguistic stimuli (with the exception of the type of errors in the incorrect versions of the sentences. This effect can be explained by differences in the main cognitive processes involved during each experiment. In this regard, the behavioural results evinced more difficulties to perform the semantic congruency task than the morphosyntactic task. Indeed, after the experiment, some participants informed that this difficulty was related to the possible metaphoric interpretation of the semantic incongruities, which hampered their decision.

Accordingly, semantic processing appears as more demanding, particularly because it relies upon memory processes (Kutas & Federmeier, 2011), while morphosyntactic correctness decision is a more categorical task, typically considered as automatic (Coulson et al., 1998; Sassenhagen et al., 2014).

Considering the time course of the ERP modulation, its negative polarity, the centro-parietal distribution, and its dependence on the experimental task, we interpret it as the Late Posterior Negativity (LPN) effect. This neurophysiological response is related to highly demanding processes, such as information retrieval (Johansson & Mecklinger, 2003; Mecklinger, Rosburg & Johanson, 2016), action monitoring (Johansson & Mecklinger, 2003), response-related processes in recognition memory tasks (Wilding & Rugg, 1997), or higher order stimulus evaluation (Sommer, Vita & De Pascalis, 2018). The LPN effect may have emerged in our semantic task but not in the morphosyntactic one due to the higher difficulty of the former together with the higher complexity of the social context and the communicative situation when compared to the non-face situation.

Summarizing, in line with previous studies (e.g. Bornkessel-Schlesewsky et al., 2013; Jouralev et al., 2018; Rueschemeyer et al., 2014; Van Berkum et al., 2008), we have shown that an outstanding social variable, namely the presence of the speaker's face, affects language comprehension at least in the semantic domain. This has been the case even if the social variable here explored is utterly irrelevant to the content of the linguistic message. These findings are of interest for future research studying language in face-to-face communication contexts and uphold the idea that language should be ideally studied in situations more realistic than the typically used, such as written language comprehension, or listening to sentences without a minimal social context.

8. CHAPTER 6. STUDY 3

8.1. Introduction

Recent brain-based models of emotion (e.g. Pessoa, 2017) rely on the idea that the functional architecture of the brain is highly non-modular and there is an overlap of distinct brain networks. Emotion processing therefore extends through cortical and subcortical neuronal populations sensitive to context, thus being flexible and dynamic. Considering the distributed processing of emotions within the brain, Pessoa (2017) encourages to investigate the interactions with other brain processes and mental operations, instead of attempting to isolate its neural underpinnings. Similarly, certain voices within psycholinguistics aim to step away from the classical written language paradigms to investigate language comprehension in interaction with visual environments. This has been referred to as *(visually) situated language comprehension* (Knoeferle et al., 2016). After all, human language is an audiovisual adaptation. Since the visual information processed during communicative interactions usually derives from a speaker, we can also refer to *socially (visually) situated language comprehension* (Münster & Knoeferle, 2018). To extend current research in this line, in the present study we will investigate with event-related brain potentials (ERPs) the effects that the speaker's emotional facial expressions may exert overall semantic and syntactic processing of connected speech.

Neuroimaging literature suggests that the distributed brain processing of emotional facial expressions and language may involve common neural hubs. For instance, the superior temporal sulcus (STS). Emotion expressed by a static face has been related to activity in this structure (Engell & Haxby, 2007). The STS has also been more activated during a semantic decision task compared to listening to a tone (Binder et al., 1997) and it is also involved in the processing of syntactically complex sentences

(Friederici, Makuuchi & Bahlmann, 2009). Moreover, it plays a main role in multisensory integration (Barraclough, Xiao, Baker, Oram & Perrett, 2005). Accordingly, the STS may be critical to integrate both multisensory linguistic information (syntactic and semantic) and emotions. Other brain region that is involved in the integration of both multisensory linguistic information and emotion is the anterior temporal lobe (ATL). This region has been proposed as a trans-modal semantic hub (Patterson & Lambon Ralph, 2016), where several primary, secondary and motor areas converge. Moreover, emotion-related structures like the amygdala or the orbitofrontal cortex connect with the ATL through the uncinate fasciculus (Olson, McCoy, Klobusicky & Ross, 2013), which is also involved in syntactic combinatory operations (Friederici, Bahlman, Heim, Schubotz & Anwender, 2006).

Increasing amount of ERP studies also demonstrate that online language comprehension is accessible to the influence of emotion. The ERP technique provides fine-grained temporal resolution for the study of language in emotional contexts by means of the ERP brain components -see the Introduction Chapter for a description of the language-related ERPs LAN, P600 and N400-. The emotion-related ERP component that appears most often in the frame of language is the late positive complex (LPC) - sometimes referred to as the late positive potential (LPP)-. This modulation is related to an elaborated processing of the emotional stimuli (Schacht & Sommer, 2009), arising about 300 ms after the stimulus onset, with a centroparietal topography (Hajcak, Weinberg, MacNamara, Foti, 2012). Several studies evince a *negativity bias*, since the largest amplitudes relate to negative emotions (e.g. Carretié et al., 2008; Espuny et al., 2018a; Holt, et al., 2009; Jiménez-Ortega et al., 2017; Zhang et al, 2018), including those elicited by emotional facial expressions (Recio, Sommer & Schacht, 2011; Schacht & Sommer, 2009; Schupp et al., 2004). Nevertheless, a *positivity bias* has been also reported (Herbert et al., 2009; Kissler, Herbert, Winkler & Junghofer, 2009).

The semantic and syntactic domains of sentence processing may be differently affected by emotional valence and the moment at which emotion is processed. Hence, some studies set a time lag between the presentation of the emotion laden stimulus and the subsequent processing of the sentence (e.g. Espuny et al., 2018a; Jiménez-Ortega et al., 2012). In turn, in other studies emotion is manipulated within the sentence, sometimes in the critical word (Jiménez-Ortega, Espuny, Herreros de Tejada, Vargas-Rivero, Martín-Loeches, 2017; Martín-Loeches et al., 2012). While this differentiation may not be so important for online semantic comprehension, this seems to be critical for online syntactic processing. This idea will be evinced hereunder.

A typical procedure to study semantic sentence comprehension is to measure the N400 effect by comparing congruent and incongruent words, relative to the sentence context. The amplitude of this effect is positively related with the difficulty of processing. Martín-Loeches et al., (2012) used sentences containing an emotion-laden word (positive, negative or neutral) that was either congruent or incongruent with the semantic context. No interaction was found between the N400 effect and the valence of the words. A similar result was reported when the presentation of emotional paragraphs preceded the processing of coherent and incoherent neutral sentences (Jiménez-Ortega et al., 2012). Thus, the amplitude of the N400 effect did not vary regarding the paragraph emotional valence. On the contrary, Federmeier, Kirson, Moreno & Kutas (2001) manipulated participant's mood with positive or neutral pictures previously to the presentation of pairs of sentences and found that positive mood significantly reduced the N400 to semantic violations. Other studies with distinct procedures have found either a reduction of the N400 component to emotional words compared to neutral by manipulating the emotional coherence (Delaney-Busch & Kuperberg, 2013) or even the largest N400 component to emotional words in coherent contexts (Holt et al., 2009).

In the syntactic domain, Martín-Loeches et al., (2012) manipulated both the morphosyntactic correctness and the emotional valence of critical words in a sentence context. They found the largest LAN effect to negative words and the smallest to positive words, compared to neutral valence. In this line, Jiménez-Ortega et al., (2017) also manipulated emotion and correctness within subliminal words embedded in supraliminal sentences and reported a LAN banishment in the happy condition, being an N400 elicited instead. On the contrary, none of these studies found emotion effects on the P600.

It is striking that studies presenting the emotional stimuli preceding to the sentences show dissimilar modulations on the LAN-P600 components. In this case, the LAN effect is typically enhanced in emotion-laden words compared to neutral condition (Espuny et al., 2018b; Jiménez-Ortega et al., 2012). Regarding the P600 component, it may not be so dependent on the pre- or within emotion processing. Thus, it was either not affected by the previous emotional presentation (Jimenez-Ortega et al., 2012) or significantly reduced in the negative condition (Espuny et al., 2018b).

While those studies used emotion-laden language -e.g. words, paragraphs-, others have served of a film clip to manipulate participants' mood. Thus, Vissers et al. (2010) exposed participants either with a happy or sad film clip previously to the presentation of neutral sentences. They found a different correlation between these emotions and the amplitude of the P600 effect to subject-verb morphosyntactic disagreements, namely a positive correlation to the happy mood -bigger P600- and a negative correlation to the sad mood -smaller P600-. These differences on the P600 effect were supported by another study applying a similar manipulation of the mood state (Verhees, Chwilla, Tromp & Vissers 2015). Results were interpreted on the base of *heuristics*, thus the linguistic processor would take a shortcut and do not use all the linguistic information available to complete the syntactic parsing. On the contrary,

negative emotions would trigger an analytic processing (Bless & Schwarz, 1999; Gasper & Clore, 2002; Isen, 2001). In this context, the authors argued that happy mood fostered a heuristic processing, this leading to a superficial processing of the morphosyntactic mismatches, and consequently promoting P600 reanalysis effects. The opposite then happened in the sad mood, being the reanalysis less necessary -smaller P600-, consequence of a detailed first-pass analysis.

The literature reviewed so far did not consider the communicative context where language naturally unfolds. In the specific case of the present topic this turns even more important because people usually face each other while processing language and faces are a source of emotional information. The speaker's face can be used in psycholinguistic research to investigate the influence of emotions on language comprehension more ecologically. Thus, the visualization of a face concomitant to language processing, especially if accompanied by auditory speech, increases validity.

Rohr and Abdel Rahman (2015; 2018) presented a video of the speaker's face with neutral expression uttering emotion-laden words. In the communicative condition, the speaker gazed at the participant while speaking. In the non-communicative condition, the speaker remained with his mouth and eyes closed. The personal relevance of the communicative contexts speeded up, boosted, and extended in time the emotion effects (Rohr & Abdel Rahman, 2015). Moreover, this was associated with higher arousal ratings. In addition, Schindler et al., (2015) found that communicative contexts enhanced the brain processing of evaluative adjectives (positive, negative and neutral). When participants believed that the adjectives were generated by a real person taking participant's personal characteristics into consideration (communicative context), instead of randomly selected by a computer (non-communicative context), their motivated attention increased. On previous studies we focused on the effect of communicative contexts on language processing by situating speech comprehension on

face-to-face visual contexts (Hernández-Gutiérrez et al., 2018 -*Study One*- and *Study Two*). Accordingly, we found that audiovisual social communication implies specific processes. Self-reference processing and the feeling of being attended can enhance the relevance of the processing and increase motivated attention to the communicative context, in line with the interpretation by Schindler et al., (2015).

Considering this evidence, in the present study we want to investigate the impact of emotional facial expressions of the speaker on language comprehension. Participants will see the static face of the speaker while listening to auditory sentences that may be correct or incorrect, both semantically or syntactically. A strong impact of faces is expected according to the social significance of this stimulus. Since we want to isolate the emotional effect of the facial expression from the audiovisual integration of speech, we decided to use static pictures of the speakers' faces instead of dynamic videos. Indeed, we already probed in *Study One* that the dynamism of the face, especially of the orofacial movements, has general influence on language processing (Hernández-Gutiérrez et al., 2018). Thereafter, we carried out two experiments: one semantic and one syntactic.

In the semantic experiment -Experiment 1- we manipulate the semantic congruency of critical words embedded in natural-speech sentences. Participants listened to the auditory stimuli while seeing a picture of the speaker's static face with three types of emotional facial expressions -happy, fear, or neutral-. This manipulation is expected to modulate the N400 and P600 semantic effects. Considering results from previous studies, we expect faces and the communicative context to strengthen the emotion effects. However, predictions cannot be straightforward at this stage. Therefore, the N400 effect may be reduced while facing the speaker with positive or negative facial expression (Delaney-Busch & Kuperberg, 2013; Federmeier, Kirson, Moreno & Kutas, 2001), or conversely, it might be increased (Holt et al., 2009). P600

semantic effects are also expected. If speakers' emotional facial expressions facilitate semantic processing, reducing the N400 amplitude, the P600 effect would be increased in the emotional conditions because the reanalysis of the semantic violations would be necessary. On the contrary, if semantic processing costs are increased while processing emotional faces, the opposite direction of the effects may be observed.

In the syntactic experiment -Experiment 2- we manipulate the morphosyntactic correctness of target words, while keeping visual stimuli and experimental procedures the same. Here, we will focus on the LAN and P600 correctness effects. As said before, the processing of negative emotions is related to analytic processing and detailed first pass linguistic processing, while positive emotions are related to heuristic processing. In addition, previous experiments that manipulated emotion within critical words found an increase of the LAN effect to negative emotions and a reduction to the positive. In view of these previous findings, we expect that fear faces would elicit the largest LAN amplitude, because of increasing alert and allocating more attentional resources to the morphosyntactic processing compared to happy and neutral conditions. Further, we predict a minimal LAN effect when facing the happy speaker compared to the neutral and fear emotional expressions. Regarding the P600 effect, some experiments using emotion laden critical words did not find significant modulations. However, other studies that manipulated mood with film clips found consistent effects. Therefore, since speakers' emotional faces are strong emotional stimuli we expect them to modulate the P600 effect. Consequently, if the happy speakers' faces foster a heuristic morphosyntactic processing, we predict larger P600 effects compared to controls because a deeper reanalysis will be necessary. However, the P600 will be reduced when facing the fear speaker's face because negative emotions are associated with an analytic processing style that facilitates the detection of the morphosyntactic errors, therefore the reanalysis will not be so necessary, reducing the P600 amplitude.

Finally, we also predict LPC modulations by the emotional facial expressions in both experiments. However, the ERP will be time-locked to the critical word, not to the face onset, which may affect the modulations. Considering the existing literature, the largest amplitude may appear either to the fear facial expression confirming a negativity bias, or to the happy speaker's face related to a positivity bias.

8.2. Experiment 1. Semantic domain

8.2.1 Methods

8.2.1.1 Participants

Thirty native Spanish speakers participated in this experiment (15 males, 15 females; age range 18 – 25 [M = 19.8]). They all were right handed (Mean Oldfield scores + 65) and declared normal or corrected to normal vision and hearing, and absence of disorders. Participants gave written informed consent and were reimbursed 15€ for participating in the experiment. The study was approved by the ethics committee of the Hospital Clínico San Carlos (Madrid, Spain), and performed in accordance with the Declaration of Helsinki.

8.2.1.2 Materials and procedure

The linguistic material used in this experiment was already tested in *Study Two* (see Chapter 3 for specifications).

Auditory sentences were accompanied by the visual presentation of the speaker's face either with happy, fear or neutral emotional facial expression (see Figure 11). Three pictures of one male and of one female speaker were taken from the NimStim set of facial expressions (Tottenham et al., 2009). Each facial identity was assigned to the corresponding voice of its gender.

The experiment was performed in an electrically shielded cabin. Participants were seated in a comfortable chair facing a computer screen (1280 x 1024 pt) at a viewing distance of 60 cm. The auditory stimuli were presented through a pair of shielded speakers placed at both sides of the screen. Sound level was kept constant through all participants, who first confirmed that the loudness of the voice was comfortable. Every participant listened to 240 sentences distributed in six conditions: 40 congruent and 40 semantically incongruent sentences seeing the happy speaker (half male, half female), and the same proportion seeing the fear and neutral speakers. The presentation of the 240 sentences and faces was randomized. Each sentence was presented to a given participant only once. Three pauses were included in total, each after 60 sentences. Enough presentation sets of 240 sentences were designed to cover all the possible combinations between sentences, semantic congruency and emotional facial expressions -note that participants were presented only 240 out of the total 480 sentences, because the participants in the present experiment also participated in Experiment 2, in which they were presented the other 240 sentences, this way avoiding repetition effects-. At the end of both experiments (semantic and syntactic), the whole set of 480 sentences had been presented in the congruent and incongruent versions by each of the speakers' faces, hence no differences in the results could be explained by any linguistic characteristic of the sentences, faces or the voices.

To situate participants in a communicative context, they were informed that they will listen to sentences while being visually presented the face of the individual who was speaking to them. They were instructed to perform a post-sentence semantic congruency task to decide whether the sentences had sense by pressing one of two different buttons on a response box. The buttons were counterbalanced across participants as well as the response hand. Participants were asked to try not to blink while the sentences were presented. At the beginning of each trial the speaker's face

appeared in the center of the screen and after 500 ms the audio started. The face was present until the auditory sentence finished, when, after a second, a question mark (“?”) appeared at the center of the screen that notified the moment to respond. The experiment took 25 minutes to be completed.



Figure 11 – Emotional visual stimuli. Pictures of the female and male speakers with the three different emotional facial expressions: Happy (A), Neutral (B) and Fear (C)

8.2.1.3 EEG recording

The EEG was recorded from 59 cephalic electrodes placed within an elastic cap according to the international 10-20 system. Impedances were kept below 5 k Ω . Vertical (VEOG) and horizontal (HEOG) bipolar ocular electrodes were used to record blinks and horizontal eye movements. One reference electrode was also placed on each mastoid, although EEG recordings were initially referenced to the right mastoid. Raw data were sampled at 250 Hz and recorded with a band-pass from 0.01 to 100 Hz.

The EEG was re-referenced offline to average mastoids and filtered with a bandpass from 0.1 to 15 Hz. EEG epochs of 1600 ms were segmented from the continuous EEG data, starting 200 ms before the critical word onset. The correction of

the ocular artifacts (blinks and horizontal eye movements) was performed by Independent Component Analysis (ICA). The rejection of the remaining artifacts was semi-automatically performed, removing trials exceeding a range of 100 μ V and others by visual inspection. Overall, the mean rate of rejected segments was 15 %. ERPs were computed only for trials followed by correct responses.

8.2.1.4 Data analysis

Repeated-measures ANOVAs were performed including the following factors: Electrode (59 levels), Semantic Congruency (congruent vs incongruent), and Emotional Facial Expression (fear vs happy vs neutral). Based upon visual inspection of the average waveforms, the statistical analysis included the following time windows after the critical word onset: 300-600 ms for the N400, and 700-850, 850-1000, 1000-1150, and 1150-1300 ms for the P600.

In consonance with *Study Two*, a 200 ms post-stimulus baseline was applied to the N400 to be sure that differences between conditions are explained by the experimental manipulations and not by artefacts in the baseline due to connected speech stimuli. Furthermore, to measure the P600 amplitude we applied a baseline in the time-window of the N400, since both components can partly overlap (Brouwer & Crocker, 2017). For a detailed description about the baseline, see *Study Two* (Chapter 3, *Methods* section). -Appendix 2 include alternative P600 ANOVA results with the 0-200 baseline-

8.2.2 Results and discussion

Regarding accuracy, the mean error rate in the semantic congruency task was 11.01%. Statistical analysis of the main factors Semantic Congruency ($F(1, 29) = 0.575$; $p = .454$) and Emotional Facial Expression ($F(2, 58) = 1.092$; $p = .332$) did not yield significant

results, neither in interaction ($F(2, 58) = 0.334; p = .659$). Regarding reaction time, neutral facial expressions were associated to the longest reaction times ($M = 429.04$ ms), followed by fear ($M = 415.23$ ms) and happy ($M = 413.98$ ms), but the differences just reached a statistical trend ($F(2, 58) = 2.529; p = .080$). Semantic Congruency ($F(1, 29) = 0.63; p = .802$) and the interaction Semantic Congruency by Emotional Facial Expression ($F(2, 58) = 0.35; p = .965$) also yielded non-significant results.

A visual inspection of the ERP waves shows a larger N400 component to incongruent target words compared to the congruent versions between about 200 and 700 ms (see Figure 12). The semantic N400 effect depicts a wide distribution of the negativity, with a typical amplitude peak at central electrodes for the happy and fear emotional expressions, but maximal around Fz for the neutral face. The ANOVA confirmed the effect of Semantic Congruency in the N400 latency, between 300 and 600 ms ($F(1, 29) = 21.401; p < .001; \eta^2 = .425; \pi = .994$). The interaction of Semantic Congruency with Electrode also resulted significant ($F(58, 1682) = 3.04; p = .022; \eta^2 = .095; \pi = .777$). Neither Emotional Facial Expression ($F(2, 58) = 1.813; p = .174; \eta^2 = .059; \pi = .364$), nor Emotional Facial Expression by Electrode ($F(116, 3364) = 1.04; p = .411; \eta^2 = .035; \pi = .591$) yielded significant effects in this time window. The interaction Semantic Congruency by Emotional Facial Expression did not reach statistical significance ($F(2, 58) = 0.3; p = .742; \eta^2 = .01; \pi = .095$), and neither did the three-way interaction with Electrode ($F(116, 3364) = 1.133; p = .335; \eta^2 = .038; \pi = .627$).

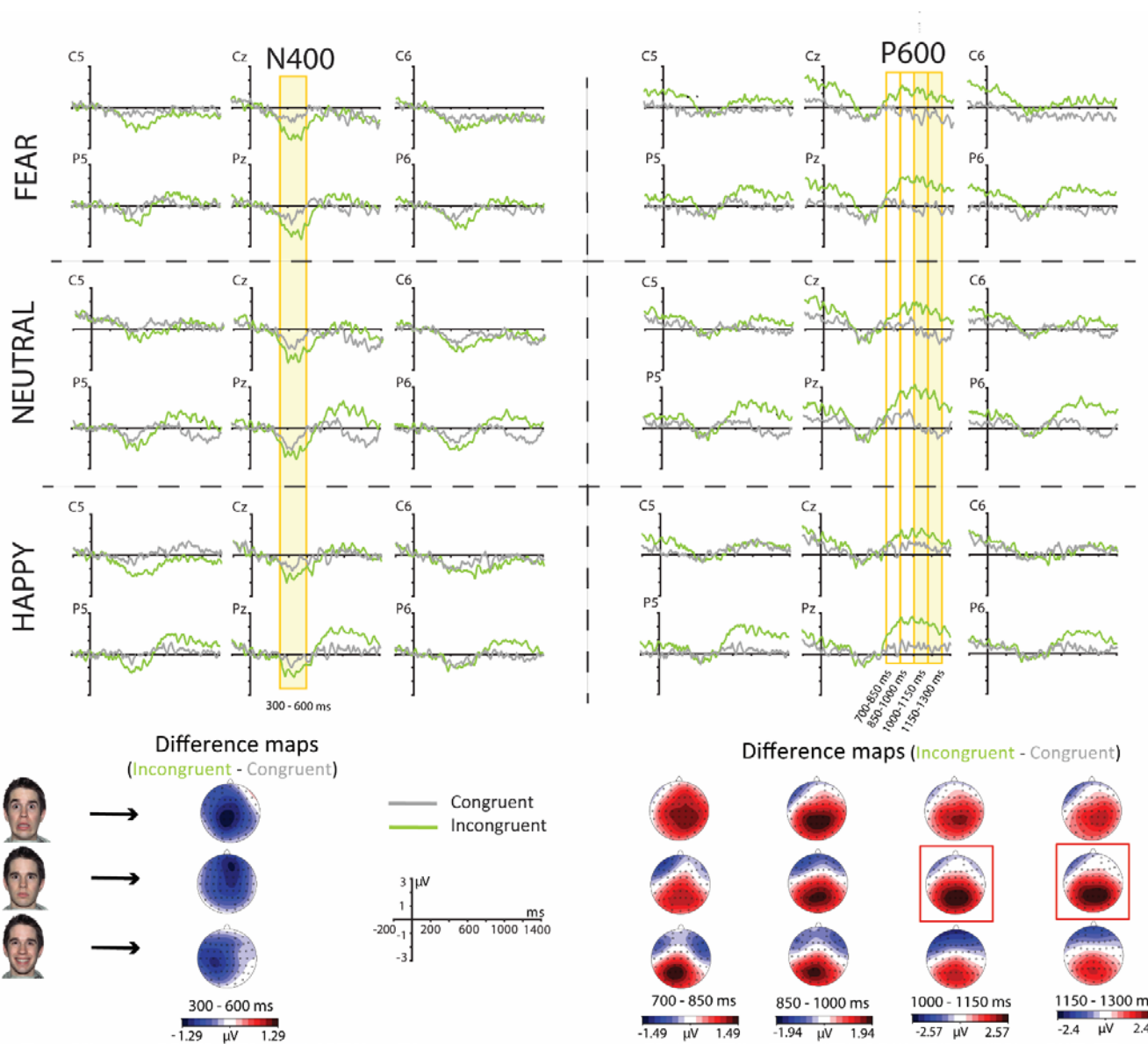


Figure 12 - Effect of Congruency for each Emotional Facial Expression. ERPs are plotted separately for the N400 and P600 components because of the different baselines (0-200 ms and 200-700 ms, respectively). The difference maps represent the Congruency effect (incongruent minus congruent) for each emotion on the corresponding time window

As expected from *Study Two*, ERPs in Figure 12 also depict a central-parietal P600 component from 600 to 1400 ms being larger to incongruent words. Semantic Congruency yielded a trend for significance in the latency 700-850 ms ($F(1,29) = 3.75$; $p = .063$; $\eta^2 = .007$; $\pi = .08$) and a significant effect from 850 to 1300 ms (850-1000 ms: $F(1,29) = 4.645$; $p = .04$; $\eta^2 = .138$; $\pi = .549$; 1000-1150 ms: $F(1,29) = 8.715$; $p = .006$; $\eta^2 = .237$; $\pi = .813$; 1150-1300 ms: $F(1,29) = 11.593$; $p = .002$; $\eta^2 = .293$; $\pi = .908$). Moreover, the ANOVA showed a strong interaction of Semantic Congruency and Electrode for the whole P600 segment (700-850 ms: $F(58, 1682) = 14.569$; $p < .001$; $\eta^2 = .334$; $\pi = 1$; 850-1000 ms: $F(58, 1682) = 23.641$; $p < .001$; $\eta^2 = .449$; $\pi = 1$; 1000-1150 ms: $F(58, 1682) = 23.457$; $p < .001$; $\eta^2 = .456$; $\pi = 1$; 1150-1300 ms: $F(58, 1682) = 17.669$; $p < .001$; $\eta^2 = .387$; $\pi = 1$).

The ANOVA also revealed a significant interaction of Semantic Congruency by Emotional Facial Expression in the second half of the P600, from 1000 to 1300 ms (1000-1150 ms: $F(2, 56) = 5.278$; $p = .009$; $\eta^2 = .159$; $\pi = .815$; 1150-1300 ms: $F(2, 56) = 2.285$; $p = .045$; $\eta^2 = .105$; $\pi = .601$), but this interaction did not succeed from 700 to 1000 ms (700-850 ms: $F(2, 56) = 0.64$; $p = .938$; $\eta^2 = .002$; $\pi = .059$; 850-1000 ms: $F(2, 56) = 0.183$; $p = .821$; $\eta^2 = .006$; $\pi = .077$). Post-hoc pairwise comparisons were performed between 1000 and 1300 ms revealing that the difference between congruent and incongruent target words was significant when accompanied with the Neutral speaker's face (1000-1150 ms: $\Delta = 1.067 \mu\text{V}$, $p < .001$; 1150-1300 ms: $\Delta = 1.071 \mu\text{V}$, $p < .001$). The Happy (1000-1150 ms: $\Delta = 0.12 \mu\text{V}$, $p = .961$; 1150-1300 ms: $\Delta = 0.213 \mu\text{V}$, $p = .386$) and Fear (1000-1150 ms: $\Delta = 0.524 \mu\text{V}$, $p = .326$; 1150-1300 ms: $\Delta = 0.286 \mu\text{V}$, $p = .346$) speakers did not show significant semantic effects in this time window. Finally, the interaction of Semantic Congruency by Emotional Facial Expression by Electrode was not significant, but reached an statistical trend between 1000 and 1150 ms (700-850 ms: $F(116, 3364) = 1.599$; $p = .123$; $\eta^2 = .052$; $\pi = .711$; 850-1000 ms: $F(116, 3364) = .719$; $p = .706$; $\eta^2 =$

.024; $\pi = .377$; 1000-1150 ms: $F(116, 3364) = 1.869$; $p = .058$; $\eta^2 = .063$; $\pi = .815$; 1150-1300 ms: $F(116, 3364) = .936$; $p = .491$; $\eta^2 = .032$; $\pi = .448$).

Emotional Facial Expression reached a significant main effect interpreted as an LPC effect (Figure 13) from 1000 to 1150 ms ($F(2, 58) = 4.868$; $p = .011$; $\eta^2 = .148$; $\pi = .781$), and a statistical trend from 850 to 1000 ms ($F(2, 58) = 3.081$; $p = .054$; $\eta^2 = .096$; $\pi = .573$) However, this factor was significant neither from 700 to 850 ms ($F(2, 58) = 6.715$; $p = .810$; $\eta^2 = .007$; $\pi = .081$;) nor from 1150 to 1300 ms ($F(2, 58) = 2.346$; $p = .105$; $\eta^2 = .077$; $\pi = .450$). Post-hoc pairwise comparisons over the significant interval (1000-1150 ms) revealed a significant difference between Happy and Fear expressions ($\Delta = 0.447 \mu\text{V}$, $p = .018$), showing larger amplitudes to Happy ($M = 0.653 \mu\text{V}$) than to Fear ($M = 0.206 \mu\text{V}$). No other comparison yielded a significant difference.

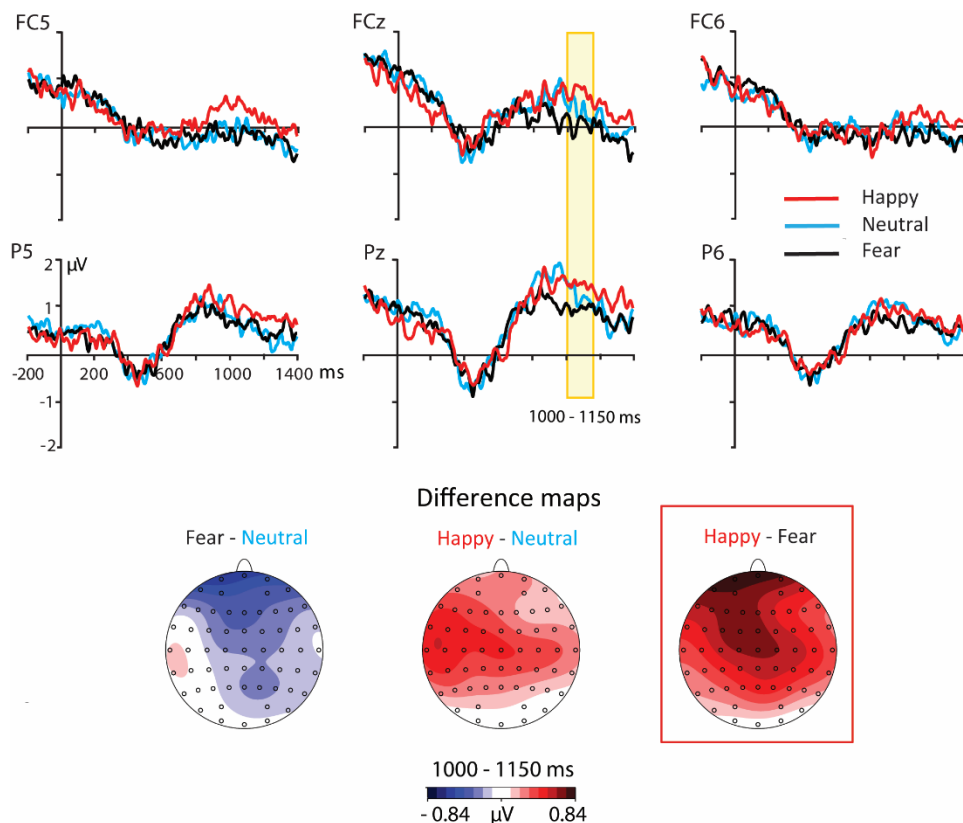


Figure 13 – ERP waves are plotted on a selection of six electrodes for each Facial Emotional Expression (200-700 ms baseline). Difference maps represent the three possible pairwise comparisons. The Happy minus Fear difference map showed a significant antero-central LPC topography.

The use of emotional facial stimuli ultimately affected semantic processing, particularly happy compared to fear expressions in the interval 1000 and 1150 ms. Moreover, the topography shows a broad negativity more frontal than the typical LPC. Remarkably, the fear facial expression yielded a smaller effect compared to the control condition but was not statistically significant. Overall, the N400 effect was insensitive to the speaker's emotional facial expression. Therefore, it seems that emotional facial expressions in communicative contexts do not impact the semantic processing of speech, in line with previous findings with written emotion-laden language stimuli (Jiménez-Ortega et al., 2012; Martín-Loeches et al., 2012). On the other hand, the speaker's facial emotion was able to modulate the semantic P600. Later latencies of this effect displayed reduced amplitude in both fear and happy emotions compared to the control (neutral). In sum, the N400 was not significantly affected, indicating similar efforts in the processing of semantic incongruences (Kutas & Federmeier, 2011) when facing emotional and neutral speakers. However, the subsequent linguistic reanalysis seems to be similarly facilitated at late stages for both negative and positive emotions.

8.3. Experiment 2. Syntactic domain

8.3.1 Methods

8.3.1.1 Participants

Participants were the same as in Experiment 1. Both experiments were performed in a row with a pause of 10 minutes, and the order was counterbalanced across participants.

8.3.1.2 Materials and procedure

The same 480 sentences used in Experiment 1 were modified to include a morphosyntactic violation of gender or number in the critical word. Depending on the structure of the sentence, there could be a noun-adjective mismatch (structure 1) or a

determiner-noun mismatch (structures 2 and 3. An example of the sentences is given in *Study Two* (see Chapter 3)

Participants listened to 240 sentences, different to the ones presented to a specific participant in Experiment 1, so that at the end of the whole study every participant listened to the 480 sentences only once. For this experiment, given that the critical information for morphosyntactic violations relates to the gender/number markers, triggers were set on critical words at the offset of the lexeme, just before the gender/number declension.

Participants performed a post-sentence morphosyntactic-correctness task to decide whether the sentences were correct by pressing one of two different buttons on a response box. The buttons were counterbalanced across participants as well as the response hand. The stimulation procedure was identical to Experiment 1.

8.3.1.3 *EEG recording*

The characteristics of the EEG recording were identical to Experiment 1.

8.3.1.4 *Data analysis*

The procedures to analyze the data matched the description of Experiment 1. Overall, the mean rate of rejected segments was 13%. We performed a repeated-measures ANOVA including the factors Electrode (59 levels), Morphosyntactic Correctness (correct vs incorrect), and Emotional Facial Expression (fear vs happy vs neutral). Considering a visual inspection of the ERP waves and the difference maps, statistical analyses were computed on the following time segments: 250-400 ms for the LAN and 400-550, 550-700, 700-850, and 850-1000 ms for the P600 after the morphosyntactic declension onset. A post-stimulus baseline of 150 ms was applied for the LAN and P600

components. In this experiment we did not apply a different baseline for the P600 because no spatial overlapping exists between these components.

8.3.2 Results and discussion

The mean error rate in the morphosyntactic correctness task was 2.26%. An ANOVA including the factors Morphosyntactic Correctness and Emotional Facial Expression revealed a significant effect of Morphosyntactic Correctness ($F(1,29) = 5.95$; $p = .021$). Incongruent sentences showed a higher error rate (2.76%) compared to congruent sentences (1.77%). Neither Emotional Facial Expression ($F(2,58) = 0.1$; $p = .986$) nor the interaction of Morphosyntactic Correctness by Emotional Facial Expression ($F(2, 58) = 0.458$; $p = .635$) yielded significant results.

Regarding response reaction times, the ANOVA revealed significant main effects of Morphosyntactic Correctness ($F(1,29) = 68.095$; $p < .001$). Participants were significantly faster responding to incorrect sentences ($M = 363.14$ ms) compared to correct sentences ($M = 403.78$ ms). Conversely, results of Emotional Facial Expression ($F(2, 58) = 0.361$; $p = .696$) and the interaction with Morphosyntactic Correctness ($F(2, 58) = 0.361$; $p = .696$) were not significant.

Figure 14 shows the ERPs to morphosyntactically correct and incorrect target words for each emotional communicative context. A LAN component was obtained to the violations of gender and number that was apparently larger for the fear speaker's face. The topography of the LAN effect also differs between emotional conditions. While the happy and neutral emotional facial expressions elicited a LAN effect in left anterior sites, the LAN effect to the fear speaker shows a much more distributed effect, peaking around FC5 electrode. The ANOVA in the LAN latency (250-400 ms) confirmed a significant interaction of Morphosyntactic Correctness by Electrode ($F(58, 1682) = 4.37$; $p = .001$; $\eta^2 = .131$; $\pi = .949$). However, the main effect of Morphosyntactic Correctness

failed to reach significance in this period ($F(1,29) = 0.317$; $p = .578$; $\eta^2 = .011$; $\pi = .085$). The factor Emotional Facial Expression was not statistically significant ($F(2,58) = .497$; $p = .611$; $\eta^2 = .017$; $\pi = .128$), neither in interaction with Electrode ($F(116, 3364) = 0.924$; $p = .501$; $\eta^2 = .031$; $\pi = .444$). The ANOVA yielded a significant interaction Morphosyntactic Correctness by Emotional Facial Expression ($F(2, 58) = 4.002$; $p = .024$; $\eta^2 = .121$; $\pi = .694$). The post-hoc pairwise comparison of correct and incorrect target words was significant when seeing the fear speaker's face ($\Delta = 0.559 \mu\text{V}$, $p = .012$), but not for the neutral ($\Delta = 0.003 \mu\text{V}$, $p = .987$) and happy ($\Delta = 0.3 \mu\text{V}$, $p = .291$) speakers. The triple interaction Morphosyntactic Correctness by Emotional Facial Expression by Electrode however, was not significant ($F(116, 3364) = 0.767$; $p = .627$; $\eta^2 = .036$; $\pi = .345$).

A visual inspection of the ERP waves in Figure 14 also evidences a prominent P600 component for morphosyntactic violations, peaking at 600 ms, with a long-lasting effect from 400 to 1400 ms. The difference maps (incorrect minus correct words) depict a typical P600 topography at central-parietal sites, with maximal voltage around CPz electrode. Separated ANOVAs on the four time windows that cover this component revealed a strong significant main effect of Morphosyntactic Correctness (400-550 ms: $F(1,29) = 8.042$; $p = .008$; $\eta^2 = .217$; $\pi = .783$; 550-700 ms: $F(1,29) = 44.983$; $p < .001$; $\eta^2 = .608$; $\pi = 1$; 700-850 ms: $F(1,29) = 84.037$; $p < .001$; $\eta^2 = .743$; $\pi = 1$; 850-1000 ms: $F(1,29) = 36.871$; $p < .001$; $\eta^2 = .56$; $\pi = 1$) and Morphosyntactic Correctness by Electrode (400-550 ms: $F(58, 1682) = 16.513$; $p < .001$; $\eta^2 = .363$; $\pi = 1$; 550-700 ms: $F(58, 1682) = 36.27$; $p < .001$; $\eta^2 = .556$; $\pi = 1$; 700-850 ms: $F(58, 1682) = 35.262$; $p < .001$; $\eta^2 = .549$; $\pi = 1$; 850-1000 ms: $F(58, 1682) = 15.53$; $p < .001$; $\eta^2 = .349$; $\pi = 1$).

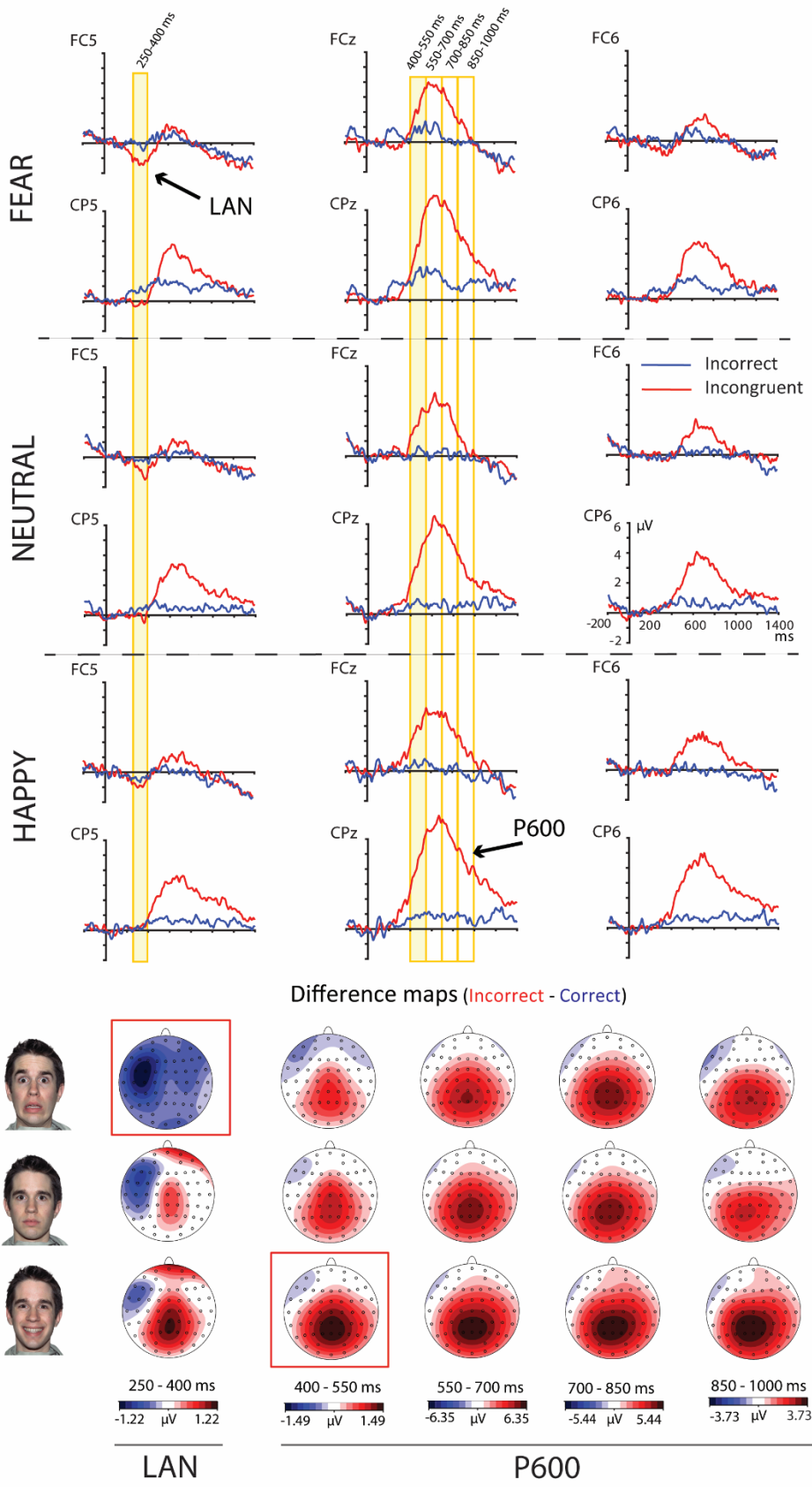


Figure 14 – ERPs of critical words. Correct words are plotted in blue line and morphosyntactic violations in red line. The topographies represent the difference maps for the LAN and P600 effects on each Emotional Facial Expression.

The P600 effect also varied among emotional expressions, and hence the interaction Morphosyntactic Correctness by Emotional Facial Expression resulted significant in the first segment of the component, between 400 and 550 ms ($F(2, 58) = 4.912$; $p = .011$; $\eta^2 = .145$; $\pi = .784$). Moreover, the adjacent segment 550-700 ms reached a trend very near to significance ($F(2, 58) = 2.978$; $p = .059$; $\eta^2 = .093$; $\pi = .557$). The other two segments were not significant (700-850 ms: $F(2, 58) = 1.126$; $p = .331$; $\eta^2 = .037$; $\pi = .239$; 850-1000 ms: $F(2, 58) = 1.979$; $p = .147$; $\eta^2 = .064$; $\pi = .393$). Post-hoc pairwise comparisons between 400 and 550 ms showed that the comparison of correct and incorrect words was not significant for the Fear speaker's face ($\Delta = 0.456 \mu\text{V}$, $p = .150$) while being significant for the Happy ($\Delta = 1.416 \mu\text{V}$, $p = .005$) and the Neutral ($\Delta = 0.907 \mu\text{V}$, $p = .013$) faces. The three-way interaction Morphosyntactic Correctness by Emotional Facial Expression by Electrode could not yield significant results (400-550 ms: $F(116, 3364) = 0.83$; $p = .591$; $\eta^2 = .028$; $\pi = .417$; 550-700 ms: $F(116, 3364) = 0.887$; $p = .546$; $\eta^2 = .029$; $\pi = .431$; 700-850 ms: $F(116, 3364) = 0.337$; $p = .949$; $\eta^2 = .011$; $\pi = .16$; 850-1000 ms: $F(116, 3364) = 0.667$; $p = .752$; $\eta^2 = .021$; $\pi = .285$).

Figure 15 shows a posterior positivity when comparing the Happy and Fear emotional facial expressions with the control Neutral condition, that we interpret as an LPC effect. The ANOVA revealed that the factor Emotional Facial Expression was not significant, but reached a statistical trend between 550 and 700 ms (400-550 ms: $F(2, 58) = 1.75$; $p = .183$; $\eta^2 = .057$; $\pi = .353$; 550-700 ms: $F(2, 58) = 2.68$; $p = .077$; $\eta^2 = .085$; $\pi = .511$; 700-850 ms: $F(2, 58) = .828$; $p = .44$; $\eta^2 = .028$; $\pi = .184$; 850-1000 ms: $F(2, 58) = 1.696$; $p = .192$; $\eta^2 = .055$; $\pi = .343$). However, the interaction of Emotional Facial Expression with Electrode yielded a significant effect from 550 to 850 ms (550-700 ms: $F(116, 3364) = 2.007$; $p = .029$; $\eta^2 = .065$; $\pi = .897$; 700-850 ms: $F(116, 3364) = 1.937$; $p = .049$; $\eta^2 = .063$; $\pi = .826$), but the two other periods of time were not significant (400-550 ms: $F(116, 3364) = 1.58$; $p = .112$; $\eta^2 = .052$; $\pi = .772$; 850-1000 ms: $F(116, 3364) =$

1.67; $p = .090$; $\eta^2 = .054$; $\pi = .789$). To elucidate this effect, post-hoc pairwise comparisons were performed between 550 and 850 ms on a selected central-parietal ROI including the electrodes C3, C1, Cz, C2, C4, CP3, CP1, CPz, CP2, CP4, P3, P1, Pz, P2, P4. Within the segment 550-700 ms, only the comparison of Fear ($M = 3.533 \mu\text{V}$) with Neutral ($M = 2.733 \mu\text{V}$) emotional expressions yielded a significant result ($\Delta = 0.8 \mu\text{V}$, $p = .007$). However, no pairwise comparison between emotions reached significance between 700 and 850 ms, possibly because of the low significance ($p = .049$) obtained in the ANOVA for the interaction Emotional Facial Expression by Electrode.

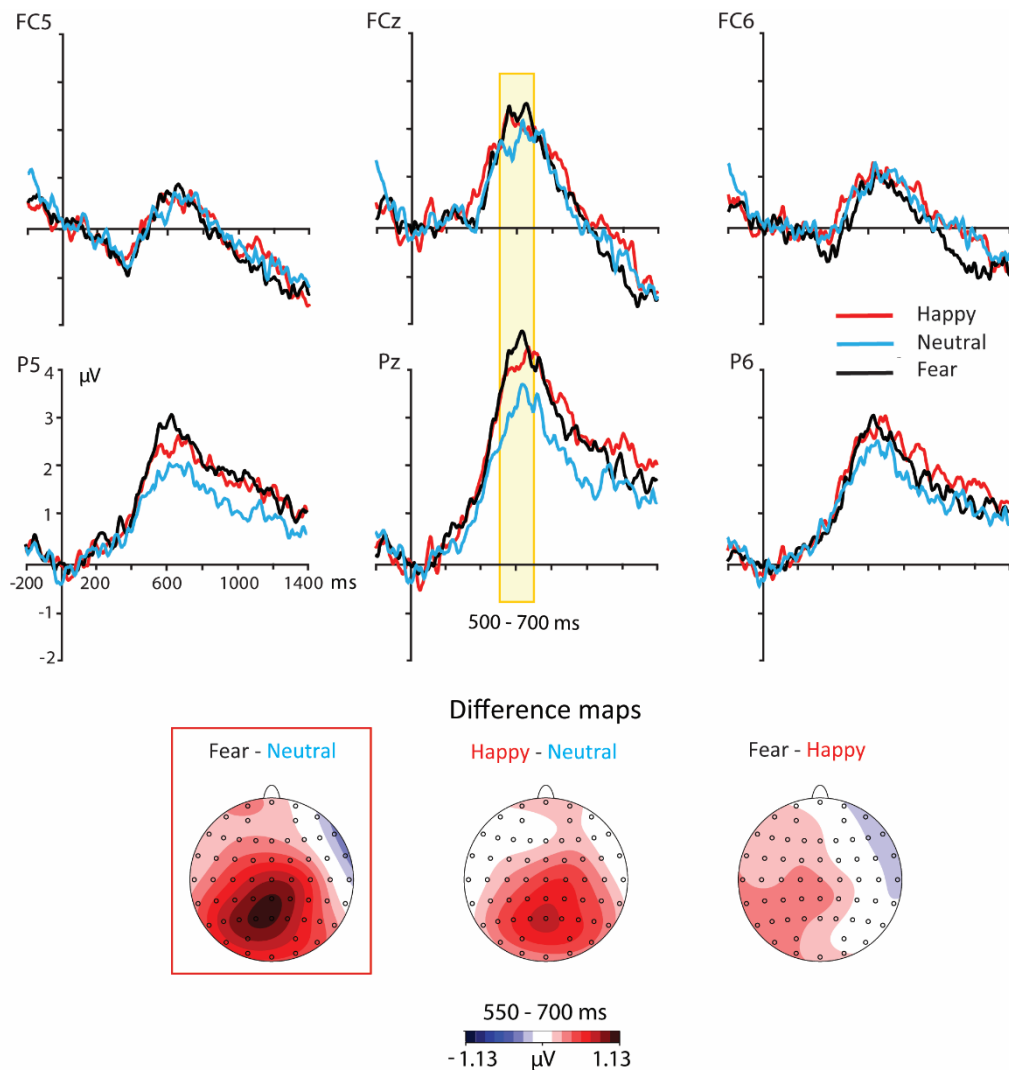


Figure 15 - ERP waves are plotted with a 0 - 150 ms baseline on a selection of six electrodes for each Facial Emotional Expression. Difference maps represent the three possible pairwise comparisons. A significant LPC effect was found for the comparison of Fear and Neutral speakers' faces.

These results confirm a successful manipulation of the emotional context with the speaker's facial expressions, yielding ERP main effects. Therefore, a larger centro-parietal LPC effect was found to fear compared to the neutral face but no other comparison resulted significant. This result diverged from the one found in the Experiment 1, where happy faces yielded stronger emotional effect. Further, in this experiment the LPC has typical centro-parietal topography.

Summarizing, in this experiment the LAN effect to the fear facial expression was larger than neutral and happy conditions. Therefore, first-pass syntactic processes were boosted when seeing the fear speaker. In addition, the LAN topography in this condition shows a negative effect apparently distributed throughout the scalp but maximal at left anterior sites. The difference maps, and specially the ERP waves, evince a LAN barely vanished in the happy condition. Moreover, happy facial expressions related to an earlier P600 onset coinciding with the LAN latency, contrary the fear expressions, which did not yield significant P600 effects at these latencies. Taken together, these findings indicate a differential pattern of languageprocessing when parsing syntactic anomalies as a function of the emotional valence of the speaker's face. Namely, fear emotion may engage an analytical processing, whilst seeing the happy speakers may engage heuristic processing, in coherence with previous reports (Vissers et al., 2010; Verhees et al., 2015). Results are also in line with studies that manipulated emotion within the critical words (e.g. Martín-Loeches et al., 2012).

8.4. General discussion

The general purpose of this study was to investigate language in social affective communicative contexts. Particularly, we investigated the psychophysiological effect of seeing the emotional facial expression of the speaker on the semantic and morphosyntactic processing of natural speech.

In agreement with our predictions we found pure emotion effects on both experiments. In the syntactic experiment, fear expressions yielded larger LPC amplitude compared to neutral condition. However, in the semantic experiment the happy speaker yielded a larger LPC compared to the fear speaker. Thus, a *positivity bias* can be inferred in the semantic experiment, whereas a *negativity bias* relates to the syntactic experiment. Both results have been reported before (for negativity bias see Carretié et al., 2008; Espuny et al., 2018a; Holt et al., 2009; Jiménez-Ortega et al., 2017, Kanske & Kotz, 2007; Recio et al., 2011; Schupp et al., 2004; Zhang et al., 2018; for positivity bias see Herbert et al., 2009; Kissler et al., 2009). In both experiments, the LPC showed a slightly different topography, that is, a more typical central-parietal distribution in the syntactic experiment, and more frontal in the semantic experiment. This differential pattern may be related to a frontal artefact and more noisy ERPs in the former -compare Figure 13 and Figure 15-. Interestingly, identical emotional facial expressions and sentences revealed different emotional brain responses in each experiment. Considering that the context modulates the effect of emotional faces (Wieser & Brosch, 2012), it seems that the different type of task on each experiment -Experiment 1: semantic congruency task, Experiment 2: morphosyntactic correctness task- has contributed to these results.

In previous studies, affective language in communicative situations enhanced and extended the ERP effects compared to non-communicative processing (Rohr & Abdel Rahman, 2015; Schindler et al., 2015; Schindler & Kissler, 2016, 2017). Although long-lasting effects were predicted to the speakers' emotional facial expressions, the significant LPC effects are confined to one segment of 150 ms on each experiment. Whereas previous experiments studying communicative contexts presented isolated emotion-laden words (Rohr & Abdel Rahman, 2015; Schindler et al., 2015), either the use of connected speech or facial stimuli might have prevented a wider effect, in

coherence with the sensitivity of the LPC to experimental manipulations (Schacht & Sommer, 2009). However, emotional faces are strong emotional stimuli, therefore it is probable that if measuring the ERP to onset of the emotional facial expression results would have been stronger. It should be noted that in the present experiment the ERP is calculated to the critical words. Therefore, the late LPC effects, though sustained, may have decreased its strength.

Contrary to our hypothesis, the semantic experiment did not show modulations of the N400 effect by the emotional facial expressions of the speaker, and neither the behavioural results yielded significant results. At first sight, certain differences might appear between emotional facial expressions that were not confirmed by the statistical analyses. Thus, despite the wide distribution, the N400 effect in the neutral condition peaked at frontal sites, while the emotional faces showed the usual central-parietal topography -although slightly left in the happy-. Indeed, frontal N400s -FN400- have been previously reported (e.g. Imbir, Bernatowicz, Duda-Goławska, Pastwa, & Żygierewicz, 2018; Strózak, Abedzadeh & Curran, 2016; Voss & Federmeier, 2011). Although not supported by main statistical results, to confirm this result we performed planned analysis on two regions of interest around Fz and CPz electrodes that ratified the similar topography between emotions. Accordingly, the N400 distribution does not seem different among the three emotional social contexts, and the wide dispersion across the scalp may be related to the auditory language presentation (e.g. Hagoort & Brown, 2000; Li et al., 2008; Wang et al., 2011). Some previous studies did not find modulations of the N400 effect, neither manipulating emotional valence within the critical words (Martín-Loeches et al., 2012) nor presenting emotion-laden words before the sentences (Jiménez-Ortega et al., 2012). Therefore, the N400 modulation by emotion may not be dependent on the moment when the affective stimulus is processed (previously or within), nor on the type of emotional stimuli used (words,

faces...) even if faces increase the relevance of the context as compared to previous experiments.

In the semantic experiment -Experiment 1-, the late P600 effect in the fear condition was reduced and could not reach significance, similarly to previous reports for this component in the syntactic domain (Vissers et al., 2010; Verhees et al., 2015; Espuny et al., 2018b). A similar reduction of the P600 effect occurred to the happy speaker, and hence only the neutral emotional expression yielded a significant effect. We predicted an increase of the P600 amplitude if semantic processing was facilitated by the speaker's emotional facial expression since the reanalysis of the incoherence would be more necessary. However, the reduction of the P600 effect did not accompany an increase of the N400 effect. In previous studies (for instance, van de Meerendonk, et al., 2010) the biphasic N400-P600 -instead of an N400 alone- has been associated to semantic incongruencies when they are salient. Therefore, although semantic processing is not affected by speakers' emotions -same N400 effect-, semantic violations may be considered less salient when facing the neutral speaker, thus reducing the P600 amplitude.

In the syntactic experiment -Experiment 2-, a main finding was the larger LAN effect to fear speakers compared to neutral and happy conditions. Though LAN effect in both neutral and happy conditions did not reach significance, the LAN amplitude was more reduced and even banished in the happy condition relative to the neutral facial expression -see the difference maps relative to 250-400 ms in Figure 14-. These results confirm our hypothesis, in line with previous studies (Jimenez Ortega et al., 2012; Martín-Loeches et al., 2012). Particularly, Martín-Loeches et al., (2012) also found a LAN more extended to right frontal sites in the negative words than in the neutral and positive valences. The broad distribution of the negativity to central and posterior sites of the scalp in the fear condition may seem odd at first sight but can be explained as an

overlap of a negative (LAN) and a positive component with different topographies within the same period -250-400 ms- as follows.

In this regard, the fear facial expression yielded a positivity -probably an LPC- to correct words that was larger compared to the neutral and happy emotions (see Figure 14). Note that the maps represent the difference between correct and incorrect words and therefore it is not possible to see the distribution of the positivity in this specific condition, however the comparison of frontal and centroparietal waves suggests a centroparietal maximum. Between 250 and 400 ms, the incorrect words in the central electrodes (FCz, CPz) barely show any activity, however correct words exhibit a positive shift in amplitude from 200 ms. As seen in Figure 14 this only happened in the fear emotion. Therefore, when focusing on the (fear) difference map between 250-400ms, the negative effect seen around FC5 can be explained by the negative polarity of the LAN component in incorrect words minus the barely-null voltage of the correct words (see Figure 14, fear, FC5 electrode), while the negative effect across central and posterior sites of the scalp accounts for the positive polarity of correct words minus the barely-null voltage of the incorrect (see Figure 14, fear, FCz and FC5 electrodes). Post-hoc analyses performed between 250 and 400 ms however did not confirm statistical differences between emotions in correct words, but such differences in amplitude are sufficient to yield visual disparities. The absence of visual differences in the incorrect words within this period may be explained in view of the results found in *Study One* (Hernández-Gutiérrez et al., 2018), where a posterior positivity to critical words in correct sentences was found when accompanied by a video of the speaker's face, compared to his still face -similar to the control pictures in the present study-. Unexpected critical words were not affected by the type of visual presentation, however. Therefore, the increased motivated attention to the realistic communicative context yielded a posterior positivity only when the linguistic task is not cognitively

demanding. The same could be the case here, yet emotion would have triggered motivated attention instead of the communicative context. It is possible that in the present study the use of static emotional facial expressions -instead of dynamic- prevented significant differences in correct words between emotions.

The P600 effect to morphosyntactic anomalies was delayed when facing the fear facial expression and consequently it was not significant in the first period, contrary to the happy and neutral expressions. Thus, the fear condition yielded the smallest P600, as predicted from other studies using images instead of language stimuli to manipulate emotion (Vissers et al., 2010; Verhees et al., 2015). We also expected a P600 enhancement in the happy condition. The difference maps revealed the largest P600 effect to the happy speaker. In addition, a visual inspection of Figure 14 suggests that the P600 effect is speeded up in this emotion compared to neutral and fear. Van Berkum, De Goede, Van Alphen, Mulder, Kerstholt (2013) also found an earlier onset of the P600 in the happy mood condition related to an anticipation of the processing costs.

Interestingly, differences in the information processing styles can explain the LAN and P600 findings. In this regard, the LAN was expected to increase in the fear condition because negative emotions trigger an analytic processing mode compared to positive emotions, which in turn relate to a heuristic, less demanding, processing style (Bless & Schwarz, 1999; Gasper & Clore, 2002; Isen, 2001). A heuristic linguistic processing does not consider all the information available to complete the syntactic parsing. The LAN increased its amplitude when participants faced the fear speaker's face, reflecting an increase of the resources invested in first-pass syntactic processing and better detection of the morphosyntactic errors (Friederici, 2002; Molinaro et al., 2011). Consequently, participants had to invest less resources in the reanalysis of the morphosyntactic errors, yielding the smallest P600 effect in the fear condition. To the contrary, when participants were faced with happy expressions, morphosyntactic

mismatches engaged a superficial processing -smaller LAN-. In this case the reanalysis was deeper, giving rise to a strong P600. These results also agree with differences in attentional processing between positive and negative emotional stimuli. Negative stimuli typically summon more attentional resources and more attentional focus (Srinivasan and Gupta, 2010) compared to positive ones (Srivastava and Srinivasan, 2010; Gupta and Srinivasan, 2015; Gupta et al., 2016). However, behavioural results did not show differences on the detection of morphosyntactic errors, as a function of emotional expression. It is possible that the online ERP effects are not strong enough to yield differences in a post-sentence correctness task.

The LAN and the P600 effects were more similar between neutral and happy conditions compared to fear. Therefore, fear facial expressions seem more effective triggering a detailed first-pass analysis than happy expressions, this latter triggering heuristic processing. Therefore, fear emotion may be more influential during morphosyntactic linguistic tasks, in line with the negativity bias found in the LPC in this particular experiment. Thus, stimuli with negative valence capture more processing resources (Carretié, Albert, López-Martín, Tapia, 2009), in line with the finding that negative words have been associated to stronger brain responses when compared with positive and neutral valence words (Carretié et al, 2008, Kanske & Kotz, 2007).

Regarding possible limitations of our study, one might consider that coupling the speaker's emotional facial expression with certain sentences would be incongruent by itself, since the speaker might add positive or negative valence to the communicative context that does not correspond with the affective connotations of the sentence. In such case, we would expect congruent/correct sentences uttered by happy and fear speakers to generate larger N400s compared to speakers with neutral expression, therefore yielding a significant interaction of semantic congruency and emotional facial expression. However, in the semantic experiment we did not find such interaction, and

in the syntactic experiment the post-hoc analyses in congruent sentences did not confirm significant differences between emotions. Besides, correct words in emotional contexts yielded an LPC, not an N400 component. In addition, this potential limitation was not actually detrimental to our results.

Ultimately, our results support the claim that affective processing of the speaker's face may impact speech processing, mostly in the syntactic domain. However, the differential result between syntax and semantics could be also related to peculiarities of the tasks, that could have induced mood-like state differences. Modulations of linguistic-related ERP components were found even in absence of an emotion-related task and the emotional information being irrelevant to the main linguistic task.

9. CHAPTER 7. GENERAL DISCUSSION

The study of language comprehension in communicative contexts has been rapidly capturing attention of language scientists (e.g. Münster & Knoeferle, 2017; Rohr & Abdel Rahman, 2016, 2018). Most language research has been performed with visual word-by-word presentations in laboratory settings devoid of social context. However, language evolved as a social adaptation and its use in natural situations is typically associated with face-to-face communication. Considering the special status of faces for human beings and its relevance for communicative purposes, more focus should be devoted study the effect of facial information on language comprehension. Although the field of speech perception has already recognized the importance of the effect of visual speech on phonetic analysis (Baart, Stekelenburg, & Vroomen, 2014; Stekelenburg & Vroomen, 2007; Soto-Faraco, Navarra, & Alsius, 2004), the semantic and syntactic components of language awaited to be studied, especially through electrophysiological measures. This thesis took a first step and provided relevant insight about the influence of the speaker's facial information on the semantic and syntactic brain processing of speech. In particular, the ERP technique was used to shed light into three points: 1. The effect of the speaker's facial dynamism on semantic processing, focusing on the eyes and mouth, 2. The effect of the mere visualization of the speaker's face on semantic and syntactic processing, and 3. The effect of the speaker's facial emotional expressions on semantic and syntactic processing, specifically fear and happy.

The advantage of using the ERP technique has been its fine-grained temporal resolution (Luck, 2014). Thus, it was not only possible to differentiate between syntactic and semantic brain processing but also to observe how the interaction between face-related information and linguistic processing occurred at different stages across time.

The first study (Chapter 3) addressed the multimodal integration of facial dynamics and speech. Contrary to our predictions, semantic comprehension was not affected by the facial movements of the speaker. The N400 component, a neural index of semantic comprehension, was not affected by the visual presentation of a video of the speaker compared to a static picture of his face. Even when the mouth or the eyes of the speaker were covered, the N400 was not sensitive to the manipulation of the facial features. By contrast, the main result of the study was the LPP that appeared in the dynamic condition and specifically to expected sentences, that is, sentences that did not contain semantic errors and hence were easy to process. This finding may reveal an increment of motivated attention in the dynamic visual context that resembled the most a real-life communicative context (Schindler et al., 2015; Schindler & Kissler, 2016; 2017). This communicative effect was significantly reduced when the mouth of the speaker was covered, compared to seeing the complete face, but not when the eyes were covered. Therefore, the brain processing of language seems prioritized to the detriment of the visual integration of the speaker when semantic processing is demanding. By contrast, the visual communicative context is considered when linguistic processing is not constrained. Although the facial movements in face-to-face contexts do not make an impact on semantic comprehension, communication is affected by the increase of motivated attention to the message because of the similarity to a real interaction.

In the second study (Chapter 4) we enquired into the effect that the mere perception of the speaker's face (compared to non-face) has on semantic and syntactic sentence comprehension. Our results suggest that the semantic N400 effect is enhanced when facing a picture of the speaker compared to a scrambled face. Therefore, just situating language in a minimal social context can influence semantic comprehension because more attention may be directed to the linguistic stimuli (McCarthy & Nobre,

1993). Further, this context may lead to a deeper processing of the message as well (Wang et al., 2011). Considering the increasing interest that language research has putted on situated language processing, this finding is of substantial interest because previous investigations did not consider that just by situating language in a social context can be enough to influence the processing of meaning. Syntactic processing, conversely, did not show any ERP modulation elicited by this visual context.

In the third study (Chapter 5) we studied language processing (both semantics and syntax) in an approximation social affective context. Particularly participants faced the speaker with three different facial emotional expressions: fear, neutral and happy. This manipulation allowed to study emotion effects on language more similarly to natural situations compared to alternative manipulations of emotion (e.g. film clips, emotional paragraphs, etc). ERPs revealed a remarkable influence on syntactic processing, as different modulations were found to the positive and negative emotion. The LAN effect was increased to fear facial emotional expression compared to both neutral and happy emotions, which in turn did not yield significant effects. However, the happy condition showed the smallest LAN effect. In coherence with these effects, the P600 did not yield a significant effect when facing the fear speaker and the happy facial expression. These results are congruent with previous investigations that manipulated emotion within the sentence (Jiménez-Ortega et al., 2017; Martín-Loeches et al., 2012) and with predictions based on the information processing style (Vissers et al., 2010; Verhees et al., 2015). Accordingly, while negative emotions may prompt an analytic processing mode, positive emotions prompt a heuristic processing mode. As the N400 was not modulated by emotional facial expressions, we can conclude that semantic processing was not affected by emotion. However, the late semantic P600 effect was reduced when facing both positive and negative emotions relative to the control condition.

Altogether, the results of this thesis demonstrate that the visual social information in communicative contexts plays an active role during online sentence processing. The semantic and syntactic linguistic domains may be sensitive to the influence of the speaker's facial information, but they are differently affected by each manipulation. However, we cannot disregard that social visual information received from the speaker may not directly impact the core language machinery itself, but instead modulate other cognitive processes involved in linguistic comprehension, like attentional processing. The neurophysiological correlate of semantic comprehension, the N400, was modulated by the presence of the speaker's face. When semantic comprehension is situated in a social context, even if minimal, its processing by the brain is different from a non-social visual context. However, once the context is social, neither the dynamism of the face nor the emotional facial expressions of the speaker modulate the N400. In contrast, syntactic processing may not be particularly affected when being socially situated compared to a non-social context. Thus, neither the LAN nor the P600 were modulated by this manipulation. However, seeing the speaker with an emotional facial expression can either promote or hinder the concurrent morphosyntactic processing, depending on whether the emotional valence is positive -happy- or negative -fear-, respectively.

Our results agree with an interactive conception of language and, particularly, they demonstrate an interaction between syntax and semantics in communicative contexts. Behavioural studies using the visual world paradigm showed that the visual context could be useful for both semantic (Holler et al., 2014b; Richardson & Dale, 2005) and syntactic linguistic purposes, like referents disambiguation (Hanna & Brennan, 2007) or thematic role assignment and syntactic structuring (Knoeferle & Kreysa, 2012). In the present ERP studies, the semantic information conveyed by the speaker's face was influential during syntactic and semantic sentence comprehension, despite being

irrelevant for the comprehension of the sentences. None of the visual inputs that participants received was necessary for correct linguistic comprehension, but nevertheless it impacted its neural mechanisms.

The thesis has some limitations that should be discussed in view of follow-up investigations on this research project. First, although our studies used connected speech instead of visual linguistic stimuli, the presentation of the stimuli was not like in real communication because participants listened to a set of unrelated sentences. In order to have a better approach to a more ecological study of language comprehension, one possibility could be that the whole set of sentences were part of the same discourse. Even more, face-to-face communication is characterized by a dialogue between the interlocutors. Although language has been already studied in these interactive contexts (e.g. Kuhlen, Bogler, Brennan & Hyman, 2017; Menenti, Pickering & Garrod, 2012), they entail several difficulties related to the lack of control of the linguistic material. Since the linguistic ERPs are very sensitive to linguistic parameters like frequency of use, concreteness or imageability (Swaab, Ledoux, Camblin & Boudewyn, 2011), it is necessary that every condition does not differ significantly from each other. Therefore, the more naturalistic an experimental context is, the more difficult to control the variables.

Another limitation is the presentation of pictures of the speakers on a screen instead of a real person talking. Although this would be the ideal situation to achieve, it also entails some problems regarding the control of variables that potentially could affect language processing. For instance, it would not be easy for the speaker to keep the same emotional facial expression and prosody across both sentences and participants. Although the thesis aimed to improve the ecological validity in the study of language comprehension, it is necessary to recognize the enormous difference between our experimental set-up and a real communicative situation. Advances may

come with the use of virtual reality environments. The strategy seems promising and some papers have been already published in the context of psycholinguistic research (e.g. Peeters, 2019; Tromp, Peeters, Meyer & Hagoot, 2018). Also, a significant step forward will probably come with the use of new techniques to study the brain activity like the functional near-infrared spectroscopy (fNIRS). This haemodynamic method provides better temporal resolution compared to the fMRI (although worse spatial resolution). However, the participant only needs to wear a cap similar to the EEG, being much more comfortable than the fMRI and, moreover, without the background noise (Rodd & Davis, 2017). Therefore, the participant could listen clearly to the speech and new experimental paradigms could be designed, even for interactive contexts.

In our studies it was not possible to assess that the semantic and syntactic processing were the only components of linguistic processing affected by our experimental manipulations. Since language comprehension is a hierarchical process, previous processes like the phonological analysis may be also affected. In the *second* and *third study* these effects were not expected because we used static pictures of the speakers instead of videos. Even though, it should be confirmed in future studies. For instance, emotion might have influenced the phonological analysis of auditory sentences.

A limitation of our linguistic material in the *second* and *third study* is that emotional valence of the sentences was not measured. However, the experiments were properly designed to control any possible related effect. Therefore, since every sentence appeared in every experimental condition, differences between them cannot be endorsed to distinct emotional valences.

A methodological limitation regarding the number of participants on each experiment is that it was not decided in the basis of previous analysis of statistical power. This would have been useful to demonstrate that the number of participants was

enough to detect the effect of interest. However, the number of participants on each experiment (20-30 individuals) was similar to the majority of psycholinguistic studies with ERPs.

In addition, in the present studies we did not applied any mathematical method to minimize the risk of false positives (beyond the Bonferroni correction in post-hoc comparisons). In future statistical analysis, this procedure may be advisable to achieve robustness in the results.

Regarding another methodological issue, the present thesis used ERP to benefit from its fine-grained temporal resolution compared to behavioural measures (Luck, 2014). Although this technique exhibits well-known advantages, it also has some limitations that should not be ignored. Thus, our results are limited to time-locked and phase-locked brain activity, while induced brain responses that are not phase-locked are also informative (David, Kilner & Friston, 2006) and may be necessary for a complete understanding of language processing in social contexts. For instance, it would be interesting to investigate how the brain integrates neural activity from “social brain” areas with that coming from linguistic networks by means of its neural synchrony (Fries, 2015). In addition, ERPs are measured at a specific moment, the critical word. In future work it would be interesting to study the dynamics of the brain electrical activity from the appearance of the speaker’s face and during the whole course of sentence comprehension.

These studies were a first approach to the neurophysiological study of syntax and semantics in face-to-face contexts; this line of research can be continued and improved with further experiments. A follow-up study, already in course, investigates the effect of social attention on language comprehension by manipulating speaker’s gaze direction (averted vs direct). Moreover, in another study we are investigating the

influence of the speaker's pupil size on speech processing. This one has been further improved by including eye-tracking measures, in addition to the EEG.

Therefore, the present thesis has provided the basis for a larger body of research. The field seems promising. Hence, for the future to come, I wish I had the opportunity to continue enquiring into the neural mysteries of socially-situated language comprehension.

10. CHAPTER 8. CONCLUSIONS

1. Our results indicate that contexts that are more similar to real face-to-face communicative situations entail higher attentional processing when language comprehension is not demanding. We predicted that semantic comprehension would be affected by the dynamic facial information, but the latter did not impact the neural correlates of semantic processing. Interestingly, when semantic comprehension is demanding, the brain prioritizes the processing of the auditory linguistic stream and neglects visual information from the speaker's face. By contrast, when listening to congruent sentences, the concomitant perception of the dynamic speaker's face generated a long-lasting posterior positivity. This was interpreted as a communicative effect because this situation largely resembles a natural situation.
2. We succeeded on the demonstration that the mere situation of the listener in a visual social context affects language comprehension. Our hypothesis described semantic and syntactic modulations when participants were presented the static face of the speaker compared to a control, non-social stimulus. Increased attention and deeper processing lead to an enhancement of the semantic N400 in the minimal social context. Even though, morphosyntactic processing was not affected at all by this manipulation.
3. This thesis has expanded the knowledge regarding the interaction between emotion and language processing to face-to-face contexts. In an attempt to increase ecological validity, we used connected speech instead of visual presentation of the linguistic stimuli, and the emotional conditions were manipulated by means of the speaker's emotional facial expression. Contrary to our predictions, semantic processing was not affected by the emotional facial expression of the speaker, though the reanalysis was facilitated when facing an

emotion-laden face, independently of its valence. On the other hand, our syntactic findings agree with our hypothesis, in line with previous studies that manipulated emotion within the processing of the sentences. The negative emotion prompted first-pass syntactic processes and consequently reduced the reanalysis of the morphosyntactic mismatches. To the contrary, the positive emotion almost eliminated the main syntactic processing and, therefore, caused the investment of more resources during the reanalysis. These results can be explained on the basis of differences in information processing styles -analytic and heuristic, respectively-.

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12. APPENDIX 1. LINGUISTIC MATERIAL *STUDY TWO AND STUDY THREE*

| CORRECT | SYNTACTICALLY INCORRECT | SEMANTICALLY INCORRECT |
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| 1. Algunos pintores abstractos discutieron sobre su arte | Algunos pintores abstractas discutieron sobre su arte | Algunos pintores aéreos discutieron sobre su arte |
| 2. El tráfico aéreo colapsó con la tormenta | El tráfico aérea colapsó con la tormenta | El tráfico abstracto colapsó con la tormenta |
| 3. Varios grupos africanos entretuvieron con sus ritmos | Varios grupos africanas entretuvieron con sus ritmos | Varios grupos colgados entretuvieron con sus ritmos |
| 4. Los timbres agudos resuenan en las puertas | Los timbres agudas resuenan en las puertas | Los timbres arados resuenan en las puertas |
| 5. Los paisajes alpinos predominan en esa región | Los paisajes alpino predominan en esa región | Los paisajes cautivos predominan en esa región |
| 6. La limusina alquilada disponía de un chófer | La limusina alquilado disponía de un chófer | La limusina batida disponía de un chófer |
| 7. Las pendientes altas imponen a los caminantes | Las pendientes alta imponen a los caminantes | Las pendientes persas imponen a los caminantes |
| 8. Un portero amable ayudó con las bolsas | Un portero amables ayudó con las bolsas | Un portero azul ayudó con las bolsas |
| 9. La flor amarilla crece en el jardín | La flor amarillo crece en el jardín | La flor asidua crece en el jardín |
| 10. Los maleteros amplios benefician a los pasajeros | Los maleteros amplias benefician a los pasajeros | Los maleteros citados benefician a los pasajeros |
| 11. Las sábanas anchas van con esa cama | Las sábanas anchos van con esa cama | Las sábanas cíclicas van con esa cama |
| 12. Estos dibujos animados entretienen a los niños | Estos dibujos animadas entretienen a los niños | Estos dibujos cardados entretienen a los niños |
| 13. El instinto animal importa para la supervivencia | El instinto animales importa para la supervivencia | El instinto cerrado importa para la supervivencia |
| 14. Este papiro antiguo procede de ese museo | Este papiro antigua procede de ese museo | Este papiro copioso procede de ese museo |
| 15. Ese campo arado perteneció a mi familia | Ese campo arados perteneció a mi familia | Ese campo típico perteneció a mi familia |
| 16. Los pollos asados humean en el horno | Los pollos asadas humean en el horno | Los pollos bordados humean en el horno |

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| 17. Las clientas asiduas comprarán durante las vacaciones | Las clientas asiduos comprarán durante las vacaciones | Las clientas amarillas comprarán durante las vacaciones |
| 18. Las máscaras azules triunfaron durante el carnaval | Las máscaras azul triunfaron durante el carnaval | Las máscaras amables triunfaron durante el carnaval |
| 19. Las persianas bajadas informan de su ausencia | Las persianas bajados informan de su ausencia | Las persianas borradas informan de su ausencia |
| 20. La galería barroca cuenta con ochenta obras | La galería barroco cuenta con ochenta obras | La galería ciega cuenta con ochenta obras |
| 21. Las explicaciones básicas interesaron a los aprendices | Las explicaciones básica interesaron a los aprendices | Las explicaciones domadas interesaron a los aprendices |
| 22. La crema batida salpicó a los cocineros | La crema batido salpicó a los cocineros | La crema alquilada salpicó a los cocineros |
| 23. Estos cojines blandos provienen de mi salón | Estos cojines blandas provienen de mi salón | Estos cojines clínicos provienen de mi salón |
| 24. El pañuelo bordado era de mi abuela | El pañuelo bordada era de mi abuela | El pañuelo asado era de mi abuela |
| 25. Las huellas borradas pertenecían a un humano | Las huellas borrados pertenecían a un humano | Las huellas bajadas pertenecían a un humano |
| 26. Las hojas caídas planean sobre la terraza | Las hojas caída planean sobre la terraza | Las hojas gallegas planean sobre la terraza |
| 27. La ensalada campera gustó a los comensales | La ensalada campero gustó a los comensales | La ensalada concreta gustó a los comensales |
| 28. Un minero cansado ascendió por el conducto | Un minero cansada ascendió por el conducto | Un minero amplio ascendió por el conducto |
| 29. El comité cántabro puntuará a los participantes | El comité cántabra puntuará a los participantes | El comité excesivo puntuará a los participantes |
| 30. Los pájaros cantores pían por el jardín | Los pájaros cantoras pían por el jardín | Los pájaros cuadrados pían por el jardín |
| 31. Esos peinados cardados aguantarán sin ningún retoque | Esos peinados cardadas aguantarán sin ningún retoque | Esos peinados forenses aguantarán sin ningún retoque |
| 32. Las enfermedades cardíacas preocupan a los fumadores | Las enfermedades cardiacos preocupan a los fumadores | Las enfermedades altas preocupan a los fumadores |
| 33. Unos delfines cautivos nadan en la piscina | Unos delfines cautivo nadan en la piscina | Unos delfines alpinos nadan en la piscina |
| 34. Los entrenadores cautos aconsejan a los jugadores | Los entrenadores cauto aconsejan a los jugadores | Los entrenadores compactos aconsejan a los jugadores |
| 35. El paquete cerrado sigue en la maleta | El paquete cerrados sigue en la maleta | El paquete velado sigue en la maleta |

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| 36. Los pasatiempos chinos entretienen a los viajeros | Los pasatiempos chinas entretienen a los viajeros | Los pasatiempos cortados entretienen a los viajeros |
| 37. La migración cíclica cambia durante la primavera | La migración cíclico cambia durante la primavera | La migración ancha cambia durante la primavera |
| 38. La señora ciega camina con un bastón | La señora ciego camina con un bastón | La señora barroca camina con un bastón |
| 39. El baño cincelado enamoró a los compradores | El baño cincelada enamoró a los compradores | El baño gastado enamoró a los compradores |
| 40. Los ejemplos citados convencieron por su claridad | Los ejemplos citadas convencieron por su claridad | Los ejemplos pardos convencieron por su claridad |
| 41. El derecho civil consta de estas leyes | El derecho civiles consta de estas leyes | El derecho oculto consta de estas leyes |
| 42. La ropa clara peligra con esa comida | La ropa claro peligra con esa comida | La ropa fiera peligra con esa comida |
| 43. La música clásica sonó durante la ceremonia | La música clásico sonó durante la ceremonia | La música pecosa sonó durante la ceremonia |
| 44. Estos análisis clínicos informarán a los médicos | Estos análisis clínicas informarán a los médicos | Estos análisis oscuros informarán a los médicos |
| 45. Los jamones colgados impresionaron a los turistas | Los jamones colgado impresionaron a los turistas | Los jamones técnicos impresionaron a los turistas |
| 46. La época colonial acabó con sus tradiciones | La época coloniales acabó con sus tradiciones | La época tosca acabó con sus tradiciones |
| 47. Sus discos compactos suenan en el reproductor | Sus discos compactas suenan en el reproductor | Sus discos cautos suenan en el reproductor |
| 48. El grupo completo asistirá a la convención | El grupo completa asistirá a la convención | El grupo frito asistirá a la convención |
| 49. La vestimenta comprada encogió tras el lavado | La vestimenta comprado encogió tras el lavado | La vestimenta flaca encogió tras el lavado |
| 50. Las zonas comunes llegaban a la cocina | Las zonas común llegaban a la cocina | Las zonas graduadas llegaban a la cocina |
| 51. Aquel espejo cóncavo entusiasmó a los niños | Aquel espejo cóncava entusiasmó a los niños | Aquel espejo civil entusiasmó a los niños |
| 52. El discurso conciso versa sobre la materia | El discurso concisa versa sobre la materia | El discurso estirado versa sobre la materia |
| 53. La hora concreta aparecerá en la pantalla | La hora concreto aparecerá en la pantalla | La hora campera aparecerá en la pantalla |
| 54. Las zonas conectadas mejorarán en sus comunicaciones | Las zonas conectada mejorarán en sus comunicaciones | Las zonas mansas mejorarán en sus comunicaciones |

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| 55. El desorden constante enfadó a mi madre | El desorden constantes enfadó a mi madre | El desorden elegido enfadó a mi madre |
| 56. El buque construido viajará por el Mediterráneo | El buque construida viajará por el Mediterráneo | El buque urbano viajará por el Mediterráneo |
| 57. La brisa continua duró hasta el amanecer | La brisa continuo duró hasta el amanecer | La brisa delgada duró hasta el amanecer |
| 58. Un detective contratado investiga en el caso | Un detective contratada investiga en el caso | Un detective doblado investiga en el caso |
| 59. Los desayunos copiosos llenaron a los huéspedes | Los desayunos copiosas llenaron a los huéspedes | Los desayunos nevados llenaron a los huéspedes |
| 60. Algunas rebanadas cortadas sobran en el plato | Algunas rebanadas cortada sobran en el plato | Algunas rebanadas africanas sobran en el plato |
| 61. Tus pantalones cortos caben en la bolsa | Tus pantalones cortas caben en la bolsa | Tus pantalones densos caben en la bolsa |
| 62. El clima costero varía en la península | El clima costera varía en la península | El clima digital varía en la península |
| 63. Las expectativas creadas acabaron con su tristeza | Las expectativas creados acabaron con su tristeza | Las expectativas sureñas acabaron con su tristeza |
| 64. El agua cristalina fluyó por el riachuelo | El agua cristalino fluyó por el riachuelo | El agua distinta fluyó por el riachuelo |
| 65. Las líneas cruzadas partían de dos puntos | Las líneas cruzados partían de dos puntos | Las líneas guisadas partían de dos puntos |
| 66. Los marcos cuadrados sirven para los dibujos | Los marcos cuadradas sirven para los dibujos | Los marcos cantores sirven para los dibujos |
| 67. Ese cobertizo cubierto protege a los animales | Ese cobertizo cubierta protege a los animales | Ese cobertizo entregado protege a los animales |
| 68. Los objetivos cumplidos sirvieron para el propósito | Los objetivos cumplidas sirvieron para el propósito | Los objetivos forrados sirvieron para el propósito |
| 69. Las carreteras curvas marearon a varios viajeros | Las carreteras curvos marearon a varios viajeros | Las carreteras etéreas marearon a varios viajeros |
| 70. La chica delgada anda por la acera | La chica delgadas anda por la acera | La chica continua anda por la acera |
| 71. Los olores densos perduran en el aire | Los olores denso perduran en el aire | Los olores inclinados perduran en el aire |
| 72. La cadena dentada gira en la bicicleta | La cadena dentado gira en la bicicleta | La cadena guiada gira en la bicicleta |
| 73. El ciudadano desconfiado vota con ciertas dudas | El ciudadano desconfiada vota con ciertas dudas | El ciudadano fucsia vota con ciertas dudas |

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| 74. La estantería desmontada sigue en el trastero | La estantería desmontado sigue en el trastero | La estantería nativa sigue en el trastero |
| 75. Un cura devoto sermonea a los creyentes | Un cura devotos sermonea a los creyentes | Un cura hueco sermonea a los creyentes |
| 76. La constancia diaria benefició a los opositores | La constancia diario benefició a los opositores | La constancia pintada benefició a los opositores |
| 77. El jefe diestro delegó en los operarios | El jefe diestros delegó en los operarios | El jefe construido delegó en los operarios |
| 78. El reloj digital vendrá con una luz | El reloj digitales vendrá con una luz | El reloj conciso vendrá con una luz |
| 79. Las perspectivas distintas aportaron a su aprendizaje | Las perspectivas distintos aportaron a su aprendizaje | Las perspectivas fundidas aportaron a su aprendizaje |
| 80. Un sobre doblado entra en el buzón | Un sobre doblada entra en el buzón | Un sobre contratado entra en el buzón |
| 81. Las focas domadas participan en la función | Las focas domados participan en la función | Las focas básicas participan en la función |
| 82. Las monedas doradas brillan con la luz | Las monedas dorados brillan con la luz | Las monedas lanosas brillan con la luz |
| 83. Los alcaldes electos destacan en la portada | Los alcaldes electas destacan en la portada | Los alcaldes cortos destacan en la portada |
| 84. Los azulejos elegidos combinan con el lavabo | Los azulejos elegidas combinan con el lavabo | Los azulejos lacios combinan con el lavabo |
| 85. Un público entregado acompañó durante las canciones | Un público entregada acompañó durante las canciones | Un público cubierto acompañó durante las canciones |
| 86. El archivo enviado llegará a su destino | El archivo enviada llegará a su destino | El archivo constante llegará a su destino |
| 87. El regalo envuelto intriga a los concursantes | El regalo envuelta intriga a los concursantes | El regalo numérico intriga a los concursantes |
| 88. Los autobuses escolares aparcan en la explanada | Los autobuses escolar aparcan en la explanada | Los autobuses liados aparcan en la explanada |
| 89. Los mensajes escritos informan con mayor claridad | Los mensajes escritas informan con mayor claridad | Los mensajes inflables informan con mayor claridad |
| 90. El ingeniero espacial consultó con su equipo | El ingeniero espaciales consultó con su equipo | El ingeniero neto consultó con su equipo |
| 91. El dedo estirado apuntó hacia el lugar | El dedo estirada apuntó hacia el lugar | El dedo costero apuntó hacia el lugar |
| 92. Esos ríos estrechos fluyen con la corriente | Esos ríos estrecho fluyen con la corriente | Esos ríos infantiles fluyen con la corriente |
| 93. Las respuestas etéreas abundan entre ciertos políticos | Las respuestas etéreos abundan entre ciertos políticos | Las respuestas chinas abundan entre ciertos políticos |

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| 94. El dato exacto coincide con la predicción | El dato exacta coincide con la predicción | El dato marrón coincide con la predicción |
| 95. El volumen excesivo perjudica a la salud | El volumen excesivos perjudica a la salud | El volumen cántabro perjudica a la salud |
| 96. Las actividades externas incluyen a los guías | Las actividades externos incluyen a los guías | Las actividades claras incluyen a los guías |
| 97. El tenista famoso entrena en la cancha | El tenista famosa entrena en la cancha | El tenista relativo entrena en la cancha |
| 98. La leona fiera ruge en la sabana | La leona fiero ruge en la sabana | La leona inglesa ruge en la sabana |
| 99. La luz fija alumbra en la noche | La luz fijas alumbra en la noche | La luz rociada alumbra en la noche |
| 100. La escena filmada termina con una canción | La escena filmado termina con una canción | La escena plantada termina con una canción |
| 101. Esa cortina fina trasluce con bastante luz | Esa cortina fino trasluce con bastante luz | Esa cortina animal trasluce con bastante luz |
| 102. Los documentos firmados comprometen a ambas partes | Los documentos firmadas comprometen a ambas partes | Los documentos hondos comprometen a ambas partes |
| 103. Los deportes físicos atraen a muchos hombres | Los deportes físicas atraen a muchos hombres | Los deportes licuados atraen a muchos hombres |
| 104. La chica flaca sonrío a su novio | La chica flaco sonrío a su novio | La chica comprada sonrío a su novio |
| 105. Las bailaoras flamencas actuarán en este tablao | Las bailaoras flamencos actuarán en este tablao | Las bailaoras creadas actuarán en este tablao |
| 106. Los horarios flexibles benefician a las familias | Los horarios flexible benefician a las familias | Los horarios rellenos benefician a las familias |
| 107. Los médicos forenses exploran con sus aparatos | Los médicos forense exploran con sus aparatos | Los médicos nacidos exploran con sus aparatos |
| 108. Los libros forrados duran por más tiempo | Los libros forradas duran por más tiempo | Los libros cumplidos duran por más tiempo |
| 109. Los aviones franceses vuelan con cierta frecuencia | Los aviones francesas vuelan con cierta frecuencia | Los aviones golosos vuelan con cierta frecuencia |
| 110. El tiempo frío volverá con el otoño | El tiempo fría volverá con el otoño | El tiempo indio volverá con el otoño |
| 111. El pescado frito agrada a los invitados | El pescado frita agrada a los invitados | El pescado tenso agrada a los invitados |
| 112. El vestido fucsia destaca por su color | El vestido fucsias destaca por su color | El vestido desconfiado destaca por su color |
| 113. Las campanas fundidas replican en la catedral | Las campanas fundidos replican en la catedral | Las campanas flexibles replican en la catedral |

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| 114. Las empanadas gallegas triunfan por toda España | Las empanadas gallegos triunfan por toda España | Las empanadas postizas triunfan por toda España |
| 115. Mi bolígrafo gastado escribe con bastante dificultad | Mi bolígrafo gastada escribe con bastante dificultad | Mi bolígrafo cincelado escribe con bastante dificultad |
| 116. Los comensales golosos disfrutaron con las tartas | Los comensales golosas disfrutaron con las tartas | Los comensales pasados disfrutaron con las tartas |
| 117. Las cuerdas gordas sirven para la embarcación | Las cuerdas gordos sirven para la embarcación | Las cuerdas veraniegas sirven para la embarcación |
| 118. El arte gótico surgió tras el románico | El arte gótica surgió tras el románico | El arte saltarín surgió tras el románico |
| 119. La música grabada suena con mucha calidad | La música grabado suena con mucha calidad | La música rizada suena con mucha calidad |
| 120. Las lentes graduadas proceden de mi óptica | Las lentes graduados proceden de mi óptica | Las lentes reales proceden de mi óptica |
| 121. El botón grande abrocha sin gran dificultad | El botón grandes abrocha sin gran dificultad | El botón solar abrocha sin gran dificultad |
| 122. El deportista griego entrena para las Olimpiadas | El deportista griega entrena para las Olimpiadas | El deportista plegable entrena para las Olimpiadas |
| 123. Las chaquetas gruesas abrigan durante el invierno | Las chaquetas gruesos abrigan durante el invierno | Las chaquetas líricas abrigan durante el invierno |
| 124. El dinero guardado pertenece a su socio | El dinero guardada pertenece a su socio | El dinero oral pertenece a su socio |
| 125. Las visitas guiadas cumplieron con las expectativas | Las visitas guiados cumplieron con las expectativas | Las visitas dentadas cumplieron con las expectativas |
| 126. La carne guisada cuece en la olla | La carne guisado cuece en la olla | La carne cruzada cuece en la olla |
| 127. Los puros habanos satisfacen a los fumadores | Los puros habano satisfacen a los fumadores | Los puros neutros satisfacen a los fumadores |
| 128. La comida hecha aguanta en el congelador | La comida hecho aguanta en el congelador | La comida morena aguanta en el congelador |
| 129. El viento helado sopla en el Ártico | El viento helada sopla en el Ártico | El viento completo sopla en el Ártico |
| 130. Las fibras hiladas sirvieron para el tejido | Las fibras hilados sirvieron para el tejido | Las fibras ocupadas sirvieron para el tejido |
| 131. Los pozos hondos atemorizan a su hijo | Los pozos hondo atemorizan a su hijo | Los pozos firmados atemorizan a su hijo |

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| 132. Un tronco hueco arde en la chimenea | Un tronco huecos arde en la chimenea | Un tronco devoto arde en la chimenea |
| 133. El caballo huesudo requiere de más cuidados | El caballo huesuda requiere de más cuidados | El caballo meloso requiere de más cuidados |
| 134. El carácter humano difiere entre las personas | El carácter humana difiere entre las personas | El carácter enviado difiere entre las personas |
| 135. Ese trapo húmedo limpió a la primera | Ese trapo húmeda limpió a la primera | Ese trapo secreto limpió a la primera |
| 136. El libro inclinado sobresale de la estantería | El libro inclinada sobresale de la estantería | El libro molesto sobresale de la estantería |
| 137. Algunas culturas indígenas luchan por su supervivencia | Algunas culturas indígena luchan por su supervivencia | Algunas culturas semanales luchan por su supervivencia |
| 138. El cine indio prolifera en la cartelera | El cine india prolifera en la cartelera | El cine quieto prolifera en la cartelera |
| 139. Los juegos infantiles cautivan a los abuelos | Los juegos infantil cautivan a los abuelos | Los juegos estrechos cautivan a los abuelos |
| 140. Varias pelotas inflables rodaron por la arena | Varias pelotas inflable rodaron por la arena | Varias pelotas escritas rodaron por la arena |
| 141. Una llave inglesa quebró por la presión | Una llave inglesas quebró por la presión | Una llave llena quebró por la presión |
| 142. Los presentadores jóvenes animan a los concursantes | Los presentadores joven animan a los concursantes | Los presentadores ovalados animan a los concursantes |
| 143. Aquellos terrenos labrados esperan hasta la siembra | Aquellos terrenos labradas esperan hasta la siembra | Aquellos terrenos mezclados esperan hasta la siembra |
| 144. Las mesas lacadas armonizan con la decoración | Las mesas lacados armonizan con la decoración | Las mesas mudas armonizan con la decoración |
| 145. Los mechones lacios caen sobre sus hombros | Los mechones lacias caen sobre sus hombros | Los mechones antiguos caen sobre sus hombros |
| 146. Los productos lácteos fermentan en los recipientes | Los productos lácteos fermentan en los recipientes | Los productos oblicuos fermentan en los recipientes |
| 147. Unas ovejas lanosas balan en el prado | Unas ovejas lanosos balan en el prado | Unas ovejas doradas balan en el prado |
| 148. Aquella vía larga termina en la estación | Aquella vía largo termina en la estación | Aquella vía ronca termina en la estación |
| 149. El ritmo lento caracteriza a ese baile | El ritmo lenta caracteriza a ese baile | El ritmo húmedo caracteriza a ese baile |
| 150. Esos arbustos leñosos enraízan en la tierra | Esos arbustos leñoso enraízan en la tierra | Esos arbustos válidos enraízan en la tierra |

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| 151. Los cigarrillos liados sustituirán a los normales | Los cigarrillos liadas sustituirán a los normales | Los cigarrillos escolares sustituirán a los normales |
| 152. Los plátanos licuados gustan a los bebés | Los plátanos licuadas gustan a los bebés | Los plátanos físicos gustan a los bebés |
| 153. Las maderas lijadas encajarán en esa estantería | La maderas lijados encajarán en esa estantería | La maderas masivas encajarán en esa estantería |
| 154. Algunas obras líricas emocionaron por su contenido | Algunas obras líricos emocionaron por su contenido | Algunas obras cardiacas emocionaron por su contenido |
| 155. Su melena lisa ondeaba con el viento | Su melena liso ondeaba con el viento | Su melena cristalina ondeaba con el viento |
| 156. El tejido liviano refrescaba durante el verano | El tejido liviana refrescaba durante el verano | El tejido paterno refrescaba durante el verano |
| 157. El camino llano reconfortó a los senderistas | El camino llana reconfortó a los senderistas | El camino plástico reconfortó a los senderistas |
| 158. La luna llena alumbra en el desierto | La luna lleno alumbra en el desierto | La luna clásica alumbra en el desierto |
| 159. Las frutas maduras abundan en el huerto | Las frutas maduros abundan en el huerto | Las frutas planas abundan en el huerto |
| 160. El militar manco volvió con su familia | El militar manca volvió con su familia | El militar vacuno volvió con su familia |
| 161. Las perras mansas olfatean a sus cachorros | Las perras mansos olfatean a sus cachorros | Las perras conectadas olfatean a sus cachorros |
| 162. Los objetivos marcados motivan a los empleados | Los objetivos marcadas motivan a los empleados | Los objetivos verdes motivan a los empleados |
| 163. La guardia marina vigila a los navegantes | La guardia marinas vigila a los navegantes | La guardia fina vigila a los navegantes |
| 164. El grillo marrón enmudece por el frío | El grillo marrones enmudece por el frío | El grillo selecto enmudece por el frío |
| 165. Las importaciones masivas continúan desde esos países | Las importaciones masivos continúan desde esos países | Las importaciones lijadas continúan desde esos países |
| 166. Los señores mayores duermen durante el descanso | Los señores mayor duermen durante el descanso | Los señores tostados duermen durante el descanso |
| 167. Unas armaduras medievales impresionaron a los historiadores | Unas armaduras medieval impresionaron a los historiadores | Unas armaduras personales impresionaron a los historiadores |
| 168. Las canciones melódicas entretienen a los presentes | Las canciones melódicos entretienen a los presentes | Las canciones externas entretienen a los presentes |

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| 169. El arroz meloso hierve en la olla | El arroz melosa hierve en la olla | El arroz huesudo hierve en la olla |
| 170. Las ovejas merinas rentan por su lana | Las ovejas merina rentan por su lana | Las ovejas sonrientes rentan por su lana |
| 171. Los líquidos mezclados explotaron en el laboratorio | Los líquidos mezcladas explotaron en el laboratorio | Los líquidos animados explotaron en el laboratorio |
| 172. Las batas mojadas gotean en el tendedero | Las batas mojados gotean en el tendedero | Las batas periódicas gotean en el tendedero |
| 173. El hombre molesto gritó a la dependienta | El hombre molesta gritó a la dependienta | El hombre olímpico gritó a la dependienta |
| 174. Las cebollas moradas sirven para las ensaladas | Las cebollas morados sirven para las ensaladas | Las cebollas oficiales sirven para las ensaladas |
| 175. La chica morena cerró con un portazo | La chica moreno cerró con un portazo | La chica hecha cerró con un portazo |
| 176. Las películas mudas triunfaron hace muchos años | Las películas mudos triunfaron hace muchos años | Las películas lacadas triunfaron hace muchos años |
| 177. Los recién nacidos lloran en sus cunas | Los recién nacidas lloran en sus cunas | Los recién labrados lloran en sus cunas |
| 178. Las ventas nacionales superarán a las exportaciones | Las ventas nacional superarán a las exportaciones | Las ventas peludas superarán a las exportaciones |
| 179. La profesora nativa tradujo sin ninguna ayuda | La profesora nativo tradujo sin ninguna ayuda | La profesora desmontada tradujo sin ninguna ayuda |
| 180. El camión negro frena en la carretera | El camión negros frena en la carretera | El camión otoñal frena en la carretera |
| 181. Tu sueldo neto constará en el contrato | Tu sueldo neta constará en el contrato | Tu sueldo espacial constará en el contrato |
| 182. Los colores neutros combinan con el gris | Los colores neutras combinan con el gris | Los colores habanos combinan con el gris |
| 183. Las colinas nevadas abundan en el paisaje | Las colinas nevados abundan en el paisaje | Las colinas moradas abundan en el paisaje |
| 184. La imagen nítida apareció en el telescopio | La imagen nítido apareció en el telescopio | La imagen merina apareció en el telescopio |
| 185. Muchos trenes nocturnos llegan a la ciudad | Muchos trenes nocturnas llegan a la ciudad | Muchos trenes pocos llegan a la ciudad |
| 186. Este edredón nórdico conjuntará con la decoración | Este edredón nórdica conjuntará con la decoración | Este edredón remoto conjuntará con la decoración |
| 187. Mi pluma nueva viene con esa tinta | Mi pluma nuevo viene con esa tinta | Mi pluma rápida viene con esa tinta |

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| 188. Este código numérico corresponde con tu vuelo | Este código numérica corresponde con tu vuelo | Este código griego corresponde con tu vuelo |
| 189. Los planos oblicuos sustituyeron a los horizontales | Los planos oblicuas sustituyeron a los horizontales | Los planos lácteos sustituyeron a los horizontales |
| 190. El testigo oculto mira por la rejilla | El testigo oculta mira por la rejilla | El testigo partido mira por la rejilla |
| 191. Las taquillas ocupadas son de los estudiantes | Las taquillas ocupados son de los estudiantes | Las taquillas hiladas son de los estudiantes |
| 192. Tus documentos oficiales van con un sello | Tus documentos oficial van con un sello | Tus documentos pillos van con un sello |
| 193. El presupuesto olímpico aumenta con estos acuerdos | El presupuesto olímpica aumenta con estos acuerdos | El presupuesto diestro aumenta con estos acuerdos |
| 194. La bandera ondeada emocionó a los ganadores | La bandera ondeado emocionó a los ganadores | La bandera rubia emocionó a los ganadores |
| 195. Estos materiales opacos protegerán de la luz | Estos materiales opacas protegerán de la luz | Estos materiales regados protegerán de la luz |
| 196. La fibra óptica beneficia a los usuarios | La fibra óptico beneficia a los usuarios | La fibra rústica beneficia a los usuarios |
| 197. Las piezas opuestas encajan en el puzle | Las piezas opuestos encajan en el puzle | Las piezas sembradas encajan en el puzle |
| 198. El lenguaje oral surgió hace muchísimos años | El lenguaje orales surgió hace muchísimos años | El lenguaje guardado surgió hace muchísimos años |
| 199. Ese niño osado observa a la cuidadora | Ese niño osada observa a la cuidadora | Ese niño sólido observa a la cuidadora |
| 200. El bolso oscuro gustó a la señora | El bolso oscura gustó a la señora | El bolso sentado gustó a la señora |
| 201. Los problemas óseos disminuyeron con el tratamiento | Los problemas óseas disminuyeron con el tratamiento | Los problemas sujetos disminuyeron con el tratamiento |
| 202. El aire otoñal enfría a los vecinos | El aire otoñales enfría a los vecinos | El aire negro enfría a los vecinos |
| 203. Los globos ovalados flotan por el cielo | Los globos ovaladas flotan por el cielo | Los globos jóvenes flotan por el cielo |
| 204. El ganado ovino pasta en la montaña | El ganado ovinos pasta en la montaña | El ganado frio pasta en la montaña |
| 205. El acuerdo pactado agradó a ambos bandos | El acuerdo pactada agradó a ambos bandos | El acuerdo rosado agradó a ambos bandos |
| 206. Los ciervos pardos corren por la explanada | Los ciervos pardas corren por la explanada | Los ciervos nítidos corren por la explanada |
| 207. El horario partido caracteriza a esos comercios | El horario partida caracteriza a esos comercios | El horario filmado caracteriza a esos comercios |

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| 208. Los problemas pasados sirvieron como un aprendizaje | Los problemas pasadas sirvieron como un aprendizaje | Los problemas teñidos sirvieron como un aprendizaje |
| 209. El encuentro paterno terminó con un abrazo | El encuentro paternos terminó con un abrazo | El encuentro liviano terminó con un abrazo |
| 210. La cajera pecosa cobró a los ancianos | La cajera pecoso cobró a los ancianos | La cajera salvaje cobró a los ancianos |
| 211. Unas ardillas peludas saltan por las ramas | Unas ardillas peludos saltan por las ramas | Unas ardillas sugeridas saltan por las ramas |
| 212. Los tornillos pequeños funcionan a la perfección | Los tornillos pequeñas funcionan a la perfección | Los tornillos servidos funcionan a la perfección |
| 213. Los análisis periódicos previnieron de una recaída | Los análisis periódicas previnieron de una recaída | Los análisis mojados previnieron de una recaída |
| 214. Las alfombras persas contrastan con el tapiz | Las alfombras persa contrastan con el tapiz | Las alfombras leñosas contrastan con el tapiz |
| 215. Sus argumentos personales convencerán a la asamblea | Sus argumentos personal convencerán a la asamblea | Sus argumentos franceses convencerán a la asamblea |
| 216. El recipiente pesado cayó desde la mesa | El recipiente pesados cayó desde la mesa | El recipiente unánime cayó desde la mesa |
| 217. Los alumnos pillos juegan en el recreo | Los alumnos pillas juegan en el recreo | Los alumnos caídos juegan en el recreo |
| 218. Una casa pintada resalta en la maqueta | Una casa pintado resalta en la maqueta | Una casa diaria resalta en la maqueta |
| 219. Las suelas planas triunfaron ante los tacones | Las suelas planos triunfaron ante los tacones | Las suelas maduras triunfaron ante los tacones |
| 220. Las hortalizas plantadas crecerán con mucho agua | Las hortalizas plantados crecerán con mucho agua | Las hortalizas marinas crecerán con mucho agua |
| 221. Los cirujanos plásticos operarán en esa cabina | Los cirujanos plásticas operarán en esa cabina | Los cirujanos llanos operarán en esa cabina |
| 222. El ordenador plegable funciona con ese cargador | El ordenador plegables funciona con ese cargador | El ordenador ovino funciona con ese cargador |
| 223. El mantel plegado cabe en el cajón | El mantel plegada cabe en el cajón | El mantel pulido cabe en el cajón |
| 224. Estos tomates pocos siguen con mucho moho | Estos tomates pocas siguen con mucho moho | Estos tomates nocturnos siguen con mucho moho |
| 225. Las dentaduras postizas abundan entre los ancianos | Las dentaduras postizos abundan entre los ancianos | Las dentaduras coloniales abundan entre los ancianos |

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| 226. El agua potable sirve para el consumo | El agua potables sirve para el consumo | El agua redonda sirve para el consumo |
| 227. El examen práctico benefició a los expertos | El examen práctica benefició a los expertos | El examen terso benefició a los expertos |
| 228. Los colores primarios abundan en la foto | Los colores primarias abundan en la foto | Los colores pequeños abundan en la foto |
| 229. El sector privado negocia con la Administración | El sector privada negocia con la Administración | El sector rugoso negocia con la Administración |
| 230. El estanque profundo impresiona a los caminantes | El estanque profunda impresiona a los caminantes | El estanque sorprendido impresiona a los caminantes |
| 231. La universidad pública necesita de más profesores | La universidad público necesita de más profesores | La universidad tupida necesita de más profesores |
| 232. La noticia publicada atañe a los inversores | La noticia publicado atañe a los inversores | La noticia potable atañe a los inversores |
| 233. El mármol pulido reluce en la sala | El mármol pulida reluce en la sala | El mármol plegado reluce en la sala |
| 234. El niño quieto lee en la biblioteca | El niño quieta lee en la biblioteca | El niño envuelto lee en la biblioteca |
| 235. El coche rápido adelanta a los camiones | El coche rápida adelanta a los camiones | El coche suelto adelanta a los camiones |
| 236. Los motivos reales desconcertaron a la policía | Los motivos real desconcertaron a la policía | Los motivos romanos desconcertaron a la policía |
| 237. Una información reciente culpa a los acusados | Una información recientes culpa a los acusados | Una información soriana culpa a los acusados |
| 238. El oso recostado vigilaba a sus crías | El oso recostada vigilaba a sus crías | El oso primario vigilaba a sus crías |
| 239. Los trazos rectos enloquecían a ese pintor | Los trazos rectas enloquecían a ese pintor | Los trazos rurales enloquecían a ese pintor |
| 240. La lona redonda protegía de la nieve | La lona redondo protegía de la nieve | La lona publicada protegía de la nieve |
| 241. Los campos regados producirán para la cosecha | Los campos regadas producirán para la cosecha | Los campos opacos producirán para la cosecha |
| 242. El valor relativo interesa a los compradores | El valor relativos interesa a los compradores | El valor famoso interesa a los compradores |
| 243. Los bollos rellenos gustan para la merienda | Los bollos rellenas gustan para la merienda | Los bollos viejos gustan para la merienda |
| 244. El control remoto funciona con las pilas | El control remota funciona con las pilas | El control grande funciona con las pilas |
| 245. La cabellera rizada resalta en la foto | La cabellera rizado resalta en la foto | La cabellera grabada resalta en la foto |

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| 246. El agua rociada refrescaba en las terrazas | El agua rociado refrescaba en las terrazas | El agua fija refrescaba en las terrazas |
| 247. El puente romano permanece en su lugar | El puente romana permanece en su lugar | El puente total permanece en su lugar |
| 248. Su voz ronca tembló durante la declaración | Su voz ronco tembló durante la declaración | Su voz larga tembló durante la declaración |
| 249. El vino rosado emborrachó a la pareja | El vino rosada emborrachó a la pareja | El vino recto emborrachó a la pareja |
| 250. Mi pantalón roto cuelga de la ventana | Mi pantalón rotos cuelga de la ventana | Mi pantalón trazado cuelga de la ventana |
| 251. La alumna rubia aprende de los compañeros | La alumna rubio aprende de los compañeros | La alumna ondeada aprende de los compañeros |
| 252. La sogá rugosa raspaba con el roce | La sogá rugoso raspaba con el roce | La sogá privada raspaba con el roce |
| 253. Los municipios rurales abundan en esa zona | Los municipios rural abundan en esa zona | Los municipios blandos abundan en esa zona |
| 254. La vivienda rústica resultó de su agrado | La vivienda rústicas resultó de su agrado | La vivienda óptica resultó de su agrado |
| 255. El texto sagrado orienta a los feligreses | El texto sagrada orienta a los feligreses | El texto helado orienta a los feligreses |
| 256. El gato saltarín corre por el desván | El gato saltarines corre por el desván | El gato gótico corre por el desván |
| 257. La pantera salvaje dormía en el árbol | La pantera salvajes dormía en el árbol | La pantera nueva dormía en el árbol |
| 258. Las flores secas abundan en el cementerio | Las flores secos abundan en el cementerio | Las flores sonoras abundan en el cementerio |
| 259. El escondite secreto apareció tras los matorrales | El escondite secreta apareció tras los matorrales | El escondite flamenco apareció tras los matorrales |
| 260. Varios profesores selectos enseñarán en mi universidad | Varios profesores selectas enseñarán en mi universidad | Varios profesores visibles enseñarán en mi universidad |
| 261. Las ofertas semanales abundan en la teletienda | Las ofertas semanal abundan en la teletienda | Las ofertas indígenas abundan en la teletienda |
| 262. Las semillas sembradas florecerán en los jardines | Las semillas sembrados florecerán en los jardines | Las semillas opuestas florecerán en los jardines |
| 263. Un cura sentado escucha en el confesionario | Un cura sentada escucha en el confesionario | Un cura pactado escucha en el confesionario |
| 264. Los licores servidos embriagan a la clientela | Los licores servidas embriagan a la clientela | Los licores cóncavos embriagan a la clientela |
| 265. La crema solar protege por su composición | La crema solares protege por su composición | La crema pública protege por su composición |

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| 266. El cemento sólido dura con el tiempo | El cemento sólidos dura con el tiempo | El cemento osado dura con el tiempo |
| 267. Las señas sonoras avisan a los peatones | Las señas sonoros avisan a los peatones | Las señas secas avisan a los peatones |
| 268. La niña sonriente juega con su hermano | La niña sonrientes juega con su hermano | La niña reciente juega con su hermano |
| 269. La cocina soriana deleita por su variedad | La cocina soriano deleita por su variedad | La cocina zurda deleita por su variedad |
| 270. El ladrón sorprendido escapó de la casa | El ladrón sorprendida escapó de la casa | El ladrón profundo escapó de la casa |
| 271. El dinero suelto tintinea en la caja | El dinero suelta tintinea en la caja | El dinero tintado tintinea en la caja |
| 272. Las pinturas sugeridas estaban en el folleto | Las pinturas sugeridos estaban en el folleto | Las pinturas vaqueras estaban en el folleto |
| 273. Los mástiles sujetos vibran en la plataforma | Los mástiles sujetas vibran en la plataforma | Los mástiles óseos vibran en la plataforma |
| 274. La comida sureña pica por la salsa | La comida sureño pica por la salsa | La comida rota pica por la salsa |
| 275. Varios especialistas técnicos trabajaron en ese proyecto | Varios especialistas técnico trabajaron en ese proyecto | Varios especialistas comunes trabajaron en ese proyecto |
| 276. El cable tenso viene de la antena | El cable tensa viene de la antena | El cable tropical viene de la antena |
| 277. Los cueros teñidos destiñen con los años | Los cueros teñidas destiñen con los años | Los cueros exactos destiñen con los años |
| 278. Los aislantes térmicos protegieron de la helada | Los aislantes térmicas protegieron de la helada | Los aislantes cansados protegieron de la helada |
| 279. La piel tersa caracteriza a los jóvenes | La piel tersas caracteriza a los jóvenes | La piel práctica caracteriza a los jóvenes |
| 280. Unas lunas tintadas ocultaron a los famosos | Unas lunas tintados ocultaron a los famosos | Unas lunas nórdicas ocultaron a los famosos |
| 281. Las historias típicas abundan entre sus cuentos | Las historias típica abundan entre sus cuentos | Las historias vendidas abundan entre sus cuentos |
| 282. La imagen tosca correspondía a ese animal | La imagen tosco correspondía a ese animal | La imagen aguda correspondía a ese animal |
| 283. Los panes tostados crujen en la boca | Los panes tostadas crujen en la boca | Los panes mayores crujen en la boca |
| 284. La recuperación total dependerá de la rehabilitación | La recuperación totales dependerá de la rehabilitación | La recuperación lisa dependerá de la rehabilitación |
| 285. El itinerario trazado involucró a más localidades | El itinerario trazados involucró a más localidades | El itinerario térmico involucró a más localidades |

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| 286. El pájaro tropical canta en la selva | El pájaro tropicales canta en la selva | El pájaro humano canta en la selva |
| 287. La cortina tupida cuelga de la ventana | La cortina tupido cuelga de la ventana | La cortina lenta cuelga de la ventana |
| 288. La decisión unánime influirá sobre su condena | La decisión unánimes influirá sobre su condena | La decisión pesada influirá sobre su condena |
| 289. El autobús urbano para en la comisaría | El autobús urbana para en la comisaría | El autobús sagrado para en la comisaría |
| 290. El queso vacuno cuaja en la bodega | El queso vacuna cuaja en la bodega | El queso manco cuaja en la bodega |
| 291. Los billetes válidos pasarán por la máquina | Los billetes válidas pasarán por la máquina | Los billetes gruesos pasarán por la máquina |
| 292. Las blusas vaqueras caben en la maleta | Las blusas vaqueros caben en la maleta | Las blusas nacionales caben en la maleta |
| 293. Las propuestas variadas encantaron a los votantes | Las propuestas variados encantaron a los votantes | Las propuestas curvas encantaron a los votantes |
| 294. Mi foto velada sirvió para el ejemplo | Mi foto velado sirvió para el ejemplo | Mi foto electa sirvió para el ejemplo |
| 295. El piso vendido necesita de varias reformas | El piso vendida necesita de varias reformas | El piso variado necesita de varias reformas |
| 296. Las hogueras veraniegas reúnen a muchos amigos | Las hogueras veraniegos reúnen a muchos amigos | Las hogueras gordas reúnen a muchos amigos |
| 297. Las judías verdes nutren a esa población | Las judías verde nutren a esa población | Las judías marcadas nutren a esa población |
| 298. Algunos barriles viejos están en el desván | Algunos barriles viejas están en el desván | Algunos barriles melódicos están en el desván |
| 299. Los carteles visibles avisan de los peligros | Los carteles visible avisan de los peligros | Los carteles recostados avisan de los peligros |
| 300. El futbolista zurdo avanzó por la izquierda | El futbolista zurda avanzó por la izquierda | El futbolista medieval avanzó por la izquierda |
| 301. Estos olivos han producido un aceite exquisito | Estos olivos han producido un aceites exquisito | Estos olivos han producido un altavoz exquisito |
| 302. Un pasajero ha inclinado el asiento trasero | Un pasajero ha inclinado el asientos trasero | Un pasajero ha inclinado el buceador trasero |
| 303. El comandante ha pilotado un avión ultrasónico | El comandante ha pilotado un aviones ultrasónico | El comandante ha pilotado un suelo ultrasónico |
| 304. El naufragio ha sido un barco transatlántico | El naufragio ha sido un barcos transatlántico | El naufragio ha sido un brazo transatlántico |
| 305. La destilería ha apartado el barril defectuoso | La destilería ha apartado el barriles defectuoso | La destilería ha apartado el cordero defectuoso |

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| 306. Los ciclistas han recogido las bebidas isotónicas | Los ciclistas han recogido las bebida isotónicas | Los ciclistas han recogido las calles isotónicas |
| 307. La novia ha elegido el blanco marfil | La novia ha elegido el blancos marfil | La novia ha elegido el dedo marfil |
| 308. Unos guardabosques habían divisado un búho real | Unos guardabosques habían divisado un búhos real | Unos guardabosques habían divisado un horno real |
| 309. Este jinete ha montado un caballo enorme | Este jinete ha montado un caballos enorme | Este jinete ha montado un azúcar enorme |
| 310. Un policía había parado el camión sospechoso | Un policía había parado el camiones sospechoso | Un policía había parado el póster sospechoso |
| 311. La lluvia había dejado los campos encharcados | La lluvia había dejado los campo encharcados | La lluvia había dejado los programas encharcados |
| 312. Los golpes habían dejado sus caras hinchadas | Los golpes habían dejado sus cara hinchadas | Los golpes habían dejado su tierra hinchada |
| 313. Los gladiadores habían protagonizado el circo romano | Los gladiadores habían protagonizado el circos romano | Los gladiadores habían protagonizado el ascensor romano |
| 314. Los albañiles han dejado la cocina sucia | Los albañiles han dejado la cocinas sucia | Los albañiles han dejado el astronauta sucio |
| 315. El restaurante ha contratado un cocinero profesional | El restaurante ha contratado un cocinera profesional | El restaurante ha contratado un chaleco profesional |
| 316. EL obrero ha reparado la columna agrietada | El obrero ha reparado la columnas agrietada | El obrero ha reparado el folleto agrietado |
| 317. Los perros han capturado muchos conejos grandes | Los perros han capturado muchos conejas grandes | Los perros han capturado muchos corchos grandes |
| 318. El cartero ha repartido el correo ordinario | El cartero ha repartido el correos ordinario | El cartero ha repartido el molinillo ordinario |
| 319. Esta crema ha hidratado sus cuellos quemados | Esta crema ha hidratado sus cuello quemados | Esta crema ha hidratado sus adultos quemados |
| 320. Unos montañeros han encontrado su cuerpo inerte | Unos montañeros han encontrado su cuerpos inerte | Unos montañeros han encontrado su edificio inerte |
| 321. Su jefe ha tenido un detalle feo | Su jefe ha tenido un detalles feo | Su jefe ha tenido un pienso feo |
| 322. Algunas tiendas han admitido los dólares americanos | Algunas tiendas han admitido los dólar americanos | Algunas tiendas han admitido los leones americanos |
| 323. El lesionado ha evitado los ejercicios pesados | El lesionado ha evitado los ejercicio pesados | El lesionado ha evitado los géneros pesados |

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| 324. Los jóvenes han denunciado los empleos precarios | Los jóvenes han denunciado los empleo precarios | Los jóvenes han denunciado los cuencos precarios |
| 325. Aquella familia ha comido una ensalada mixta | Aquella familia ha comido una ensaladas mixta | Aquella familia ha comido una arena mixta |
| 326. Su maestro había sido un erudito oriental | Su maestro había sido un erudita oriental | Su maestro había sido un farol oriental |
| 327. El editor había encontrado un escritor competente | El editor había encontrado un escritora competente | El editor había encontrado un otoño competente |
| 328. Las furgonetas han ocupado los espacios vacíos | Las furgonetas han ocupado los espacio vacíos | Las furgonetas han ocupado los huevos vacíos |
| 329. La mujer había deseado un esposo fiel | La mujer había deseado un esposa fiel | La mujer había deseado un lápiz fiel |
| 330. La marea ha generado bastante espuma blanquecina | La marea ha generado bastante espumas blanquecina | La marea ha generado bastantes ventanas blanquecinas |
| 331. Un electricista ha arreglado la estufa rota | Un electricista ha arreglado la estufas rota | Un electricista ha arreglado la carretera rota |
| 332. Su novia había acariciado el gato peludo | Su novia había acariciado el gata peludo | Su novia había acariciado el mercado peludo |
| 333. El torneo ha reunido varios gimnastas europeos | El torneo ha reunido varios gimnasta europeos | El torneo ha reunido varios inviernos europeos |
| 334. Los turistas habían fotografiado los glaciares árticos | Los turistas habían fotografiado los glaciar árticos | Los turistas habían fotografiado los pensamientos árticos |
| 335. El edificio había albergado algún habitante extranjero | El edificio había albergado algún habitantes extranjero | El edificio había albergado algún cuaderno extranjero |
| 336. Ese perro había comido la hamburguesa cruda | Ese perro había comido la hamburguesas cruda | Ese perro había comido la bombilla cruda |
| 337. Los alemanes habían preferido los hoteles costeros | Los alemanes habían preferido los hotel costeros | Los alemanes habían preferido los cuellos costeros |
| 338. La freidora ha generado un humo insoportable | La freidora ha generado un humos insoportable | La freidora ha generado un banco insoportable |
| 339. Ese cantante había sido mi ídolo juvenil | Ese cantante había sido mi ídolos juvenil | Ese cantante había sido mi escenario juvenil |
| 340. El deportista ha ejecutado una jugada agresiva | El deportista ha ejecutado una jugadas agresiva | El deportista ha ejecutado una botella agresiva |
| 341. Los chavales habían perseguido una lagartija gris | Los chavales habían perseguido una lagartijas gris | Los chavales habían perseguido una horquilla gris |

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| 342. Los italianos han elaborado una lasaña buenisima | Los italianos han elaborado una lasañas buenisima | Los italianos han elaborado una roca buenisima |
| 343. La asistenta ha limpiado los lavabos sucios | La asistenta ha limpiado los lavabo sucios | La asistenta ha limpiado los molinos sucios |
| 344. Esta nevera ha conservado la leche fresca | Esta nevera ha conservado la leches fresca | Esta nevera ha conservado la cortina fresca |
| 345. Los lectores han comprado algunos libros nuevos | Los lectores han comprado algunos libro nuevos | Los lectores han comprado algunos centros nuevos |
| 346. El señor ha comido una magdalena casera | El señor ha comido una magdalenas casera | El señor ha comido una puerta casera |
| 347. El pianista ha tenido la mano dolorida | El pianista ha tenido la manos dolorida | El pianista ha tenido la ciudad dolorida |
| 348. Los pequeños han observado las mariquitas rojas | Los pequeños han observado las mariquita rojas | Los pequeños han observado las mentes rojas |
| 349. El accidente había dañado sus memorias pasadas | El accidente había dañado sus memoria pasadas | El accidente había dañado sus noticias pasadas |
| 350. La psicología ha investigado la mente humana | La psicología ha investigado la mentes humana | La psicología ha investigado la lámpara humana |
| 351. Un puñetazo ha dejado su mentón dolorido | Un puñetazo ha dejado su mentones dolorido | Un puñetazo ha dejado su rojo dolorido |
| 352. La cooperativa había elaborado una mermelada ecológica | La cooperativa había elaborado una mermeladas ecológica | La cooperativa había elaborado una nieve ecológica |
| 353. El bizcocho había rebasado el molde metálico | El bizcocho había rebasado el moldes metálico | El bizcocho había rebasado el mono metálico |
| 354. El banco ha cambiado las monedas antiguas | El banco ha cambiado las moneda antiguas | El banco ha cambiado las mantequillas antiguas |
| 355. La nieve ha cubierto las montañas catalanas | La nieve ha cubierto las montaña catalanas | La nieve ha cubierto las novias catalanas |
| 356. Sus madres habían sido unas mujeres valientes | Sus madres habían sido unas mujer valientes | Sus madres habían sido unas clases valientes |
| 357. El médico ha escayolado su muñeca rota | El médico ha escayolado su muñecas rota | El médico ha escayolado su linterna rota |
| 358. Las reformas habían transformado el museo arqueológico | Las reformas habían transformado el museos arqueológico | Las reformas habían transformado el secador arqueológico |
| 359. Un colibrí ha absorbido el néctar dulce | Un colibrí ha absorbido el néctares dulce | Un colibrí ha absorbido el halcón dulce |
| 360. Su profesora ha sacado las notas finales | Su profesora ha sacado las nota finales | Su profesora ha sacado las neveras finales |
| 361. EL chico ha fotografiado las nubes rosáceas | EL chico ha fotografiado las nube rosáceas | EL chico ha fotografiado las memorias rosáceas |

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| 362. El sorteo ha incluido una olla exprés | El sorteo ha incluido una ollas exprés | El sorteo ha incluido una pancarta exprés |
| 363. La decisión ha requerido una opinión experta | La decisión ha requerido una opiniones experta | La decisión ha requerido una jarra experta |
| 364. Esta semana ha tocado la orquesta sinfónica | Esta semana ha tocado la orquestas sinfónica | Esta semana ha tocado la llave sinfónica |
| 365. Las fotografías han mostrado un paisaje fabuloso | Las fotografías han mostrado un paisajes fabuloso | Las fotografías han mostrado un calor fabuloso |
| 366. El documental ha mostrado unos pájaros preciosos | El documental ha mostrado unos pájaro preciosos | El documental ha mostrado unos esposos preciosos |
| 367. Los pacifistas han soltado varias palomas blancas | Los pacifistas han soltado varias palomos blancas | Los pacifistas han soltado varias estatuas blancas |
| 368. Los colegios han fomentado el pensamiento racional | Los colegios han fomentado el pensamientos racional | Los colegios han fomentado el cuarto racional |
| 369. Esta asociación ha denunciado los perros abandonados | Esta asociación ha denunciado los perras abandonados | Esta asociación ha denunciado los relojes abandonados |
| 370. Unos camareros han servido el pescado asado | Unos camareros han servido el pescados asado | Unos camareros han servido el taburete asado |
| 371. El disolvente ha eliminado la pintura seca | El disolvente ha eliminado la pinturas seca | El disolvente ha eliminado la tostada seca |
| 372. Esta constructora ha edificado algunos pisos altísimos | Esta constructora ha edificado algunos piso altísimos | Esta constructora ha edificado algunos vinos altísimos |
| 373. Su jardinero había regado la planta mustia | Su jardinero había regado la plantas mustia | Su jardinero había regado la trompeta mustia |
| 374. Su hijo había sido un portero excelente | Su hijo había sido un portera excelente | Su hijo había sido un naranja excelente |
| 375. Los voluntarios han repartido las prendas donadas | Los voluntarios han repartido las prenda donadas | Los voluntarios han repartido las tiendas donadas |
| 376. Mi empresa ha facilitado la promoción interna | Mi empresa ha facilitado la promociones interna | Mi empresa ha facilitado la torre interna |
| 377. Unos ladrones habían robado las radios nuevas | Unos ladrones habían robado las radio nuevas | Unos ladrones habían robado las paredes nuevas |
| 378. La señora ha tirado el ramo seco | La señora ha tirado el ramos seco | La señora ha tirado el barco seco |

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| 379. La decoradora ha preferido un rojo carmín | La decoradora ha preferido un rojos carmín | La decoradora ha preferido un champiñón carmín |
| 380. La madre ha comprado un sonajero nuevo | La madre ha comprado un sonajeros nuevo | La madre ha comprado un pasaje nuevo |
| 381. Mi tío ha adquirido un taxi propio | Mi tío ha adquirido un taxis propio | Mi tío ha adquirido una célula propia |
| 382. Tu bolígrafo ha soltado mucha tinta azul | Tu bolígrafo ha soltado mucha tintas azul | Tu bolígrafo ha soltado mucha mesa azul |
| 383. EL médico ha vendado el tobillo hinchado | EL médico ha vendado el tobillos hinchado | El médico ha vendado el papel hinchado |
| 384. El acróbata ha alcanzado el trampolín elevado | El acróbata ha alcanzado el trampolines elevado | El acróbata ha alcanzado el tenedor elevado |
| 385. Unos agentes habían encontrado varios vehículos calcinados | Unos agentes habían encontrado varios vehículo calcinados | Unos agentes habían encontrado varios ejercicios calcinados |
| 386. Varios amigos han adquirido un velero enorme | Varios amigos han adquirido un veleros enorme | Varios amigos han adquirido un ministro enorme |
| 387. El viento ha arrancado las ventanas viejas | El viento ha arrancado las ventana viejas | El viento ha arrancado los maestros viejos |
| 388. Mi sobrina ha manchado su vestido nuevo | Mi sobrina ha manchado su vestidos nuevo | Mi sobrina ha manchado su metal nuevo |
| 389. El artesano ha moldeado el vidrio caliente | El artesano ha moldeado el vidrios caliente | El artesano ha moldeado la revista caliente |
| 390. El museo ha expuesto algunos violines antiguos | El museo ha expuesto algunos violín antiguos | El museo ha expuesto algunos tobillos antiguos |
| 391. La entrada es permitida a los adultos por el portero | La entrada es permitida a los adultas por el portero | La entrada es permitida a los moldes por el portero |
| 392. El reproductor fue conectado a los altavoces por su padre | El reproductor fue conectado a los altavoz por su padre | El reproductor fue conectado a los aceites por su padre |
| 393. La sombrilla fue clavada en la arena por ese chico | La sombrilla fue clavada en la arenas por ese chico | La sombrilla fue clavada en el violín por ese chico |
| 394. Esa compra fue subida en el ascensor por mi amiga | Esa compra fue subida en el ascensores por mi amiga | Esa compra fue subida en el circo por mi amiga |
| 395. Este entrenamiento fue diseñado para los astronautas por la NASA | Este entrenamiento fue diseñado para los astronauta por la NASA | Este entrenamiento fue diseñado para las cocinas por la NASA |

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| 396. La leche fue endulzada con el azúcar por su abuelo | La leche fue endulzada con el azúcares por su abuelo | La leche fue endulzada con el caballo por su abuelo |
| 397. La transferencia será realizada en el banco por aquella señora | La transferencia será realizada en el bancos por aquella señora | La transferencia será realizada en el humo por aquella señora |
| 398. Ese escudo fue cosido a la bandera por el costurero | Ese escudo fue cosido a la banderas por el costurero | Ese escudo fue cosido a la espuma por el costurero |
| 399. Un foco fue instalado sin la bombilla por el técnico | Un foco fue instalado sin la bombillas por el técnico | Un foco fue instalado sin la hamburguesa por el técnico |
| 400. El contenedor es llenado con las botellas por tu compañero | El contenedor es llenado con las botella por tu compañero | El contenedor es llenado con las jugadas por tu compañero |
| 401. Un tatuaje fue dibujado en el brazo por el tatuador | Un tatuaje fue dibujado en el brazos por el tatuador | Un tatuaje fue dibujado en el sombrero por el tatuador |
| 402. Las botellas fueron entregadas a los buceadores por los ayudantes | Las botellas fueron entregadas a los buceadoras por los ayudantes | Las botellas fueron entregadas a los asientos por los ayudantes |
| 403. La señal será cambiada en esa calle por el técnico | La señal será cambiada en esa calles por el técnico | La señal será cambiada en esa bebida por el técnico |
| 404. Los huevos fueron incubados con mucho calor por las cigüeñas | Los huevos fueron incubados con mucho calores por las cigüeñas | Los huevos fueron incubados con mucho camión por las cigüeñas |
| 405. Aquel radar fue colocado en esta carretera por los policías | Aquel radar fue colocado en esta carreteras por los policías | Aquel radar fue colocado en esta estufa por los policías |
| 406. El virus es introducido en la célula por el científico | El virus es introducido en la células por el científico | El virus es introducido en la columna por el científico |
| 407. El paciente fue atendido en ese centro por la enfermera | El paciente fue atendido en ese centros por la enfermera | El paciente fue atendido en ese libro por la enfermera |
| 408. Varias setas fueron metidas en la cesta por los caminantes | Varias setas fueron metidas en la cestas por los caminantes | Varias setas fueron metidas en la magdalena por los caminantes |
| 409. Los perdigones fueron guardados en el chaleco por el cazador | Los perdigones fueron guardados en el chalecos por el cazador | Los perdigones fueron guardados en el cocinero por el cazador |

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| 410. El pollo fue guisado con los champiñones por el cocinero | El pollo fue guisado con los champiñón por el cocinero | El pollo fue guisado con los aviones por el cocinero |
| 411. Las actuaciones serán realizadas en esas ciudades por el humorista | Las actuaciones serán realizadas en esas ciudad por el humorista | Las actuaciones serán realizadas en esas manos por el humorista |
| 412. Los niños fueron colocados en las clases por el maestro | Los niños fueron colocados en las clase por el maestro | Los niños fueron colocados en las mariquitas por el maestro |
| 413. Unas listas fueron colgadas en el corcho por el profesor | Unas listas fueron colgadas en el corchos por el profesor | Unas listas fueron colgadas en el conejo por el profesor |
| 414. Las patatas son servidas con el cordero por el mesonero | Las patatas son servidas con el cordera por el mesonero | Las patatas son servidas con el taxi por el mesonero |
| 415. Varios brillantes fueron añadidos a la corona por el joyero | Varios brillantes fueron añadidos a la coronas por el joyero | Varios brillantes fueron añadidos a la lasaña por el joyero |
| 416. La ventana fue cubierta con la cortina por ese chico | La ventana fue cubierta con la cortinas por ese chico | La ventana fue cubierta con la leche por ese chico |
| 417. El símbolo fue dibujado en el cuaderno por el alumno | El símbolo fue dibujado en el cuadernos por el alumno | El símbolo fue dibujado en el habitante por el alumno |
| 418. Varias maletas serán llevadas a los cuartos por el botones | Varias maletas serán llevadas a los cuarto por el botones | Varias maletas serán llevadas a los radiadores por el botones |
| 419. El agua fue vertida en el cuenco por el florista | El agua fue vertida en el cuencos por el florista | El agua fue vertida en el empleo por el florista |
| 420. El acusado es señalado con el dedo por la víctima | El acusado es señalado con el dedos por la víctima | El acusado es señalado con el blanco por la víctima |
| 421. Muchas obras serán realizadas en estos edificios por esa constructora | Muchas obras serán realizadas en estos edificio por esa constructora | Muchas obras serán realizadas en estos cuerpos por esa constructora |
| 422. Las obras fueron representadas en ese escenario por los actores | Las obras fueron representadas en ese escenarios por los actores | Las obras fueron representadas en ese ídolo por los actores |
| 423. Las fotos son tomadas con esa estatua por los turistas | Las fotos son tomadas con esa estatuas por los turistas | Las fotos son tomadas con esa tela por los turistas |
| 424. El camping fue iluminado con un farol por el monitor | El camping fue iluminado con un faroles por el monitor | El camping fue iluminado con un erudito por el monitor |

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| 425. Su logotipo fue incluido en el folleto por el organizador | Su logotipo fue incluido en el folletos por el organizador | Su logotipo fue incluido en el paisaje por el organizador |
| 426. Las verduras fueron clasificadas según su género por el agricultor | Las verduras fueron clasificadas según su géneros por el agricultor | Las verduras fueron clasificadas según su tablero por el agricultor |
| 427. Las vacas son trasladadas a la granja por el ganadero | Las vacas son trasladadas a la granjas por el ganadero | Las vacas son trasladadas a la cara por el ganadero |
| 428. Las grabaciones fueron realizadas a ese halcón por los biólogos | Las grabaciones fueron realizadas a ese halcones por los biólogos | Las grabaciones fueron realizadas a ese néctar por los biólogos |
| 429. La pizza fue metida en el horno por ese chico | La pizza fue metida en el hornos por ese chico | La pizza fue metida en el búho por ese chico |
| 430. El pelo es sujetado con la horquilla por mi amiga | El pelo es sujetado con la horquillas por mi amiga | El pelo es sujetado con la lagartija por mi amiga |
| 431. La tortilla fue cocinada con ocho huevos por su madre | La tortilla fue cocinada con ocho huevo por su madre | La tortilla fue cocinada con ocho espacios por su madre |
| 432. Ese colegio será vigilado durante el invierno por el conserje | Ese colegio será vigilado durante el inviernos por el conserje | Ese colegio será vigilado durante el gimnasta por el conserje |
| 433. La leche fue guardada en la jarra por la camarera | La leche fue guardada en la jarras por la camarera | La leche fue guardada en la opinión por la camarera |
| 434. La bombilla fue enroscada en la lámpara por su amigo | La bombilla fue enroscada en la lámparas por su amigo | La bombilla fue enroscada en la silla por su amigo |
| 435. Una nota fue escrita con un lápiz por su compañero | Una nota fue escrita con un lápices por su compañero | Una nota fue escrita con un velero por su compañero |
| 436. La comida será arrojada a los leones por sus cuidadores | La comida será arrojada a los leonas por sus cuidadores | La comida será arrojada a los dólares por sus cuidadores |
| 437. El pasillo fue alumbrado con la linterna por el vigilante | El pasillo fue alumbrado con la linternas por el vigilante | El pasillo fue alumbrado con la muñeca por el vigilante |
| 438. El candado fue abierto con la llave por el encargado | El candado fue abierto con la llaves por el encargado | El candado fue abierto con la orquesta por el encargado |
| 439. Un regalo fue entregado a mi maestro por sus compañeros | Un regalo fue entregado a mi maestros por sus compañeros | Un regalo fue entregado a mi glaciar por sus compañeros |

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| 440. El pan es comido con mucha mantequilla por esa niña | El pan es comido con mucha mantequillas por esa niña | El pan es comido con mucha moneda por esa niña |
| 441. Las frutas fueron compradas en el mercado por ese señor | Las frutas fueron compradas en el mercados por ese señor | Las frutas fueron compradas en el gato por ese señor |
| 442. Los adornos serán tallados en las mesas por el ebanista | Los adornos serán tallados en las mesa por el ebanista | Los adornos serán tallados en las tintas por el ebanista |
| 443. Aquellas armaduras fueron elaboradas con esos metales por los herreros | Aquellas armaduras fueron elaboradas con esos metal por los herreros | Aquellas armaduras fueron elaboradas con esos hoteles por los herreros |
| 444. Varias conversaciones fueron mantenidas con el ministro por el presidente | Varias conversaciones fueron mantenidas con el ministra por el presidente | Varias conversaciones fueron mantenidas con el ramo por el presidente |
| 445. El café fue molido con un molinillo por el anciano | El café fue molido con un molinillos por el anciano | El café fue molido con un correo por el anciano |
| 446. Unas aspas serán incorporadas a ese molino por su dueño | Unas aspas serán incorporadas a ese molinos por su dueño | Unas aspas serán incorporadas a ese lavabo por su dueño |
| 447. La herida será curada a ese mono por el veterinario | La herida será curada a ese mona por el veterinario | La herida será curada a ese barril por el veterinario |
| 448. Las paredes serán pintadas con ese naranja por los pintores | Las paredes serán pintadas con ese naranjas por los pintores | Las paredes serán pintadas con ese portero por los pintores |
| 449. Algunos filetes fueron metidos en la nevera por mi hermana | Algunos filetes fueron metidos en la neveras por mi hermana | Algunos filetes fueron metidos en la nota por mi hermana |
| 450. El muñeco fue construido con la nieve por esos niños | El muñeco fue construido con la nieves por esos niños | El muñeco fue construido con la mermelada por esos niños |
| 451. Un temporal fue televisado en las noticias por esa cadena | Un temporal fue televisado en las noticia por esa cadena | Un temporal fue televisado en las cestas por esa cadena |
| 452. El anillo es entregado a la novia por el padrino | El anillo es entregado a la novio por el padrino | El anillo es entregado a la montaña por el padrino |
| 453. Las hojas son recogidas durante el otoño por los barrenderos | Las hojas son recogidas durante el otoños por los barrenderos | Las hojas son recogidas durante el escritor por los barrenderos |

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| 454. Los eslóganes serán incluidos en la pancarta por los participantes | Los eslóganes serán incluidos en la pancartas por los participantes | Los eslóganes serán incluidos en la olla por los participantes |
| 455. Las invitaciones fueron impresas en ese papel por aquella empresa | Las invitaciones fueron impresas en ese papeles por aquella empresa | Las invitaciones fueron impresas en ese vehículo por aquella empresa |
| 456. Los enchufes son incorporados a las paredes por aquella empresa | Los enchufes son incorporados a las pared por aquella empresa | Los enchufes son incorporados a las mujeres por aquella empresa |
| 457. Esta historia será incluida en el pasaje por el escritor | Esta historia será incluida en el pasajes por el escritor | Esta historia será incluida en el sonajero por el escritor |
| 458. Los animales fueron alimentados con el pienso por los ganaderos | Los animales fueron alimentados con el piensos por los ganaderos | Los animales fueron alimentados con el detalle por los ganaderos |
| 459. La dedicatoria es escrita en el póster por el cantante | La dedicatoria es escrita en el pósteres por el cantante | La dedicatoria es escrita en el mentón por el cantante |
| 460. Las imágenes fueron diseñadas con esos programas por el publicista | Las imágenes fueron diseñadas con esos programa por el publicista | Las imágenes fueron diseñadas con esos campos por el publicista |
| 461. El albornoz fue colgado en la puerta por mi hermano | El albornoz fue colgado en la puertas por mi hermano | El albornoz fue colgado en la corona por mi hermano |
| 462. La camiseta fue secada en el radiador por su padre | La camiseta fue secada en el radiadores por su padre | La camiseta fue secada en el pájaro por su padre |
| 463. Las pilas serán cambiadas a esos relojes por el relojero | Las pilas serán cambiadas a esos reloj por el relojero | Las pilas serán cambiadas a esos perros por el relojero |
| 464. Su trabajo es citado en esa revista por el periodista | Su trabajo es citado en esa revistas por el periodista | Su trabajo es citado en ese vidrio por el periodista |
| 465. La toalla fue extendida sobre la roca por el bañista | La toalla fue extendida sobre la rocas por el bañista | La toalla fue extendida sobre la ensalada por el bañista |
| 466. Su pelo fue secado con el secador por el peluquero | Su pelo fue secado con el secadores por el peluquero | Su pelo fue secado con el museo por el peluquero |
| 467. El césped fue cortado con la segadora por mi vecino | El césped fue cortado con la segadoras por mi vecino | El césped fue cortado con la nube por mi vecino |

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| 468. El barniz es esparcido en la silla por el restaurador | El barniz es esparcido en la sillas por el restaurador | El barniz es esparcido en la bandera por el restaurador |
| 469. Un vestido fue comprado con el sombrero por la joven | Un vestido fue comprado con el sombreros por la joven | Un vestido fue comprado con la granja por la joven |
| 470. La colonia fue derramada en el suelo por el bebé | La colonia fue derramada en el suelos por el bebé | La colonia fue derramada en la paloma por el bebé |
| 471. Las fichas fueron colocadas en el tablero por el jugador | Las fichas fueron colocadas en el tableros por el jugador | Las fichas fueron colocadas en el vestido por el jugador |
| 472. El frasco fue alcanzado con el taburete por la niña | El frasco fue alcanzado con el taburetes por la niña | El frasco fue alcanzado con el pescado por la niña |
| 473. La camisa es tejida con esta tela por mi abuela | La camisa es tejida con esta telas por mi abuela | La camisa es tejida con esta segadora por mi abuela |
| 474. La pasta fue comida con los tenedores por los invitados | La pasta fue comida con los tenedor por los invitados | La pasta fue comida con los trampolines por los invitados |
| 475. La bicicleta será arreglada en la tienda por un experto | La bicicleta será arreglada en la tiendas por un experto | La bicicleta será arreglada en la prenda por un experto |
| 476. El abono fue esparcido sobre la tierra por el campesino | El abono fue esparcido sobre la tierras por el campesino | El abono fue esparcido sobre la radio por el campesino |
| 477. Aquel tesoro fue guardado en la torre por los piratas | Aquel tesoro fue guardado en la torres por los piratas | Aquel tesoro fue guardado en la promoción por los piratas |
| 478. La mantequilla fue untada en la tostada por la anciana | La mantequilla fue untada en la tostadas por la anciana | La mantequilla fue untada en la pintura por la anciana |
| 479. El himno fue tocado con la trompeta por la orquesta | El himno fue tocado con la trompetas por la orquesta | El himno fue tocado con la planta por la orquesta |
| 480. La copa fue rellenada con el vino por la invitada | La copa fue rellenada con el vinos por la invitada | La copa fue rellenada con el piso por la invitada |

APPENDIX 2. MAIN ANOVA OF THE SEMANTIC P600 WITH 0-200 MS BASELINE

Second Study: semantic experiment (experiment one)

| | d.f. | P600 windows (ms) | | | |
|--|----------|---|---|---|---|
| | | 700-850 | 850-1000 | 1000-1150 | 1150-1300 |
| Face presentation | 1, 27 | $F = 2.03$ $p = .166$ | $F = 3.558$ $p = .07$ | $F = 8.388$ $p = .007$ | $F = 5.64$ $p = .025$ |
| Electrode * Face presentation | 58, 1566 | $F = 2.08$ $p = .099$ | $F = 2.124$ $p = .093$ | $F = 1.952$ $p = .106$ | $F = 1.62$ $p = 1.77$ |
| Semantic correctness | 1, 27 | $F = 0.003$ $p = .959$ | $F = 0.12$ $p = .912$ | $F = 0.276$ $p = .276$ | $F = 0.577$ $p = .454$ |
| Electrode * Semantic correctness | 58, 1566 | $F = 4.958$ $p = .001$ | $F = 7.476$ $p = .000$ | $F = 8.026$ $p = .000$ | $F = 3.878$ $p = .006$ |
| Face presentation * Semantic correctness | 1, 27 | $F = 3.228$ $p = .084$ | $F = 1.87$ $p = .183$ | $F = 4.049$ $p = .054$ | $F = 2.778$ $p = .107$ |
| Electrode * Face presentation * Sem. Correctness | 58, 1566 | $F = 0.269$ $p = .010$ | $F = 0.483$ $p = .745$ | $F = .277$ $p = .818$ | $F = 0.598$ $p = .022$ |

Third study: semantic experiment (experiment one)

| | d.f. | P600 windows (ms) | | | |
|--|-----------|---|---|---|--|
| | | 700-850 | 850-1000 | 1000-1150 | 1150-1300 |
| Emotion | 2, 58 | $F = 0.92$ $p = .4$ | $F = 3.876$ $p = .026$ | $F = 5.621$ $p = .006$ | $F = 4.185$ $p = .02$ |
| Electrode * Emotion | 116, 3364 | $F = 0.776$ $p = .663$ | $F = 0.948$ $p = .476$ | $F = 1.354$ $p = .2$ | $F = 1.228$ $p = .264$ |
| Semantic correctness | 1, 29 | $F = 3.283$ $p = .08$ | $F = 0.979$ $p = .331$ | $F = 0.313$ $p = .58$ | $F = 0.507$ $p = .482$ |
| Electrode * Semantic correctness | 58, 1682 | $F = 9.367$ $p = .000$ | $F = 16.81$ $p = .000$ | $F = 17.62$ $p = .000$ | $F = 13.206$ $p = .000$ |
| Emotion * Semantic correctness | 2, 58 | $F = 0.033$ $p = .961$ | $F = 0.097$ $p = .907$ | $F = 2.71$ $p = .075$ | $F = 1.875$ $p = .163$ |
| Electrode * Emotion * Sem. Correctness | 116, 3364 | $F = 1.73$ $p = .084$ | $F = 1.061$ $p = .397$ | $F = 1.121$ $p = .348$ | $F = 1.121$ $p = .348$ |