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TESIS DOCTORAL

Estudio de la actividad cerebral durante la percepción y procesamiento afectivo de las expresiones faciales de la emoción

MEMORIA PARA OPTAR AL GRADO DE DOCTOR

PRESENTADA POR

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ESTUDIO DE LA ACTIVIDAD CEREBRAL DURANTE LA PERCEPCIÓN Y PROCESAMIENTO AFECTIVO DE LAS EXPRESIONES FACIALES DE LA EMOCIÓN

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SUMMARY

1. Theoretical and empirical background

Facial expressions of emotion constitute highly relevant stimuli in human interaction, as they are communicative signals that allow us to infer other people's internal state. The communicative function of facial expressions has been object of great interest and the literature about this field is substantial.

Many authors have investigated the mechanisms involved in the perception and decoding of FEE from different perspectives. Studies with brain activity measures with high temporal resolution (electroencephalography -EEG- and magnetoencephalography -MEG) have focused on the time course of the perceptual processing of facial expressions and found an early sensitivity to different emotions. For example, the N170 component has revealed differential sensitivity to facial expressions of emotion (e.g., see Hinojosa, Mercado & Carretié, 2015).

1.1. Facial expressions in the affective priming paradigm

A commonly used procedure to investigate affective processing is the affective priming paradigm, in which emotional primes and targets are sequentially presented. The event-related potentials (ERP) technique has been commonly used to investigate these processes and the studies have focused on two components: the N400 and the Late Positive Potential (LPP). The N400 has been found to be highly sensitive to semantic incongruency, although its sensitivity to affective incongruency is not so clear. In contrast, the LPP has shown modulation by affective congruency in absence of N400 effects (Herring, Taylor, White, & Crites, 2011). Based on this results, it has been suggested that N400 would reflect semantic incongruency, but not affective incongruency, and the opposite effect would occur in the LPP (Baetens, Van der Cruyssen, Achtziger, Vandekerckhove & Van Overwalle, 2011; Bartholow, Fabiani, Gratton & Bettencourt, 2001). Faces have been frequently used as primes in these studies and effects at the behavioral and brain activity levels have been reported

(Spruyt, Hermans, De Houwer & Eelen, 2004; Werheid, Alpay, Jentzsch & Sommer, 2005).

1.2. Contextual modulation of facial expression processing

Faces have been traditionally investigated by presenting them in isolation, but in our daily life we usually perceive them embedded in different situational contexts. These contexts have been object of little research although some recent studies have explored this field and have showed evidence of the great impact that context can have on perception and processing of facial expressions of emotion. (See review by Wieser & Brosch, 2012). Righart and De Gelder (2006, 2008b) found a modulation of N170 component when a facial expression is presented embedded in an emotional picture. In an experiment by Kim et al., (2004) using fMRI the importance of a verbal context to disambiguate a facial expression of surprise was observed.

2. Objectives

The main objective of the present thesis was the study of the mechanisms involved in the early processing of facial expressions of emotion. For this reason, the main dependent variable was brain activity as measured through the event-related potentials (ERP) technique, which has excellent temporal resolution. The objectives of the study were approached from two complementary perspectives. First (Experiment 1), we have investigated the extent to which facial expressions of emotion modulate response to other emotional stimuli, using an affective priming paradigm. Second (Experiments 2 and 3), we explored how a preceding social-emotional context modulates the processing of a target expression and how this modulation is influenced by task demands that directs the attention of the participant to different aspects of the target

3. Results

In Experiment 1, faces with positive and negative valence (angry and happy) were presented followed by words with the same or different valence. In some trials participants had to indicate the gender of the face and in other trials the task was to evaluate the target valence. The results showed an inversed N400 effect, with larger amplitudes in the case of congruent trials, but only in the case of negative targets. Besides, LPP showed sensitivity to affective valence but not to congruency.

In Experiment 2, sentences describing an emotional evoking situation (happy-inducing or angry-inducing) were presented followed by facial expressions showing a congruent or incongruent emotion (angry or happy), and participants had to indicate the emotion expressed by the target. Results showed a modulation of N170 and N400 components by the emotion of the face but none of them showed sensitivity to affective congruency between the prime and target. A congruency effect was observed on LPP component, with larger amplitudes on incongruent trials, as well as in behavioral results (shorter reaction times in congruent trials).

In Experiment 3 we used a similar design with a different task; in this case participants had to indicate if the sentence was congruent with the emotion expressed by the subsequent face. At a behavioral level, both factors of congruency and emotion influenced the response. At the electrophysiological level, N170 showed sensitivity to congruency and emotion as well, while the N400 component was sensitive only to the emotion expressed by the face. In the LPP we observed larger amplitudes in incongruent trials but only when the target face was positive.

4. Conclusions

In conclusion, we have shown that that facial expressions of emotion can influence the processing of other emotional stimuli in the affective priming paradigm and that this influence is manifest in the modulation of early neural markers of perceptual and evaluative processing (Experiment 1). Besides, processing of facial expression can itself be modulated by the context in which they are perceived.

Experiments 2 and 3 provide strong evidence of the high relevance of the context in which a face is perceived and processed, modulating brain activity as is reflected by the results in the LPP component. However, it didn’t influence the N400 component.

An interesting finding in our studies is a reversed priming effect. This effect could be due to a double check processing in terms of valence and emotion when a facial expression is presented with another emotional stimulus.

To sum up, these studies provide more information about how facial expressions of emotion are processed and how this processing can interact with other stimuli and the context in which the facial expressions are perceived.

RESUMEN

1. Marco teórico

Las expresiones faciales de la emoción constituyen estímulos altamente relevantes en la interacción humana, dado que son señales comunicativas que nos permiten inferir el estado interno de otras personas. La función comunicativa de las expresiones faciales de la emoción ha sido objeto de gran interés y existe abundante literatura sobre el tema.

Muchos autores han investigado los mecanismos involucrados en la percepción y decodificación de las expresiones faciales desde distintas perspectivas. En estudios realizados con medidas de la actividad cerebral de alta resolución temporal (electroencefalografía-EEG- y magnetoencefalografía-MEG) que se centran en el curso temporal del procesamiento perceptivo de las expresiones faciales de la emoción se ha encontrado una sensibilidad temprana a diversas emociones. Por ejemplo, el componente N170 ha mostrado sensibilidad diferenciada a las expresiones faciales de la emoción (ver revisión de Hinojosa, Mercado & Carretié, 2015).

1.1. Expresiones faciales en el paradigma de *priming* afectivo

Un procedimiento utilizado habitualmente para investigar el procesamiento afectivo es el paradigma de *priming* afectivo, en el que *primes* y *targets* emocionales se presentan secuencialmente. La técnica de potenciales evocados (event-related potentials-ERP) se ha empleado habitualmente para explorar estos procesos y los estudios se han centrado en dos componentes principales: el N400 y el Potencial Tardío Positivo (Late Positive Potential-LPP). Se ha encontrado que el N400 es altamente sensible a la incongruencia semántica, mientras que su sensibilidad a la incongruencia afectiva no está tan clara. Por el contrario, se ha observado modulación del LPP debida a la incongruencia afectiva en ausencia de efectos en N400 (Herring et al., 2011). Debido a estos resultados, se ha sugerido que el N400 podría reflejar incongruencia semántica pero no afectiva, y en el caso del LPP ocurriría el efecto contrario (Baetens, Van der Cruyssen, Achtziger, Vandekerckhove & Van Overwalle, 2011; Bartholow, Fabiani, Gratton & Bettencourt, 2001). Las expresiones faciales han sido empleadas frecuentemente como *primes* en este tipo de estudios, encontrando efectos tanto a nivel conductual como electrofisiológico (Spruyt, Hermans, De Houwer & Eelen, 2004; Werheid, Alpay, Jentzsch & Sommer, 2005).

1.2. Modulación contextual del procesamiento de las expresiones faciales

Las expresiones faciales se han estudiado tradicionalmente presentándolas de forma aislada, pero en la vida diaria es habitual percibirlas integradas en diferentes contextos situacionales. Estos contextos no han sido objeto de gran interés, si bien algunos estudios recientes que han explorado este ámbito muestran evidencia del gran impacto que puede tener el contexto en la percepción y procesamiento de dichas expresiones (ver revisión de Wieser & Brosch, 2012). Righart y De Gelder (2006, 2008b) encontraron modulación del componente N170 cuando una expresión facial es presentada conjuntamente con una imagen con contenido emocional. En un experimento de Kim et al. (2004) se pudo observar la gran influencia de un contexto verbal a la hora de desambiguar una expresión facial de sorpresa.

2. Objetivos

El objetivo principal de la presente tesis fue el estudio de los mecanismos involucrados en el procesamiento de las expresiones faciales de la emoción. Por ello, la principal variable dependiente fue la actividad cerebral empleando ERPs, técnica que proporciona una excelente resolución temporal. Los objetivos de este estudio se abordaron desde dos perspectivas complementarias. En primer lugar (Experimento 1), se estudió en qué medida las expresiones faciales emocionales modulan la respuesta a otros estímulos emocionales, empleando un paradigma de *priming* afectivo. En segundo lugar (Experimentos 2 y 3), se exploró cómo un contexto previo modula el procesamiento de una expresión emocional, y cómo esta modulación se ve influenciada por las demandas de la tarea que dirigen la atención del participante a distintos aspectos del *target*.

3. Resultados

En el Experimento 1 se presentaron caras con diferente valencia, positiva o negativa (caras de alegría o de ira), seguidas de palabras con igual o distinta valencia a la cara presentada previamente. En algunos ensayos la respuesta requerida era indicar el género de la cara, mientras que en otros el participante debía evaluar la valencia de la palabra. Los resultados mostraron un efecto inverso de *priming* en el N400, con mayor amplitud en los ensayos congruentes, pero únicamente cuando los *targets* eran negativos. Además, el LPP mostró sensibilidad a la valencia afectiva pero no a la congruencia.

En el Experimento 2 se presentaron frases describiendo una situación relacionada con distintas emociones (alegría o ira), seguidas de una expresión facial mostrando una emoción que podía ser congruente o incongruente con la situación descrita. Los participantes debían indicar la emoción expresada por la cara *target*. Se encontró una modulación del N170 y del N400 por la emoción de la cara pero no por la congruencia afectiva entre la frase y la cara. Sí que se observó un efecto de congruencia en el LPP, con mayor amplitud en ensayos incongruentes. Este efecto también se encontró a nivel conductual, con tiempos de reacción menores en ensayos congruentes.

En el Experimento 3 se empleó un diseño similar modificando la tarea, en este caso los participantes debían indicar si la frase era congruente con la emoción expresada por la cara. A nivel conductual, tanto la emoción de la cara como la congruencia entre frase y cara tuvieron influencia en la respuesta. A nivel electrofisiológico, el N170 mostró sensibilidad a ambos factores también, mientras que el N400 únicamente mostró sensibilidad a la emoción. En el LPP se encontró una mayor amplitud ante ensayos incongruentes pero solo cuando la cara *target* era positiva.

4. Conclusiones

En conclusión, en la presente tesis se ha mostrado que las expresiones faciales de la emoción pueden influenciar el procesamiento de otros estímulos emocionales en el paradigma de *priming* afectivo y que dicha influencia se pone de manifiesto en la modulación de marcadores neurales tempranos del procesamiento perceptual y evaluativo (Experimento 1). Además, el procesamiento de la expresión facial puede ser modulado por el contexto en que se percibe.

Los experimentos 2 y 3 proporcionan una gran evidencia de la alta relevancia del contexto en que se percibe y procesa una cara, modulando la actividad cerebral tal y como se ve reflejado por los resultados en el componente LPP. Sin embargo, este contexto no mostró influencia en el N400.

Un hallazgo interesante en estos estudios es el efecto de *priming* inverso. Este efecto podría deberse a un doble procesamiento en términos de valencia y emoción cuando se presenta una expresión facial con otros estímulo emocional.

En resumen, estos estudios proporcionan más información sobre cómo se procesan las expresiones faciales de la emoción y cómo este procesamiento puede interactuar con otros estímulos y con el contexto en que se perciben dichas expresiones.

CAPÍTULO 1. INTRODUCCIÓN

1.1 CONTEXTO TEÓRICO

La función comunicativa de las expresiones faciales de la emoción

Las expresiones faciales de la emoción constituyen uno de los estímulos con mayor relevancia en el campo de las relaciones humanas. La expresión emocional nos permite inferir el estado emocional de las personas con las que interactuamos, lo que nos proporciona la oportunidad de adaptar nuestra conducta a las necesidades de cada relación interpersonal. El estado emocional se puede comunicar mediante diversos mecanismos, tales como el tono de voz o mensajes verbales, pero sin duda alguna uno de los pilares de la expresión emocional lo constituyen las expresiones faciales.

Darwin en su obra *La expresión de las emociones en los animales y en el hombre* realizó un exhaustivo estudio sobre la expresión emocional, que ha servido de punto de partida para el desarrollo de un amplio número de investigaciones posteriores. En este trabajo Darwin postuló que el origen de las expresiones es innato y estableció una serie de principios que explicarían la relación entre las emociones y las expresiones emocionales. El primero de estos principios, llamado "principio de la asociación de las costumbres útiles" sostiene la existencia de actos o movimientos que se realizan con el objetivo de responder o satisfacer deseos, necesidades, etc., que se reproducirían ante estados similares debido a la fuerza de la costumbre. Otro principio postulado por Darwin es el llamado "principio de la acción indirecta del sistema nervioso", que reza:

> "Ciertos actos que reconocemos como expresivos de tales o cuales estados del espíritu resultan directamente de la constitución misma del sistema nervioso"
>
> La expresión de las emociones vol. I. (trad. cast. p.45)

Estos principios suponen, en cierto modo, un antecedente de las ideas actuales sobre la expresión emocional, en las que se propone la existencia de patrones expresivos específicos vinculados con cada emoción, sustentados por mecanismos neurales preorganizados de manera que permitan realizar los movimientos que conforman la expresión facial (Aguado, 2005).

No obstante, Darwin no consideró la función comunicativa como relevante en la expresión emocional. Esta cuestión ha sido objeto de debate en la literatura, principalmente en lo que concierne a su objetivo, esto es, a si la expresión facial se produce con intención comunicativa.

Ekman (1997) sostiene que, si bien las expresiones faciales de la emoción proporcionan información sobre el estado emocional del emisor, e incluso sobre la expectativa que éste tiene sobre la conducta del receptor, esta comunicación no es voluntaria. De hecho, aduce que esta característica es la base de nuestra confianza en ellas (Ekman, 1998). Asimismo, considera que las expresiones faciales de la emoción pueden ser modificadas o simuladas, pero que estas falsas expresiones faciales son distinguibles de las genuinas (Ekman, 1982). Otros autores se han manifestado en la misma dirección, considerando que las expresiones emocionales se producen como resultado del estado interno del emisor y sin intención de transmitir información (Buck, 1984; Izard & Malatesta, 1987).

Esta postura no es compartida por otros autores, para los cuales la función fundamental de las expresiones faciales de la emoción es la comunicación interpersonal (Fridlund, 1994; Blair, 2003). En opinión de Fridlund (1994) las distintas configuraciones faciales se hallan más relacionadas con la intencionalidad del comportamiento futuro que con el estado emocional propiamente dicho. Considera, asimismo, que no hay correspondencia unívoca entre expresión facial y emoción, dado que una misma emoción podría asociarse a diferentes motivaciones en diversas circunstancias. Por ejemplo, una emoción de ira podría asociarse a una respuesta de enfrentamiento o de huida, y la expresión facial será diferente en cada caso.

Diversos autores han encontrado evidencia de la importancia del contexto social en la producción de expresiones faciales. Por ejemplo, se ha encontrado que la intensidad de las expresiones faciales es mayor cuando los participantes se encuentran en presencia de otras personas (Chovil, 1991; Fridlund, 1991).

Es factible asumir que si las expresiones emocionales tienen una función comunicativa regularán o modificarán de algún modo la conducta del receptor. Diversos autores han realizado estudios en esta línea, mostrando que la percepción de la expresión emocional de otra persona produce respuestas emocionales en el participante. Por ejemplo, Dimberg, Thunberg y Grunedal (2002) encontraron que la percepción de caras expresando ira o alegría producía mayor activación en los músculos corrugador y zigomático, respectivamente. También se ha encontrado que la respuesta electrodérmica difiere ante distintos estímulos, tales como caras expresando diversas expresiones emocionales (Williams et al., 2001, 2004). Actualmente la mayor parte de los estudios sobre expresión facial de la emoción toman en consideración la importancia de las mismas para la comunicación interpersonal (Aguado, 2005).

La percepción de las expresiones faciales de la emoción

Un campo de estudio que se encuentra estrechamente relacionado con las expresiones faciales de la emoción es el de la percepción de las mismas. Para que se produzca comunicación durante la interacción social es necesario que el receptor sea capaz de percibir e interpretar correctamente las expresiones faciales de su interlocutor. Una muestra de la importancia que tiene este proceso podemos verla en casos como los trastornos del espectro autista; donde algunas teorías sugieren que el receptor no es capaz de atribuir el significado correcto a las expresiones emocionales y la interacción social se ve afectada, apareciendo grandes dificultades. (p.ej. Hobson, 1986a, 1986b)

La percepción de las expresiones faciales se ha estudiado principalmente desde dos perspectivas diferentes. El primero de estos enfoques se ha centrado en los mecanismos implicados en el reconocimiento de las expresiones faciales, tratando de identificar las características que permiten diferenciar una expresión de otra asociada a una emoción distinta. Existen numerosos estudios que muestran la gran importancia de la los ojos y la zona que los rodea, tanto para el reconocimiento de la identidad (McKelvie, 1976; Farkas et al., 1994; Caldara et al., 2005) como para la discriminación entre distintas expresiones faciales (p.ej. Ekman & Friesen, 1978). Además, se ha observado que la información obtenida durante la exploración de esta área del rostro es precisamente la que nos ayuda/posibilita distinguir una sonrisa falsa de una expresión genuina de alegría, al no producirse las características arrugas alrededor de los ojos (Itier & Batty, 2009). Por último, se ha encontrado que se reconocen con mayor rapidez expresiones faciales de alegría en presencia de información ocular que cuando ésta no está disponible (Leppänen & Hietanen, 2007).

La otra perspectiva, que ha sido objeto de una amplia investigación, es la que trata de dilucidar si las expresiones faciales son percibidas de forma configuracional o, por el contrario, como una combinación de rasgos independientes. La evidencia empírica sugiere que se produce un procesamiento configuracional, principalmente gracias a los estudios basados en el denominado *efecto de inversión*. Este fenómeno consiste en una mayor dificultad en el procesamiento de un estímulo facial cuando éste se presenta invertido que cuando es presentado en posición normal. Este fenómeno resulta de gran interés en el estudio de la percepción configuracional ya que los elementos son los mismos que cuando la cara se presenta en posición normal, de modo que no debería producirse retraso en el procesamiento si éste se realizase de forma independiente (Kemp, McManus & Piggot, 1990; Rhodes, Brake & Atkinson, 1993; DeGelder, Teunise & Benson, 1997; Itier & Taylor, 2002).

A lo largo de los últimos años el interés por el estudio de las expresiones faciales de la emoción ha ido en aumento, y gracias a esta tendencia se dispone de una vasta literatura sobre las bases neuronales de la percepción y el procesamiento de estas expresiones. Existe abundante evidencia que sugiere la existencia de diferentes redes neuronales relacionadas con el reconocimiento de las diferentes expresiones faciales de la emoción. Se ha encontrado una mayor actividad en la amígdala en respuesta a la presentación de expresiones faciales de miedo, tanto directas (Morris et al., 1996; Phillips et al., 1998) como enmascaradas (Morris, Ohman & Dolan, 1998; Whalen et al., 1998), así como en respuesta a expresiones de tristeza (Blair, Morris, Frith, Perrett & Dolan, 1999; Schneider, Habel, Kessler, Salloum & Posse, 2000). En cuanto a otras emociones, la literatura evidencia una mayor actividad en el giro cingulado ante expresiones emocionales de alegría (Phillips et al., 1998), en regiones orbitofrontales cuando se presentan expresiones faciales mostrando ira (Blair, Morris, Frith, Perrett & Dolan, 1999) y en los ganglios basales y la ínsula en el caso del asco (Calder, Keane, Manes, Antoun & Young, 2000; Phillips et al., 1997). Esto no es excluyente con otros hallazgos que muestran la implicación de otras áreas cerebrales en el procesamiento de las expresiones faciales. Por ejemplo, en el caso de una expresión de miedo, el reconocimiento de las configuraciones de rasgos faciales característicos de dicha emoción dependería de la corteza visual, la corteza somatosensorial sería responsable de la activación de representaciones somáticas asociadas al miedo, y la amígdala estaría implicada en la activación de las asociaciones emocionales (Adolphs, Damasio, Tranel, Cooper & Damasio, 2000).

De especial relevancia resulta el estudio del curso temporal de los procesos involucrados en la percepción de expresiones faciales de la emoción, ámbito que ha suscitado un creciente número de investigaciones en los últimos años. Gracias a diversos estudios de electroencefalografía (EEG) y magnetoencefalografía (MEG) disponemos de una amplia evidencia que muestra una sensibilidad temprana a las diferentes expresiones faciales de la emoción.

Modulación de la actividad cerebral por las expresiones faciales de la emoción

La técnica de los potenciales evocados (event-related potentials o ERP) se caracteriza por una alta resolución temporal, lo que permite estudiar las respuestas neurales a fenómenos de rápida aparición. El componente más temprano que presenta sensibilidad a las expresiones faciales de la emoción es el N170, alrededor del cual existe una amplia literatura. Este componente ha mostrado sensibilidad a estímulos faciales frente a no faciales (Bentin, Allison, Puce, Perez & McCarthy, 1996; ver la revisión de Rossion & Jacques, 2012).

Los primeros estudios encontraron que el componente N170 no era sensible a las distintas emociones (Eimer, Holmes & McGlone, 2003; Herrmann et al., 2002). Sin embrago, la literatura que reporta modulación de este componente por las diferentes expresiones faciales de la emoción en el N170 es abundante (ver Hinojosa, Mercado & Carretié, 2015, para una revisión y meta-análisis de estos estudios). Los resultados de alguno de estos estudios muestran un efecto general de la expresión emocional, ya que la amplitud del N170 frente a caras emocionales se ve incrementada en comparación con la respuesta ante caras neutras (Blau, Maurer, Tottenham & McCandliss, 2007; Batty & Taylor, 2003). Algunos autores han propuesto una alta influencia de diversos factores no relacionados con el estímulo en si, como podría ser la estrategia empleada por los participantes para realizar la tarea (Rellecke, Sommer & Schacht, 2012; Wronka & Walentowska, 2011).

Además, hay evidencia que sugiere la existencia de diferencias específicas en el componente N170 ante diferentes emociones discretas. Encontramos estudios que muestran una mayor amplitud en el N170 frente a la presentación de caras de miedo (Batty & Taylor, 2003, Hinojosa et al., 2015), ira (Schupp et al., 2004) o asco (Caharel, Courtay, Bernard, Lalonde & Rebaï, 2005).

Existe un gran número de factores que dificultan la integración e interpretación de esta amplia variedad de resultados, como ponen de manifiesto los resultados de un reciente metaanálisis (Hinojosa et al., 2015). En este trabajo, los autores concluyen que el N170 es particularmente sensible a expresiones faciales de miedo, alegría o ira, mientras que las caras que expresan asco o tristeza no parecen modular la amplitud de este componente. Este resultado, por tanto, indica que el N170 es sensible a las diferentes expresiones faciales de la emoción pero no a todas ellas, lo que podría sugerir una mayor relevancia de ciertas emociones respecto a otras. Esta idea está en consonancia con la importancia de la función comunicativa de las expresiones faciales de la emoción, ya que no todas las emociones requieren ser procesadas con la misma rapidez. Desde un punto de vista evolutivo, es necesario responder más rápidamente ante una expresión amenazante, de ira, que ante una expresión de tristeza, dado que ésta no representa amenaza para el receptor.

Las expresiones faciales de la emoción como moduladoras del procesamiento afectivo

En el estudio del procesamiento afectivo las expresiones faciales de la emoción constituyen estímulos de gran interés, debido a su alto valor afectivo y, como se ha visto con anterioridad, a su importancia para la interacción social. Gracias a estas características se han empleado en diversas investigaciones sobre procesamiento de estímulos con contenido emocional. Actualmente, la postura más aceptada en la literatura sostiene que este procesamiento ocurre, en gran parte, de forma automática (Öhman, Hamm, & Hugdahl, 2000) de modo que los estímulos percibidos se clasificarían como positivos o negativos en etapas muy tempranas del procesamiento y sin intervención consciente (Barrett & Bar, 2009).

En la investigación sobre esta evaluación automática de la valencia resulta de gran utilidad el paradigma de *priming* afectivo, consistente en la presentación secuencial de dos estímulos dotados de valencia afectiva, que puede ser similar entre ambos estímulos o diferente. En caso de que el estímulo antecedente -*prime*- y el estímulo posterior-*target*- presenten igual valencia (positiva o negativa) estaremos ante un ensayo congruente, y en caso de que las valencias difieran el ensayo será incongruente.

De nuevo, la técnica de los ERPs resulta conveniente para desarrollar este tipo de estudios, debido a su alta resolución temporal, ya que se trata de observar fenómenos que ocurren en etapas muy tempranas del procesamiento. La mayor parte de la literatura se centra en el componente N400, así como en el Late Positive Potential (LPP) o Potencial Tardío Positivo. Tradicionalmente, el componente N400 exhibe mayores amplitudes cuando los estímulos son semánticamente incongruentes

(Kutas & Federmeier, 2011). En el caso del *priming* afectivo, los efectos no están claros, habiéndose encontrado en algunos estudios (Steinbeis & Koelsch, 2009; Zhang, Lia, Gold & Jiang, 2010) pero no en otros (Herring, Taylor, White, & Crites, 2011; Kissler & Koessler, 2011). En cuanto al LPP, se han encontrado efectos en paradigmas de *priming* afectivo incluso en ausencia de efectos en el componente N400 (Herring et al., 2011). Algunos autores han sugerido la posibilidad de que el N400 refleje la incongruencia semántica, pero no afectiva, mientras que el LPP presentaría el caso opuesto, siendo modulado por la incongruencia afectiva pero no semántica (Baetens, Van der Cruyssen, Achtziger, Vandekerckhove, & Van Overwalle, 2011; Bartholow, Fabiani, Gratton, & Bettencourt, 2001; Herring et al., 2011). En la literatura sobre *priming* afectivo encontramos numerosos estudios que emplean caras como *prime* y muestran efectos tanto a nivel conductual (Haneda et al., 2003; Murphy & Zajonc, 1993; Spruyt, Hermans, De Houwer & Eelen, 2004) como a nivel de actividad cerebral (Hsu,Hetrick & Pessoa, 2008; Li, Zinbarg, Boehm & Paller, 2008; Tian-Tian & Yong, 2014; Werheid, Alpay, Jentzsch & Sommer, 2005) en estudios con ERPs.

Procesamiento de las expresiones faciales de la emoción en un contexto

En nuestra vida cotidiana habitualmente percibimos las caras en un contexto determinado y no de forma aislada. Si estando con un amigo vemos, por ejemplo, que muestra una expresión de ira disponemos de una serie de claves sobre la situación que puede desencadenar esta emoción; si observamos que la gente que nos rodea expresa miedo probablemente miraremos a nuestro alrededor para tratar de identificar el elemento amenazante, etc.

Asimismo, contexto es un término amplio que puede referirse a diferentes ámbitos en relación a la percepción de expresiones faciales. Wieser y Brosch (2012) realizaron una clasificación de las características o elementos que pueden actuar como contexto en la interacción social, distinguiendo cuatro tipos principales:

1. Elementos relacionados con la expresión facial, lo que englobaría la dirección de la mirada o la dinámica de la expresión.
2. Elementos relacionados con el emisor, entre los que encontramos la prosodia, la postura corporal…
3. Elementos externos del entorno, como podría ser la escena visual que rodea a la cara o la situación social.
4. Elementos relacionados con el receptor, tales como sesgos perceptivos o aprendizaje previo que pueda haberse producido.

Si bien la mayor parte de la literatura sobre percepción de expresiones faciales se ha centrado en el estudio de caras de forma aislada, existen diversos estudios que tratan de arrojar luz sobre la influencia del primer tipo de contexto considerado por Wieser y Brosch, principalmente sobre la dirección de la mirada (eye gaze), ya que ésta constituye una clave de especial importancia en la interacción social. En concreto, se ha encontrado una que las caras de ira se perciben como más airadas si la mirada está dirigida al receptor, mientras que si la cara es de miedo y la mirada se dirige al receptor la intensidad de la expresión percibida es menor (Adams & Kleck, 2005; Adams & Franklin, 2009; Benton, 2010). Se ha encontrado también modulación de la respuesta cerebral ante caras debida a la incongruencia entre la prosodia afectiva y la expresión facial (De Gelder & Vroomen, 2000; Dolan, Morris & DeGelder, 2001), así como por la incongruencia entre la expresión facial y la postura corporal (Meeren, Heijnsbergen & DeGelder, 2005). El interés acerca del último tipo de contexto propuesto por Wieser & Brosch, el que hace referencia a características relativas al emisor, ha recaído principalmente en el estudio de la influencia de los rasgos de personalidad del receptor en la percepción facial (Bishop, Duncan & Lawrence, 2004a, 2004b; Wieser, Pauli, Reicherts & Mühlberger, 2010).

La literatura existente centrada en los elementos externos que rodean a la expresión facial es, tal vez, menos abundante. Righart y DeGelder han realizado diversos estudios acerca de la influencia de la escena visual en que es percibida una cara. En sus estudios presentan una imagen con valencia igual o diferente a la de una cara presentada simultáneamente, encontrando modulación tanto conductual (Righart

& De Gelder, 2008a) como a nivel de actividad cerebral (Righart & De Gelder, 2006, 2008b). Estos resultados sugieren que, ante una misma expresión emocional, su procesamiento e identificación pueden variar en función del contexto en el que es percibida. Sin embargo, al presentar simultáneamente la escena y la expresión facial, se produce un estímulo visual diferente al que constituye la expresión facial aislada, lo que podría influir en la respuesta cerebral ante dicho estímulo.

Otro procedimiento para explorar la influencia de un contexto en la percepción de expresiones faciales es mediante la utilización de descripciones verbales. En nuestra vida diaria, habitualmente disponemos de información verbal sobre las situaciones en las que se produce la interacción social, lo que nos proporciona claves útiles para identificar correctamente las expresiones emocionales de nuestro interlocutor.

Uno de los primeros estudios en emplear información verbal como contexto fue el realizado por Carrol y Rusell (1986). Estos autores presentaron caras con distintas expresiones emocionales precedidas de relatos breves, que estaban relacionados con emociones de ira, tristeza o alegría, y pidieron a los participantes que nombrasen la emoción expresada por la cara: el hallazgo principal consistió en que los participantes tendían a nombrar la emoción correspondiente al relato en lugar de la emoción expresada por la cara.

En otro estudio realizado por Kim et al., (2004) se observó la influencia de la información verbal en la desambiguación de expresiones faciales de sorpresa. Concretamente se empleó resonancia magnética funcional para investigar la influencia de una frase con distinta valencia (positiva o negativa) sobre el procesamiento de una cara de sorpresa. Se encontró que cuando las expresiones faciales estaban precedidas por una frase negativa el patrón de activación se correspondía con el patrón habitual ante estímulos negativos, lo que no ocurría en el caso de las caras precedidas por frases positivas.

En resumen, si bien la literatura científica sobre la percepción y el procesamiento de las expresiones faciales de la emoción es abundante, el papel del contexto ha recibido una menor atención. Las escasas investigaciones que se han centrado en esta cuestión han encontrado que la situación contextual desempeña un papel importante en el procesamiento de los rostros emocionales, por lo que parece claro que es un factor a tener en cuenta en este campo de estudio.

CAPÍTULO 2. OBJETIVOS E HIPÓTESIS

2.1 Objetivos

El objetivo general de esta investigación es el estudio de la actividad cerebral relacionada con el procesamiento de las expresiones faciales de la emoción. Esto se ha abordado desde dos perspectivas diferentes: por una parte se ha investigado la influencia que tienen estas expresiones sobre el procesamiento de otros estímulos y, por otra, se ha estudiado la modulación producida por la presentación de un contexto previo sobre la percepción y posterior procesamiento de las expresiones faciales emocionales. En concreto, se pretendía explorar estas influencias a lo largo de las distintas etapas implicadas en el procesamiento de caras, para lo cual la técnica de potenciales evocados resulta de gran utilidad.

Como ya se ha visto anteriormente, las expresiones faciales de la emoción constituyen estímulos con un alto valor afectivo y de gran relevancia en la interacción social, debido a lo cual pueden tener una gran influencia en el procesamiento de otros estímulos relacionados. Nuestro primer objetivo consistió en explorar cómo modula la percepción de expresiones faciales de la emoción el procesamiento de una palabra con valencia afectiva presentada a continuación, en un paradigma de *priming*, registrando al mismo tiempo la actividad cerebral mediante electroencefalografía. Esto se llevó a cabo en el primer experimento (véase el capítulo 3).

Nuestro segundo objetivo se centró en investigar el papel del contexto en la percepción y procesamiento de las expresiones faciales de la emoción. Si bien la literatura sobre este campo no es abundante y los contextos estudiados son variados, los resultados han puesto de manifiesto que el procesamiento de las expresiones faciales es altamente sensible a elementos ajenos a las propias características del estímulo. Esta idea resulta también intuitiva, dado que en la interacción social no percibimos las expresiones faciales de forma aislada, sino rodeadas de un conjunto de estímulos (expresiones verbales, tonos de voz…) que nos ayudan a identificar correctamente la emoción expresada. Nuestro interés se centró en el curso temporal de este procesamiento e integración contexto-cara, para lo cual se empleó de nuevo la técnica de potenciales evocados.

En el segundo y tercer experimentos se planteó el papel del contexto en el procesamiento de las expresiones faciales emocionales debido a la gran importancia que tiene dicho contexto en las interacciones sociales cotidianas. En el curso de esta interacción es posible que percibamos una expresión en nuestro interlocutor que nos resulta difícil identificar con la situación en la que estamos inmersos. Las preguntas que nos planteamos son 1) si el contexto afecta al procesamiento de la expresión facial y 2) si esa influencia depende de si prestamos explícitamente atención a la relación entre el contexto y la expresión. En el Experimento 2 no era necesario tener en cuenta explícitamente el contexto, el cual actuaba simplemente como *prime* para la identificación de la emoción expresada por una cara presentada a continuación. En el Experimento 3 se modificó la tarea que debía realizar el participante de modo que fuese necesario prestar atención deliberadamente a la congruencia entre contexto y expresión facial.

2.2 Hipótesis

En el Experimento 1 se presentaron estímulos target formados por palabras con valencia positiva o negativa precedidos por expresiones faciales de igual o distinta valencia. En estudios con un procedimiento similar se han observado efectos conductuales de *priming*, con tiempos de reacción mayores ante ensayos incongruentes (distinta valencia en *prime* y *target*). En cuanto a la actividad cerebral, la literatura ha mostrado que existen dos componentes especialmente sensibles a estas manipulaciones experimentales: el N400 y el LPP. Dos elementos que parecen tener una gran influencia en la aparición de efectos de incongruencia afectiva son la tarea y el foco atencional. En nuestro experimento se ha implementado un diseño de doble tarea, con el fin de que los participantes se vieran en la necesidad de prestar atención al *prime*, y no únicamente al *target*. Asimismo, la tarea principal consistió en evaluar la valencia del *target* de manera explícita. Por tanto, se esperaba encontrar un efecto debido a la congruencia entre *prime* y *target* tanto a nivel conductual como electrofisiológico, en los componentes N400 y LPP.

En el Experimento 2, como se ha visto anteriormente, el objetivo fue explorar la influencia de un contexto lingüístico sobre la percepción y procesamiento de las expresiones faciales de la emoción. En caso de que el contexto tuviese una valencia positiva y la cara presentada a continuación también se trataría de un ensayo congruente, al igual que si ambas valencias fuesen negativas. Por el contrario, los ensayos con un contexto positivo seguido de una cara negativa, o viceversa, serían ensayos incongruentes. La literatura en este ámbito es escasa y no existen estudios con un diseño similar, si bien hay autores que han estudiado la influencia del contexto con estímulos diferentes, tales como imágenes (Righart & De Gelder, 2006, 2008b), encontrando una modulación del componente temprano N170 por la congruencia entre los estímulos *prime* y *target*. No obstante, el diseño empleado en los estudios de estos autores, con presentación simultánea de la expresión facial y la imagen-contexto, modifica las propiedades perceptivas del *prime*. En otros estudios (Puce, Allison, & McCarthy, 1999) no se han encontrado efectos de este tipo. Por ello, en el componente N170 no se esperaban efectos de congruencia afectiva. Por el contrario, la modulación del procesamiento cerebral temprano por las diferentes expresiones faciales de la emoción ha sido ampliamente reportada en la literatura, de modo que nuestras hipótesis sí incluían efectos de emoción del *target* en este componente. En este experimento se estudiaron también los componentes N400 y LPP. Debido al diseño empleado, resulta factible estudiar los efectos de congruencia tanto a nivel semántico como afectivo, por lo que se podrían esperar efectos en ambos componentes. A nivel conductual se esperaba un incremento de los tiempos de reacción ante ensayos incongruentes.

En el Experimento 3 se modificó la tarea, de modo que los participantes prestasen atención de forma explícita a la congruencia entre contexto y *target*.

En la línea del segundo experimento, se esperaba encontrar efectos de congruencia a nivel conductual, así como en los componentes N400 y LPP. De nuevo, el diseño permite estudiar la congruencia tanto semántica como afectiva, por lo que podrían encontrarse efectos en ambos componentes, a pesar de que sobre la base de los resultados del experimento anterior serían esperables en el LPP, y no necesariamente en el N400. La tarea en este experimento implicaba una integración entre contexto y *target* que no era necesaria en el caso del experimento anterior, lo que podría facilitar el procesamiento semántico y dar lugar a la aparición de un efecto de congruencia en el N400. Por otra parte, es importante tener en cuenta los resultados del primer experimento, en los que se obtuvieron resultados diferentes de congruencia en función de la valencia del *target* (Aguado et al., 2013). Este resultado podría indicar, como se expondrá con mayor detalle a continuación, una doble evaluación de la congruencia afectiva, centrada primero en el procesamiento de la valencia, seguido por el del contenido emocional específico. Dado que en el presente experimento la tarea dirige la atención de forma explícita, es posible que aparezcan efectos relacionados con este doble proceso. No obstante, ante la falta de literatura con un diseño similar, no fue posible establecer hipótesis específicas a este respecto.

CAPÍTULO 3. EFECTOS DE PRIMING EN EL N400 EN UN PARADIGMA DE PRIMING AFECTIVO CON EXPRESIONES FACIALES DE LA EMOCIÓN.

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Priming effects on the N400 in the affective priming paradigm with facial expressions of emotion

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Abstract We studied the effect of facial expression primes on the evaluation of target words through a variant of the affective priming paradigm. In order to make the affective valence of the faces irrelevant to the task, the participants were assigned a double prime–target task in which they were unpredictably asked either to identify the gender of the face or to evaluate whether the word was pleasant or unpleasant. Behavioral and electrophysiological (event-related potential, or ERP) indices of affective priming were analyzed. Temporal and spatial versions of principal components analyses were used to detect and quantify those ERP components associated with affective priming. Although no significant behavioral priming was observed, electrophysiological indices showed a reverse priming effect, in the sense that the amplitude of the N400 was higher in response to congruent than to incongruent negative words. Moreover, a late positive potential (LPP), peaking around 700 ms, was sensitive to affective valence but not to prime–target congruency. This pattern of results is consistent with previous accounts of ERP effects in the affective priming paradigm that have linked the LPP with evaluative priming and the N400 with semantic priming. Our proposed explanation of the N400 priming effects obtained in the present study is based on two assumptions: a double check of affective stimuli in terms of valence and specific emotion content, and the differential specificities of facial expressions of positive and negative emotions.

Keywords Affective priming · N400 · Facial expressions of emotion

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Most current models of affect and emotion assume that affective processing proceeds, at least in part, automatically and without the need of conscious deliberation (e.g., Bargh, 1999; Duckworth, Bargh, Garcia, & Chaiken, 2002; Ellsworth & Scherer, 2009; Fazio, 2001; Öhman, Hamm, & Hugdahl, 2000). According to this view, the initial classification of stimulus objects by valence occurs prior to deliberate cognitive analysis, takes place at early stages of information processing, and develops in parallel with perceptual processing (e.g., Barrett & Bar, 2009).

A well-known tool for measuring the effects of automatic evaluation is the affective priming procedure, which involves the sequential presentation of two valenced stimuli (see Fazio, 2001, and Klauer & Musch, 2003, for reviews). On congruent trials, the first and second stimuli (the prime and the target, respectively) are of the same valence, while on incongruent trials, one of these stimuli is positive and the other negative. The participant's task is usually to evaluate the target as good or bad, pleasant or unpleasant (e.g., De Houwer, Hermans, Rothermund, & Wentura, 2002; Fazio, Sanbonmatsu, Powell, & Karders, 1986), although naming and lexical decision tasks have also been employed in studies with verbal targets (e.g., Klauer & Musch, 2001; Wentura, 2000). Priming is observed when performance, measured in terms of accuracy or reaction time (RT), is better on congruent than on incongruent trials. This result has usually been interpreted in terms of spreading-activation mechanisms (e.g., Fazio, 2001), showing facilitated processing of affectively congruent targets and/or impaired processing of incongruent ones. According to this explanation, implicit evaluation of the prime stimulus produces a transitory increase in the activation level of representations of stimuli or objects of similar valence, thus leading to facilitated processing of affectively congruent targets. A critical parameter for obtaining this effect is the duration of the prime–target interval or stimulus onset asynchrony (SOA). Affective priming has usually been obtained with short SOA durations, up to around 300 ms (e.g., Fazio et al., 1986; Hermans, Spruyt, & Eelen, 2003). This finding suggests that the effect is mediated by automatic, noncontrolled evaluative mechanisms and that the spreading of valence activation is a fast and short-lived process.

An alternative explanation of the affective priming effect has been proposed in terms of facilitation/competition at the response level (De Houwer et al., 2002; Wentura, 1999). This account assumes that, in the absence of other explicit response assignments, affective primes automatically activate the specific response corresponding to their valence. Response facilitation, or "response priming," would then occur for targets with the same valence as the prime. A finding consistent with this account is that the affective congruency effect is eliminated when the participant is assigned a nonevaluative task (e.g., Klauer & Musch, 2001; Spruyt, Hermans, Pandelaere, De Houwer, & Eelen, 2004). According to this argument, the interpretation of the affective congruency effect is problematic because in most affective priming studies, the influence of prime–target congruency is confounded with that of the congruency between the evaluative response to the target and the response tendency activated by the prime.

Several recent studies have used the event-related potential (ERP) technique to study the electrophysiological correlates of affective processing in the affective priming paradigm. Due to its high temporal resolution, the ERP technique is especially suited to studying brain correlates and the precise timing of fast-acting and short-lived processes, such as those supposed to underlie affective priming effects. Studies on affective priming using the ERP technique have focused especially on the N400 and the late positive potential (LPP) components. The N400 (Kutas & Hillyard, 1980) is a negative deflection observed around 400 ms after target onset with a centro-parietal maximal amplitude and that is sensitive to semantic relatedness and congruency. Typically, enhanced N400 amplitudes are observed in response to semantically incongruent targets (see Kutas & Federmeier, 2011, for a recent review). Enhanced N400 amplitudes have also been reported in several studies with the affective priming paradigm in response to affectively incongruent targets (e.g., Eder, Leuthold, Rothermund, & Schweinberger, 2011; Morris, Squires, Taber, & Lodge, 2003; Steinbeis & Koelsch, 2009; Zhang, Lia, Gold, & Jiang, 2010), although negative results have also been reported (Herring, Taylor, White, & Crites, 2011; Kissler & Koessler, 2011). A critical parameter seems to be the duration of the prime–target interval or SOA. Differences in SOA duration can determine whether an N400 congruency effect is obtained at all (Zhang, Lawson, Guo, & Jiang, 2006; Zhang et al., 2010), can influence the distribution of the N400 effect across the scalp (Zhang et al., 2010), or can even lead to a reversed priming effect, with an enhanced N400 in response to congruent targets. For example, using a procedure in which target emotional faces were preceded by nonsense utterances pronounced with different emotional intonations, Paulmann and Pell (2010) found the expected N400 effect in response to affectively incongruent targets using a 400-ms SOA. However, a reversed N400 effect—that is, a more negative-going deflection in response to congruent targets—was observed with a 200-ms SOA.

Modulations of the LPP that appear in a time window between 400 and 700 ms, usually with a centro-parietal distribution and sensitive to the affective or motivational value of the stimuli, have also been found in some affective priming studies. Enhanced amplitudes of these components have been reported in response to targets that are incongruent in terms of valence (Herring et al., 2011; Werheid, Alpay, Jentzsch, & Sommer, 2005; Zhang et al., 2010) or arousal (Hinojosa, Carretié, Méndez-Bértolo, Míguez & Pozo, 2009). It is interesting to note that sensitivity of the LPP to affective congruency has been observed even in the absence of N400 effects. Herring et al., for example, found this discrepancy and considered it as being suggestive that differential mechanisms are involved in affective and semantic priming. These authors pointed out that the LPP is sensitive to evaluative congruency in the affective priming paradigm and that N400 effects reflect the effects of semantic rather than of evaluative congruency.

Facial expressions of emotion constitute a particularly relevant class of stimuli for use in affective priming studies, due to their social significance and affective power. There is, in fact, behavioral evidence that affective congruency effects on word evaluation can be obtained using positive or negative emotional expressions as primes (Carroll & Young, 2005; Raccuglia & Phaf, 1997; Sternberg, Wiking, & Dahl, 1998) and that this effect shows the expected sensitivity to SOA duration (Aguado, García-Gutierrez, Castañeda, & Saugar, 2007; Fazio et al., 1986; Hermans et al., 2003). Congruency effects using facial expressions as primes have also been obtained in two ERP studies using the affective priming paradigm. In Werheid et al.'s (2005) study, both the primes and the targets were faces showing an emotional expression (happy or angry). Congruent and incongruent trials were defined according to whether or not the two faces showed the same expression, and the participant's task was to identify the expression of the target face. Although behavioral priming was obtained only for positive targets, early (100–200 ms) and late (500–600 ms) ERP effects were observed for both types of targets. The design employed in this study, however, was aimed at evaluating repetition priming, and thus confounded affective congruency with expression congruency. In fact, the authors proposed an interpretation of the observed late ERP effects not in terms of affective congruency, but as reflecting facilitation of emotion recognition due to repetition in the expression-congruent pairs.

In the second study, Li, Zinbarg, Boehm, and Paller (2008) used a subliminal priming paradigm in which participants had to evaluate surprise faces that were preceded by briefly presented happy or fearful faces. Ratings of the target faces were biased in the direction of the preceding prime, and brain potentials also showed different modulations following each prime type (increased P100 amplitudes in trials with fear primes, and increased amplitudes of the P300 component in trials preceded by happy primes). Although these results might reflect priming effects, the authors themselves proposed an alternative interpretation in terms of perceptual integration of the prime and target faces. This explanation is plausible given the temporal parameters used, with a short prime duration and no blank interval between the prime and the target. Under these conditions, for example, a surprise face preceded by a happy prime might have received more positive ratings not because of the influence of the affective valence of the prime, but because what the participant saw was in fact a mixed happy/surprise face. In conclusion, the results of Li et al. (2008) and of Werheid et al. (2005) show that emotional faces presented as primes do influence the processing of target stimuli, as measured by the ERP technique. However, given the design of the trials and the use of faces as both the primes and targets in these studies, it is likely that the results obtained reflect perceptual interactions between the stimuli rather than affective congruency effects.

In the present study, we measured electroencephalography (EEG) activity in a sequential, cross-domain affective priming procedure, with faces as primes and words as targets. This procedure reduced the probabilities of perceptual fusion between the stimuli and of confounding affective congruency with expression repetition. Moreover, we used a dual prime–target task procedure aimed at reducing the probabilities that the participants would engage in explicit evaluation of the faces and that evaluative responses to the target would be primed by response tendencies activated by those faces. To this end, the participants were unpredictably asked in different trials to evaluate the target word (prime–target trials) or to identify the gender of the prime face (prime-only trials). With this manipulation, we tried to ensure that the participant would focus her or his attention on the gender of the face instead of on its affective meaning. At the same time, this procedure guaranteed that different response tendencies would be activated by the prime and the target. Priming obtained under these experimental conditions would be strongly suggestive of an affective congruency effect. This effect might then be attributed to automatic, nonstrategic activation of the valence of the emotion prime, and not to deliberate affective processing or response priming.

In behavioral terms, affective priming should manifest as lower accuracy or slower RTs on affectively incongruent trials. In electrophysiological terms, we expected to find priming effects on brain potentials that have previously been found to be sensitive to semantic and affective congruency in affective priming studies. On the basis of the evidence discussed above, we focused our interest on the N400 and LPP components.

Method

Participants

The participants were 24 psychology students (20 females, four males; ages 17–28 years, mean = 21) who took part in the experiments for course credit. All of them had normal or corrected-to-normal vision and were right-handed.

Apparatus and stimuli

Presentation of the stimuli and registration of responses was controlled through the E-Prime software, version 1.1. The program was run on a computer with 64 MB RAM, and the stimuli were presented on a VGA 17-in. monitor (refresh rate 60 Hz). The participants were seated at a distance of 50 cm from the screen, and responses were registered through a computer keyboard. Sessions were carried out individually in a soundproof, dimly lit room.

The prime stimuli were 32 pictures of male and female models showing a happy or an angry expression, taken from the Karolinska Directed Emotional Faces (KDEF) collection (Lundqvist, Flykt, & Öhman, 1998). There were 16 models (eight male, eight female), each showing both expressions. The happy and angry faces differed in both valence and arousal: $t(30) = 20.06$ and 9.62, respectively, both ps < .001. In order to avoid possible influences of hairstyling, the images were cut to conceal most of the hair. The images were also equated in contrast energy (root-mean square contrast = 0.2). Stimuli were presented centered on the screen against a gray background.

The target stimuli were 48 Spanish nouns with positive or negative valence (24 positive, 24 negative), selected according to their valence, concreteness, syllable number, arousal, and frequency ratings obtained in a pilot study (see the Appendix). The mean pleasantness ratings for the selected positive and negative words was 7.90 and 2.14, respectively, $t(46) = 44.09$, $p = .000$. The positive and negative words were equated in terms of frequency of use, concreteness, number of syllables, and arousal (Alameda & Cuetos, 1995). The mean frequencies were 96.79 for positive and 87.29 for negative words, $t(46) = 0.38$, $p > .05$; the mean concreteness scores, 5.75 for positive and 5.76 for negative words, $t(46) = 0.29$, $p > .05$; the mean syllable numbers, 3.21 for positive and 3.08 for negative words, $t(46) = 0.49$, $p > .05$; and finally, the arousal scores were 7.55 for positive and 7.48 for negative words, $t(46) = 0.52$, $p > .05$. A different set of words was used during the practice phase. All words were presented at the center of the screen, written in black letters (Courier New 26-point font) on a gray background.

Procedure

The instructions, presented self-paced on the computer screen, described the task to be performed. After the instructions, the practice phase began. This phase was included with the aim of familiarizing the participants with the keys that they would use in the experimental task. The participants repeated the practice trials until they reached an accuracy criterion of 80 %. The faces and words presented in the practice block were different from those used in the experimental blocks.

Two types of trials were presented, prime–target and prime-only trials, which were distributed randomly (see Fig. 1 for examples). On prime–target trials, a priming procedure with faces as primes and words as targets was employed, with a 300-ms SOA. The main within-subjects factor was the Affective Congruency between the prime and the target. On valence-congruent trials, angry-face primes were followed by a negative word and happy-face primes were followed by a positive word. On incongruent trials, the primes and targets were of opposed valences. Throughout the experimental session, presentation of the face primes was randomized, with the restriction that the same model could not appear in two consecutive trials. Each trial started with the presentation of a fixation point for 1,000 ms, followed by a face acting as a prime for 250 ms. Next, a fixation point with a duration of 50 ms appeared, and finally the target word appeared and was terminated by the participant's response. On these trials, the participant's task was to categorize each word as pleasant or unpleasant. Responses were entered via the computer keyboard, and key assignments were counterbalanced. On prime-only trials, the face prime was followed by a question mark, indicating that the participant should report the gender of the face just seen. The keys used to enter these responses were different from those used for the evaluation task. Trials were separated by a variable intertrial interval, during which only a gray background was presented.

The experimental session was composed of 192 trials (96 prime–target and 96 prime-only), divided in two blocks of 96 trials and separated by a rest period. On each block, the same numbers of prime–target and prime-only trials appeared randomly. Half of the prime–target trials had positive and the other half negative targets. In addition, half of the positive target trials had a negative prime (incongruent condition) and the other half were preceded by positive primes (congruent condition). The same distribution was applied to the trials with a negative target. As a result, 48 congruent (24 with each type of target) and 48 incongruent (24 with each type of target) trials were presented. The gender of the primes was also balanced, so half apiece of the negative and positive primes in each condition were female faces, and half were male faces. Given that 48 word stimuli but only 32 face stimuli were used and that the same faces appeared on prime-only and prime–target trials, words

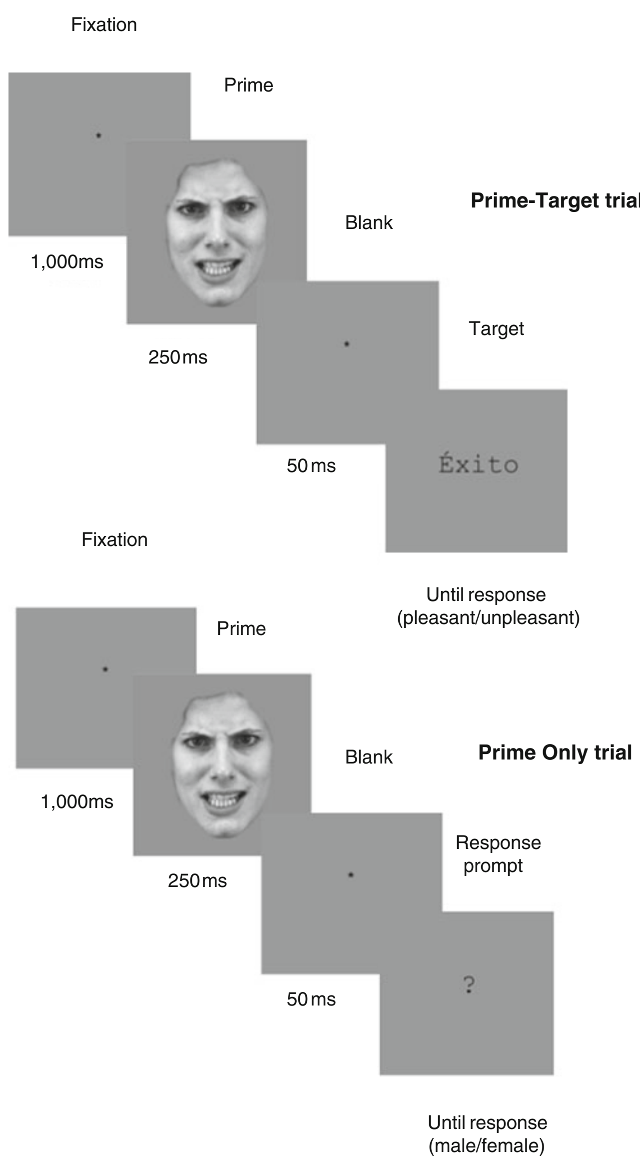

Fig. 1 Example event sequences on prime–target and prime-only trials

and pictures were repeated different numbers of times. More specifically, while each word was seen twice by the participants, each picture was repeated six times in total, three on prime-only and three more on prime–target trials.

EEG procedure and data analysis EEG activity was recorded using an electrode cap (Compumedics Neuroscan`s Quick-Cap) with Ag–AgCl disk electrodes. A total of 62 scalp locations homogeneously distributed over the scalp were used. All of the scalp electrodes were referenced to the linked mastoids. Bipolar horizontal and vertical electrooculography was recorded for artifact rejection purposes. Electrode impedances were kept below 5 KΩ. The signals were recorded continuously with a bandpass from 0.1 to 40 Hz (3-dB points for −6 dB octave roll-off) and a digitization sampling rate of 250 Hz.

Epochs were created, ranging from −250 to 800 ms after target onset. These epochs were baseline corrected and low-pass filtered (20 Hz/24 dB). Muscle artifacts, drifts, and amplifier blockings were removed by visual inspection before offline correction of eye movement artifacts (using the method described by Semlitsch, Anderer, Schuster, & Preelich, 1986). Individual ERPs were calculated for each experimental condition before grand averages were computed.

The components that explained the most ERP variance were detected and quantified through covariance-matrix-based temporal principal components analysis (tPCA). This method has been repeatedly recommended, since the exclusive use of traditional visual inspection of grand averages and voltage computation may lead to several types of misinterpretation (Chapman & McCrary, 1995; Coles, Gratton, Kramer, & Miller, 1986; Dien, Beal, & Berg, 2005; Foti, Hajcak, & Dien, 2009). The main advantage of tPCA over traditional procedures based on visual inspection of recordings and on temporal windows of interest is that it presents each ERP component separately and with its clean shape, extracting and quantifying it free of the influences of adjacent or subjacent components. Indeed, the waveform recorded at a specific electrode over a period of several hundred milliseconds represents a complex superposition of different overlapping electrical potentials. Such recordings can stymie visual inspection. In brief, tPCA computes the covariance between all ERP time points, which tends to be high between those time points involved in the same component and low between those belonging to different components. The solution is therefore a set of independent factors made up of highly covarying time points, which ideally correspond to ERP components. A temporal factor (TF) score, the tPCA-derived parameter in which the extracted temporal factors may be quantified, is linearly related to amplitude. In the present study, the number of components to select was based on the scree test (Cliff, 1987). Extracted components were submitted to promax rotation, since this rotation has been found to give the best overall results for tPCA (Dien, 2010; Dien et al., 2005). Repeated measures analyses of variance (ANOVAs) were carried out on the TF scores. Three within-subjects factors were included in the ANOVA: Congruency (two levels: congruent and incongruent), Target Valence (two levels: negative and positive), and Electrode (62 levels). The Greenhouse–Geisser epsilon correction was applied to adjust the degrees of freedom of the F ratios where necessary.

Signal overlapping may also occur in the space domain: At any given time point, several neural processes (and, hence, several electrical signals) may occur, so the recording at any scalp location at that moment is the electrical balance of these different neural processes. While tPCA "separates" ERP components across time, spatial PCA (sPCA) separates ERP components across space, each spatial factor ideally reflecting one of the concurrent neural processes underlying each temporal factor. Additionally, sPCA provides a reliable division of the scalp into different recording regions, a strategy that is advisable prior to statistical contrasts, since ERP components frequently show different behavior in some scalp areas than in others (e.g., they present different polarity or react differently to experimental manipulations). Basically, each region or spatial factor is composed of the scalp points where recordings tend to covary. As a result, the shape of the sPCA-configured regions is functionally based and scarcely resembles the shape of the geometrically configured regions defined by traditional procedures such as the creation of regions of interest. Moreover, each spatial factor can be quantified through the spatial factor score, a single parameter that reflects the amplitude of the whole spatial factor. Therefore, sPCAs were carried out for those TFs that were sensitive to our experimental manipulations. Again, the number of extracted factors was based on the scree test, and their spatial factor scores were submitted to promax rotation. Repeated measures ANOVAs were carried out on the spatial factor scores. Two within-subjects factors were included: Congruency (two levels: congruent and incongruent) and Target Valence (two levels: negative and positive). Greenhouse–Geisser epsilon correction was applied to adjust the degrees of freedom of the F ratios, and pairwise comparisons with the Bonferroni correction ($p < .05$) were carried out whenever appropriate.

Results

Behavioral results

Performance in the gender and evaluation tasks was measured in terms of accuracy and RT. Only correct responses were considered in calculating the RT measure, and in order to eliminate extreme values, responses outside the 200- to 2,000-ms range were deleted. Mean accuracy in the gender task (prime-only trials) was .89 (*SEM* = .01), and the mean RT was 750 ms (*SEM* = 34.3). A significant effect of emotional expression was obtained [$t(23) = 2.51$, $p = .019$], with gender being more accurately identified in happy than in angry faces (*M* = .90, *SEM* = .009, and *M* = .87, *SEM* = .010, respectively). A significant effect of facial expression was also found on the RT measure [$t(23) = 3.83$, $p = .001$], with longer correct RTs to happy than to angry faces (*M* = 839, *SEM* = 26.8, and *M* = 812, *SEM* = 25.9, respectively). Mean accuracy in the evaluation task (prime–target trials) was .92 (*SEM* = .007), with a mean RT of 895 ms (*SEM* = 23.5). A repeated measures 2 × 2 ANOVA with Congruency and Target Valence as the factors was performed on evaluation responses to the target. No significant effects were obtained on accuracy (*F*s < 1). For the RT measure, none of the effects reached statistical significance, although both congruency and the Congruency × Valence interaction reached marginal significance [$F(1, 23) = 3.68$, $p = .067$, $^{2} = .138$, and $F(1, 23) = 3.22$, $p = .086$, $^{2} = .123$, respectively]. This interaction was due to a trend toward shorter RTs in the congruent condition in the case of positive targets (see Table 1).

Electrophysiological data

A selection of the grand averages is represented in Fig. 2. These grand averages correspond to those scalp areas where experimental effects (described later) were most evident. As a consequence of the application of the tPCA, seven components were extracted from the ERPs. The factor loadings are represented in Fig. 3. Repeated measures ANOVAs were carried out on the TF scores for the factors Congruency, Target Valence, and Electrode, with the purpose of knowing which of these seven components were sensitive to our experimental manipulations. Hereafter, to make the results easier to understand, the ERP components associated with Temporal Factor 2 and Temporal Factor 1 will be labeled N400 and LPP, respectively, due to their latencies and polarities. The interaction between congruency and target valence was significant for the N400 component [$F(61, 1403) = 6.64$, $p < .05$]. A main effect of valence [$F(1, 23) = 8.01$, $p < .05$] and the interaction between congruency, valence, and electrode [$F(61, 1647) = 3.67$, $p < .05$] were found to be significant in the LPC. Therefore, our data show that primes modulated the amplitude of several target-related components: the N400 (which roughly corresponds to previous N400 effects), which has been related to difficulty in semantic integration (e.g., Kutas & Federmeier, 2000), and the LPP, which have been thought to index the allocation of attentional resources during the processing of emotional content (e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Hajcak & Nieuwenhuis, 2006).

Subsequent sPCAs were applied to the TF scores with the purpose of specifically locating the scalp regions that were associated with the effects found in the tPCA and further confirming that the components were sensitive to our experimental manipulations. As is shown in Table 2, the sPCAs extracted two spatial factors for the N400 and three spatial factors for the LPP. Repeated measures ANOVAs on the N400 and LPP spatial factor scores (directly related to amplitudes, as previously indicated) were carried out for the Congruency and Target Valence factors. A Congruency × Target Valence interaction was found at parietal-occipital and fronto-central regions for the N400. Post-hoc comparisons showed that negative congruent targets elicited larger amplitudes than did positive congruent stimuli in both regions. Additionally, negative congruent targets were associated with enhanced N400 amplitudes, as compared to negative incongruent targets, at fronto-central electrodes (see Table 2). For the LPP, positive targets elicited enhanced amplitudes relative to negative targets at parietal-occipital, fronto-central, and left temporal regions. An interaction between congruency and target valence was also observed at parietal-occipital regions. The results of the post-hoc analyses revealed that positive incongruent targets elicited enhanced amplitudes as compared to negative incongruent stimuli (see Table 2). The topographical maps corresponding to the scalp distribution of the sPCA effects are shown in Fig. 4.

Table 1 Behavioral priming: Mean reaction times (RTs) and accuracy (Acc.) in prime–target trials as a function of prime–target affective congruency (*SEM*s in parentheses)

Target Valence		Prime–Target Congruency		Incongruent-Congruent difference
		Congruent	Incongruent	
Positive	RT (ms)	875 (24.)	904 (23.9)	29
	Acc.	.95 (.014)	.96 (.015)	.01
Negative	RT (ms)	901 (22.3)	902 (22.8)	1
	Acc.	.96 (.010)	.96 (.009)	.00

Discussion

The objective of the present study was to investigate the neural correlates of affective priming produced by facial expressions of emotion and measured via their influence on evaluations of positive and negative target words. While this sequential face–word procedure minimized possible perceptual interactions between the prime and

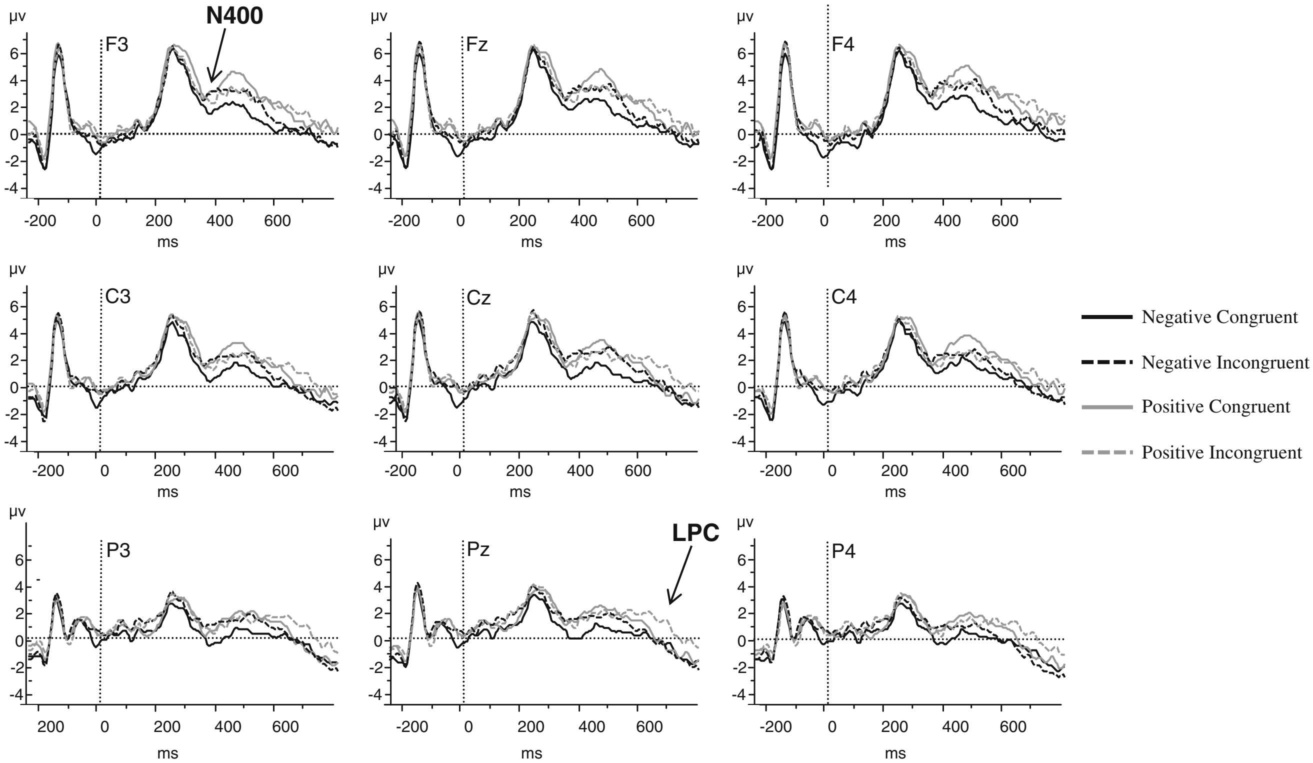

Fig. 2 Grand-average target-locked event-related potential (ERP) waveforms at selected frontal, central, and parietal electrodes as a function of target valence and prime–target affective congruency

the target, the assignment of a dual prime–target task reduced the probability that participants would engage in deliberate evaluation of the face primes and that the primes would activate evaluative responses that might interact with the response to the target. At the behavioral level, affective congruency between the primes and targets had only a marginally significant effect, and this only in the case of positive targets. Analysis of the

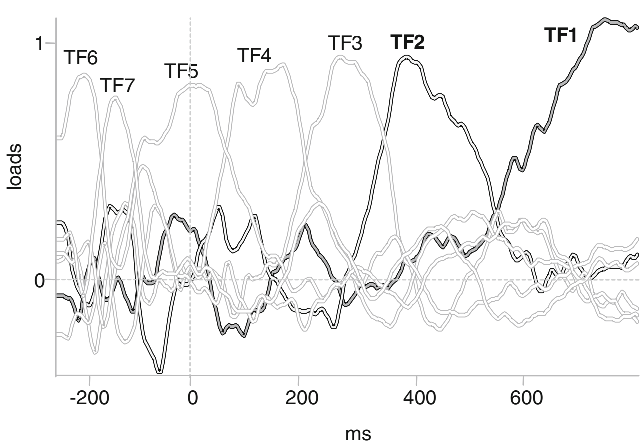

Fig. 3 The tPCA factor loadings after the promax rotation. Temporal Factors 1 and 2 correspond to the LPP and N400 components, respectively

electrophysiological results revealed significant effects of valence and congruency that indicate that priming effects were manifest at the level of brain responses, and thus that facial expression primes had a significant influence on processing of the target words. We will first discuss the lack of significant priming effects at the behavioral level, and then concentrate on interpretation of the ERP results.

A weak and nonsignificant priming effect was observed in the present study, and this only for positive targets. This is in contradiction with the abundant previous literature on affective priming (see Fazio, 2001, and Klauer & Musch, 2003, for reviews) and with our own previous results using the same double-task procedure employed in this study (Aguado et al., 2007). However, it should be pointed out that priming in evaluative tasks is not a general finding. For example, Klauer and Musch (2001) didn't find any evidence of affective priming in a series of carefully controlled experiments using a naming task with word targets. In a series of studies comparing semantic and affective priming, Storbeck and Robinson (2004) didn't find evidence of affective priming using both lexical decision and evaluative tasks either, although semantic priming was indeed present. Moreover, affective priming has been obtained in some studies only with positive, not

Table 2 Results of the statistical analyses on N400 and P700 spatial factors

	Spatial Factor	Congruency	Target Valence	Congruency × Target Valence
TF 2 (N400)	Parietooccipital	$F(1, 23) = 0.69^{n.s.}$	$F(1, 23) = 3.16^{n.s.}$	$F(1, 23) = 4.90^{*}$ NegCon > PosCon
	Frontocentral	$F(1, 23) = 0.62^{n.s.}$	$F(1, 23) = 2.89^{n.s.}$	$F(1, 23) = 7.25^{*}$ NegCon > PosCon NegCon > NegInc
TF 1 (LPP)	Parietooccipital	$F(1, 23) = 1.02^{n.s.}$	$F(1, 23) = 6.84^{*}$ *Negative < Positive*	$F(1, 23) = 4.43^{*}$ *NegInc < PosInc*
	Frontocentral	$F(1, 23) = 0.32^{n.s.}$	$F(1, 23) = 5.59^{*}$ *Negative < Positive*	$F(1, 23) = 0.53^{n.s.}$
	Left temporal	$F(1, 23) = 0.69^{n.s.}$	$F(1, 23) = 8.60^{**}$ *Negative < Positive*	$F(1, 23) = 0.03^{n.s.}$

$^{*}p < .05$. $^{**}p < .01$. n.s., nonsignificant. TF, temporal factor; NegCon, negative congruent trials; PosCon, positive congruent trials; NegInc, negative incongruent trials; PosInc, positive incongruent trials

with negative targets (e.g., Steinbeis & Koelsch, 2009; Werheid et al., 2005). Finally, affective priming has been shown to depend on stimulus variables such as word frequency, leading even to reverse priming effects when high-frequency words are used as the targets (Chan, Ybarra, & Schwartz, 2006). As to the

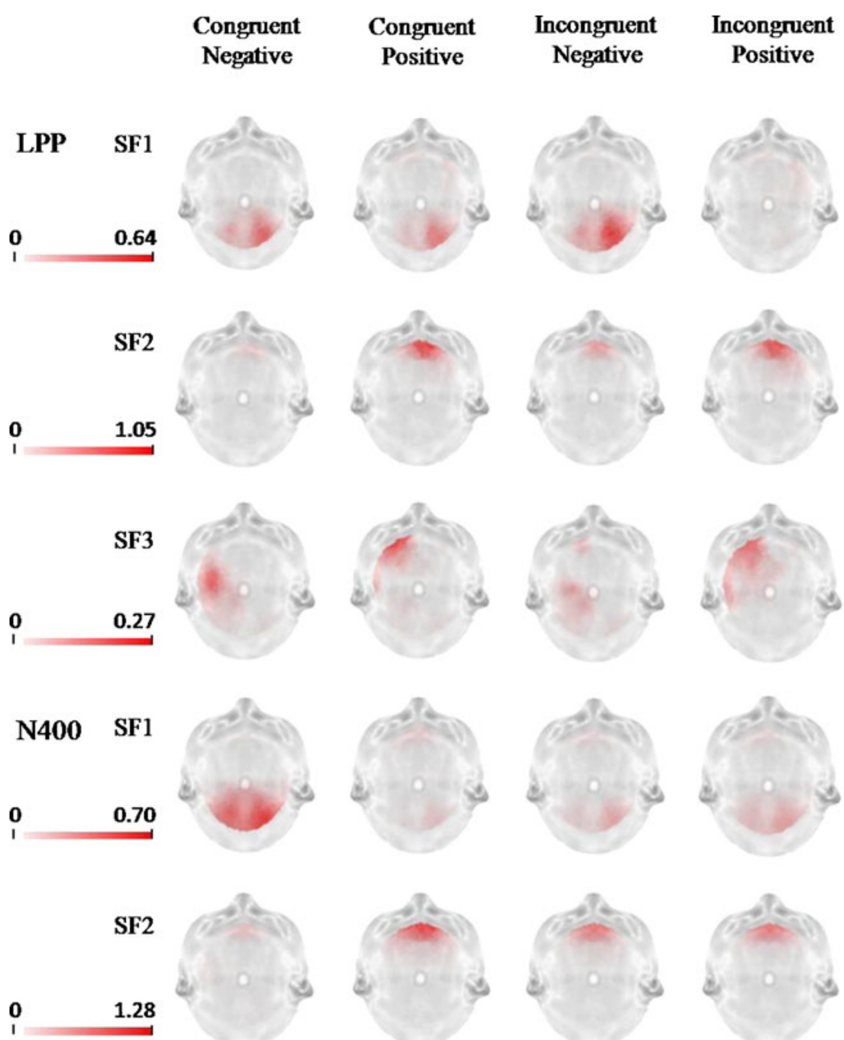

Fig. 4 Scalp maps representing the topographical distribution and values of each spatial factor across conditions. The scale has been adjusted to the highest score (absolute value) observed at each spatial factor across every condition

relationship between the behavioral and ERP results, consistency between these measures is not always observed, and a few studies have reported priming effects at the electrophysiological level in the absence of significant behavioral priming (e.g., Hinojosa et al. 2009; Kissler & Koessler, 2011). One possible explanation of the weak behavioral effects obtained in the present study is related to the demands imposed by the double-task procedure, which involved switching unpredictably between the gender and evaluation tasks. It might be that while the double task assignment was effective in directing the participants' attention away from the affective meaning of the prime faces, it also impaired the sensitivity of the task to detect subtle priming effects. The longer RT registered for target responses, as compared to that of prime responses (895 vs. 750 ms, respectively) suggests that the evaluation task might have required considerable processing resources, modulating or reducing the influence of the prime face on processing of the target word.

Turning now to the electrophysiological results, significant effects of target valence were found on the LPP component, with enhanced amplitudes in the presence of positive target words in parieto-occipital, fronto-central, and left temporal scalp locations. However, no effects of congruency were found on this component. A more complex pattern of results was found in the case of the N400. Increased negativities of this component were observed on congruent trials with negative targets—that is, in response to negative words preceded by angry faces—in parieto-occipital and fronto-central locations.[1] N400 amplitudes were enhanced on these trials as compared to positive congruent trials and, more unexpectedly, to negative incongruent trials. This last result is opposite to the usual finding of an enhanced N400 on incongruent trials that is reported in most semantic processing studies (see Kutas & Federmeier, 2011) and that has also been shown with the affective priming paradigm (Eder et al., 2011; Morris et al., 2003; Schirmer, Kotz, & Friederci, 2005; Steinbeis & Koelsch, 2009; Zhang et al., 2010). In what follows, we will first discuss briefly the results corresponding to the LPP component, and then we will concentrate on the N400, where complex congruency effects were found.

Consistent with the previous results, we found a modulation of the LPP by the valence of the target words. The finding of valence effects on LPPs is not rare (e.g., Conroy & Polich, 2007; Delplanque, Silvert, Hot, & Sequeira, 2005; Hajcak & Olvet, 2008) and has been related to the relevance or motivational significance of the stimulus (Hajcak & Olvet, 2008; Ito, Larsen, Smith, & Cacioppo, 1998). Also as in previous reports (Herbert, Junghofer, & Kissler, 2008; Kissler, Herbert, Winkler, & Junghofer, 2009), we observed an augmentation of the amplitude of the LPP in response to positive targets. On the other hand, the lack of sensitivity of the LPP to affective congruency in our results contrasts with previous reports showing enhanced amplitudes of this component in response to targets that are incongruent in terms of valence or arousal (Herring et al., 2011; Hinojosa et al. 2009; Werheid et al., 2005; Zhang et al., 2010). If, as Herring et al. suggested, evaluative congruency modulates the LPP in the affective priming paradigm, the absence of this modulation in our study would be perfectly consistent with the absence of significant priming at the behavioral level.

As we discussed in the introductory section, enhanced N400 effects on incongruent trials have been found in several studies using the affective priming paradigm (Eder et al., 2011; Morris et al., 2003; Steinbeis & Koelsch, 2009; Zhang et al., 2010). However, we also mentioned some studies reporting insensitivity of the N400 to affective congruency (Herring et al., 2011; Kissler & Koessler, 2011), or even reversed N400 effects (Hinojosa et al., 2009; Paulmann & Pell, 2010). A satisfactory account of the N400 effects found in our study should address the fact that these effects show sensitivity to congruency relations that go beyond general affective valence. A tentative explanation of the present results is based on the contextual integration view of the N400. According to this account, the N400 indexes the process by which a target stimulus is integrated into the preceding context to form a unified representation (e.g., van Berkum, Hagoort, & Brown, 1999). What we propose is that in the affective priming paradigm, this integration process involves two levels of affective evaluation, one of which refers to valence and the other to specific emotion content, and that this has different consequences for positive and negative emotional stimuli. These evaluative dimensions are similar to those of the hierarchical model of affect developed by Watson and Tellegen (1985), in which the higher hierarchical level corresponds to affective valence and the lower level to discrete emotions with specific content (see Smith & Scott, 1997, for a similar effort to integrate categorical and dimensional

[1] Most of the early studies had found that the N400 has a centro-parietal distribution. However, N400 effects with frontal distributions have been reported under some circumstances (e.g., Ganis & Kutas, 2003; Herbert, Junghofer, & Kissler, 2008). Some authors have assumed that frontal N400 components are associated with familiarity effects in recognition memory (Nyhus & Curran, 2009). However, it has been recently established that there are no functional differences between the central and centro-parietal N400s (Voss & Federmeier, 2011).

approaches in the specific case of facial expressions of emotion). The consequences of this double evaluation of valence and emotion content would be different for positive and negative affective stimuli, due to the different specificities of positive and negative affect and of their associated facial expressions. More specifically, a smiling face is the common expressive hallmark of different positive emotions, and may thus be easily integrated with a broad range of positively valenced words presented as targets in a priming paradigm (see Federmeier, Kirson, Moreno, & Kutas, 2001, for a relevant N400 study showing a facilitating effect of positive moods on processing of target words). In contrast, the integration of a negative target word with a preceding angry face would be a relatively more demanding task, due to the need to discriminate between negative targets that are congruent with the specific emotion content activated by the negative expression and those that are related to other negative emotions. This increased difficulty might explain the enhanced N400 effects observed in negative congruent as compared to positive congruent trials. A similar rationale might be used to explain the inverse N400 effect obtained with negative targets—that is, higher amplitudes on congruent than on incongruent trials. Integrating a negative word with the preceding angry face would require additional processing, because besides checking the affective congruency between the word and the face, congruent trials would require an additional evaluation of the congruency between the specific emotion contents of these two stimuli.

The results of our study have implications for the controversy over the relative roles of spreading activation and response competition in affective priming. Evidence consistent with the response competition account has been obtained in some ERP studies (Bartholow, Riordan, Saults, & Lust, 2009; Eder et al., 2011; Goerlich et al., 2012). Of special relevance here is the finding by Goerlich et al. that N400 effects on incongruent trials were shown when participants were asked to categorize the targets affectively (Exp. 1), but not when they were asked to categorize the targets on nonaffective dimensions (Exp. 2). The task conditions of Goerlich et al.'s Experiment 2 are similar to ours, in the sense that in both cases an effort was made to avoid response competition. The difference was that in our case, we gave the participants explicit instructions to categorize the prime and target stimuli on different dimensions: gender in the case of the face primes, and pleasantness in the case of the target words. Thus, our results are consistent with those of Goerlich et al. in the sense that, in either case, the typical N400 effect was absent under conditions that tended toward minimizing response competition. On the other hand, the fact that N400 amplitudes reflected the interactive effects of congruency and valence in our study, but not in that of Goerlich et al.'s, might be attributed to the different prime types used in each case (happy/sad musical excerpts and happy/angry emotional faces, respectively). Given the longstanding and varied experience that most people have with facial expressions of emotion, facial expressions might activate a more specific set of emotion associations than do musical excerpts, leading to complex priming effects such as those found in our study.

One limitation of our results is that they were obtained with a sample composed mainly of females. This might have some importance, as some studies have found gender differences in affective priming, with stronger behavioral priming in female than in male participants (Hermans, Baeyens, & Eelen, 1998; Schirmer et al., 2005). Moreover, an ERP study (Schirmer, Kotz, & Friederici, 2002) found that modulation of the N400 in an affective priming paradigm appeared with shorter SOA durations in women than in men, suggesting earlier decoding of affective meaning in women. These results suggest a higher sensitivity of female participants to affective congruency. Thus, caution should be taken when generalizing our conclusions to the male population.

To sum up, the results of our study have shown that the N400 and the LPP, two ERP components that index different stages of information processing, are differentially sensitive to affective valence and prime–target congruency in the affective priming paradigm. As we discussed on the introduction and the Discussion section, considerable evidence relates these components with incongruence detection and affective processing. The new evidence from our study reveals a complex pattern of valence and congruency effects on the N400 component. This evidence suggests that congruency effects in the affective priming paradigm are probably more complex than is predicted by more traditional accounts in terms of valence-processing and spreading-activation mechanisms. Our results suggest, instead, that a complete account of priming effects with affective stimuli must also take into account the activation of emotion-specific content by emotion primes and the ways that this content interacts with the specific affective meaning of the target stimulus.

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Appendix 1

Table 3 Affective and psycholinguistic indexes for the target words

Word		Valence	Arousal	Concreteness	Frequency	Syllables
Positive Words						
Atracción	attraction	7.73	7.73	3.27	42	3
Aventura	adventure	7.80	7.47	5.87	111	4
Celebración	celebration	8.07	7.07	6.27	19	4
Cita	date	7.20	7.47	6.20	77	2
Deseo	desire	7.93	7.20	4.80	239	3
Enamorado	lover	8.53	7.07	5.87	65	5
Entusiasmo	enthusiasm	7.53	7.33	4.87	121	4
Euforia	euphoria	7.47	8.40	4.27	21	3
Éxito	success	8.33	7.53	4.13	187	3
Extraordinario	extraordinary	8.13	7.27	3.60	41	5
Fiesta	party	8.33	8.20	6.47	140	2
Ganador	winner	7.73	7.40	6.53	6	3
Lotería	lottery	7.00	7.07	7.73	18	4
Niños	children	7.73	7.33	8.47	497	2
Orgasmo	orgasm	8.67	8.53	5.67	25	3
Pasión	passion	8.00	8.13	5.53	132	2
Piropo	compliment	7.53	7.27	6.73	1	3
Premio	prize	7.93	7.00	7.13	86	2
Seducción	seduction	7.60	7.80	4.67	29	3
Sexo	sex	8.20	7.20	7.73	203	2
Sobresaliente	outstanding	8.27	7.87	6.73	5	5
Sorpresa	surprise	7.67	8.13	5.07	137	3
Superación	self-improvement	8.27	7.47	4.20	20	4
Victoria	victory	7.87	7.20	6.20	101	3
Negative Words						
Abandono	abandonment	1.93	7.20	6.00	65	4
Amenaza	threat	1.80	8.07	5.40	94	4
Ataque	attack	2.40	7.93	4.60	76	3
Bochorno	embarrassment	2.13	7.27	5.87	11	3
Conflicto	conflict	2.47	7.73	6.13	91	3
Crisis	crisis	2.13	7.67	5.33	168	2
Desorden	untidiness	2.93	7.00	6.33	48	3
Desprecio	disdain	1.60	7.07	4.87	63	3
Dificultad	difficulty	2.87	7.20	5.07	94	4
Dolor	pain	1.27	8.00	5.47	234	2
Fracaso	failure	2.00	7.47	6.07	83	3
Gritos	shouts	2.53	7.67	7.07	108	2
Hambre	hunger	2.53	7.07	7.00	129	2
Humillación	humiliation	1.33	7.80	7.47	23	4
Infección	infection	1.80	7.33	6.93	13	3
Inútil	useless	1.93	7.00	5.13	118	3
Malo	bad	2.47	7.27	4.47	153	2
Monstruo	monster	2.73	7.20	4.60	56	2
Navaja	knife	2.27	7.07	8.33	50	3
Operación	surgery	2.80	7.33	6.73	110	4
Peligro	danger	1.80	8.20	5.20	136	3
Ridículo	ridiculous	2.13	7.87	4.73	82	4
Separación	separation	2.33	7.20	5.93	45	4
Sufrimiento	suffering	1.20	8.00	3.53	45	4

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CAPÍTULO 4. MODULACIÓN DEL PROCESAMIENTO DE LAS EXPRESIONES FACIALES DE LA EMOCIÓN POR UN CONTEXTO SITUACIONAL

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Faces in context: Modulation of expression processing by situational information

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Numerous studies using the event-related potential (ERP) technique have found that emotional expressions modulate ERP components appearing at different post-stimulus onset times and are indicative of different stages of face processing. With the aim of studying the time course of integration of context and facial expression information, we investigated whether these modulations are sensitive to the situational context in which emotional expressions are perceived. Participants were asked to identify the expression of target faces that were presented immediately after reading short sentences that described happy or anger-inducing situations. The main manipulation was the congruency between the emotional content of the sentences and the target expression. Context-independent amplitude modulation of the N170 and N400 components by emotional expression was observed. On the other hand, context effects appeared on a later component (late positive potential, or LPP), with enhanced amplitudes on incongruent trials. These results show that the early stages of face processing where emotional expressions are coded are not sensitive to verbal information about the situation in which they appear. The timing of context congruency effects suggests that integration of facial expression with situational information occurs at a later stage, probably related to the detection of affective congruency.

Keywords: Facial expression; Context; N400; N170; LPP.

Facial expressions of emotion constitute one of the most relevant stimuli in human social interaction. Studies using different brain imaging techniques have found that emotional expressive faces presented in isolation produce expression-specific activity in brain areas such as the amygdala and the insular cortex and modulate neural responses in the visual extrastriate cortex (e.g., Morris, Ohman, & Dolan, 1998; Vuilleumier, Armony, Driver, & Dolan, 2001; Winston, O'Doherty, & Dolan, 2003). Moreover, results of event-related potentials (ERPs) and magnetoencephalography (MEG) studies show that brain activity is modulated by the emotional meaning of faces since very early processing stages (e.g., Ashley, Vuilleumier, & Swick, 2004; Batty & Taylor, 2003; Eger, Jedynak, Iwaki, & Skrandies, 2003; Pourtois, Dan, Grjean, Ser, & Vuilleumier, 2005).

It is noticeable that in most studies on facial expression of emotion, participants are exposed to pictures of emotional faces presented in isolation, in the absence of any contextual reference. However, we usually perceive facial expressions of emotion in the context set by specific social interactions with our conspecifics. Emotion expressed on the face plays a crucial role in dynamic social encounters and this is the natural context where they are routinely decoded and

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understood (e.g., Barrett & Kensinger, 2010; Carroll & Russell, 1996). Although studies on isolated faces have provided valuable data about how we perceive and decode facial expressions, the question remains as to how conclusions from these studies apply to more naturalistic settings, where emotional expressions are integrated within an emotionally meaningful context. Some previous studies have explored this issue by focusing on local contextual effects, such as those caused by presenting facial expressions accompanied by different voice intonations or together with congruent or incongruent body postures (de Gelder & Vroomen, 2000; Massaro & Egan, 1996; Meeren, Van Heijnsbergen, & de Gelder, 2005). However, the possibility that processing of facial expressions of emotion is modulated by the broader situational context in which they appear has deserved less attention. This situational context refers to information about the expresser's situation, that is, about the life event or social encounter triggering the expressive reaction (Barrett, Lindquist, & Gendron, 2007; Carroll & Russell, 1996). In what follows, we make explicit the reasons for the theoretical interest of this issue and discuss relevant evidence.

A few studies have looked at how processing of facial expressions of emotion is influenced by the context in or the background on which they are presented. A study by Righart and De Gelder (2008a) reported behavioral evidence that expressions presented in emotionally congruent contexts, such as a fearful face presented on the background of a picture showing a car crash, are recognized faster than those presented on an incongruent context. In the electrophysiological domain, the N170, an ERP component that is especially sensitive to face processing, has been found to be modulated by the emotional meaning of faces, with increased negativities observed in the presence of faces that show different emotional expressions or that have acquired new emotional meaning (e.g., Aguado et al., 2012; Batty & Taylor, 2003; Blau, Maurer, Tottenham, & McCliss, 2007; Caharel, Courtay, Bernard, Lalonde, & Rebäi, 2005). Of direct relevance for the goals of the present study, amplitude of the N170 component in the presence of faces is also sensitive to different combinations of contexts and emotional expressions. Specifically, increased N170 amplitudes have been found when the facial expression is presented on the background of a congruent emotional picture (Righart & de Gelder, 2006, 2008b). This result is interesting because the N170 is the earliest ERP component identified in most studies as being differentially sensitive to faces (e.g., Bentin, Allison, Puce, Perez, & McCarthy, 1996; Bötzel, Ecker, Mayer, Schulze, & Straube, 1995; Rousselet, Husk, Bennett, & Sekuler, 2008; see Rossion & Jacques, 2012, for a review). Since the N170 component has been related to the stage of structural coding proposed by traditional models of face perception (Bruce & Young, 1986), these contextual influences would indicate that expressive information from the face is integrated with contextual information at an early processing stage. However, it cannot be totally ruled out that modulation of the N170 component caused by superimposing faces on picture backgrounds reflects processes of perceptual interaction rather than true contextual effects. A further confirmation of the possibility that early, face-sensitive ERP components, such as the N170, are modulated by context should additionally come from the comparison of activity elicited by expressive faces in affectively congruent and incongruent contexts that do not involve changes in visual stimulation at the moment when the face is perceived. This might be achieved using a procedure similar to that employed by Carroll and Russell (1996). In a behavioral study, the participants were asked to label the expression shown by faces that were each preceded by a read story that described a daily situation related to anger, fear, or sadness. Participants chose labels associated to that situation rather than those corresponding to the facial expression itself. Similar results have also been found using film clips as contexts (Walbott, 1988). Finally, in a neuroimaging study by Kim et al. (2004), emotionally ambiguous surprise faces were presented after positively or negatively valenced contextual sentences. It was found that surprised faces cued by negative contexts produced greater ventral amygdala activation (the pattern usually found with less ambiguous, negative emotional faces) compared to surprise faces cued by positive contexts.

The above-mentioned studies are suggestive of contextual modulation of emotional expression processing at the behavioral and brain levels. In the present study, we further explore the potential modulatory role of context, using the ERP technique. This approach was taken with the aim of differentiating the processing stages at which brain activity is sensitive to the specific nature of the expression (that is, if it is a happy or an angry expression) or to the congruency between the expression and an immediately preceding context. More precisely, brain activity was recorded while participants looked at pictures of expressive (happy or angry) target faces that were preceded by short sentences describing situations that would usually lead either to happy or to angry emotional reactions, and that provided the situational context for the targets. The critical comparison was between trials where the sentence and the expression were emotionally congruent (e.g., a happy face preceded by a sentence describing a happy situation) and trials where the sentence and the expression were emotionally incongruent (e.g., a happy face preceded by a sentence describing an anger-inducing situation).

The ERP measure was used because of its excellent temporal resolution, which allows precise tracking of the different stages of information processing after stimulus onset. If the context modulates brain responses to emotional expressions since the early stage at which structural processing of faces takes place, then modulations should already appear on the N170 time window, as shown in Righart and De Gelder's (2006, 2008b) studies. On the other hand, if integration of expression information with the situational context takes place at a later, post-perceptual stage, then modulations would only appear with longer latencies, corresponding to processing operations related to the decoding of affective meaning or to semantic integration of the target face with the context. Analysis of electroencepalographic (EEG) activity focused on those ERP components that have been found to be sensitive to emotional valence and to congruency between target stimuli and preceding primes. First, we focused on the face-sensitive N170 component. As has been mentioned above, the amplitude of this component can be modulated by the emotional valence of faces and there is previous evidence suggesting that it might as well be sensitive to the relationship between faces and their accompanying contexts (Righart and De Gelder, 2006, 2008a).

We also analyzed two later ERP components that are sensitive to semantic and/or affective congruencies, the N400 and the late positive potential (LPP). The N400 is a negative deflection appearing around 400 ms after stimulus onset that is usually modulated by semantic congruency (see Fabiani, Gratton, & Federmeier, 2007 and Kutas & Federmeier, 2011 for reviews). Studies with the affective priming paradigm have also found modulation of the N400 component by the congruency between the valences of the prime and target stimuli (e.g., Aguado, Dieguez-Risco, Méndez-Bértolo, Pozo, & Hinojosa, 2013; Paulmann & Pell, 2010; Zhang, Lia, Gold, & Jiang, 2010). The N400 is usually followed by an LPP, a centro-parietal positive deflection that typically becomes evident between 300 and 700 ms after stimulus onset and that may persist for several hundred milliseconds and continue after stimulus offset. In studies with emotional stimuli presented in the visual modality, this component is usually larger in the presence of both pleasant and unpleasant stimuli compared to neutral stimuli (e.g., Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Franken, Gootjes, & van Strien, 2009; Schupp et al., 2004). These emotional effects seem to be sensitive to contextual modulation, as they are influenced by preceding descriptions that bias the interpretation of the stimulus to make it more or less emotionally meaningful (Foti & Hajcak, 2008). Of direct relevance for the present study, in priming studies with affective stimuli, the LPP has also been found to be sensitive to prime–target congruency in terms of valence or arousal, with increased amplitudes in the presence of incongruent targets (Herring, Taylor, White, & Crites, 2011; Hinojosa, Carretié, Méndez-Bértolo, Míguez, & Pozo, 2009; Werheid, Alpay, Jentzsch, & Sommer, 2005; Zhang et al., 2010). Similarly, increased LPP amplitudes have been found following social expectancy violations, when participants read sentences describing behaviors inconsistent with a previously implied personality trait (Baetens, Van der Cruyssen, Achtziger, Vandekerckhove, & Van Overwalle, 2011; Bartholow, Fabiani, Gratton, & Bettencourt, 2001).

Given the design used in the present experiment, congruency between the content of the sentence context and the following face could arise at both the semantic and affective or evaluative levels. Semantic congruency would refer to the relationship between the specific emotional content of the described event (happiness vs. anger-inducing situations) and the expression shown by the face (happiness or anger). At the same time, congruency might be also affective or evaluative, as the situation could be related to an emotion of the same or of different valence than that of the facial expression. The main question that we have tried to address with our research is at what stage is the processing of facial expressions of emotion sensitive to the congruency with the preceding context. Some previous studies with affectively or socially meaningful stimuli have reported N400 and LPP priming effects that have been related to semantic and evaluative congruence, respectively (Baetens et al., 2011; Bartholow et al., 2001; Herring et al., 2011). These effects correspond to processing stages related to semantic integration (N400) and to the mobilization of attentional resources to emotionally meaningful stimuli (LPP). Since the procedure used in the present study allowed to explore the effects of semantic and affective congruencies, context influences on emotional face processing might, in principle, be expected on either one or both of these components. One main question was that whether components linked to early visual processing, such as the N170, would also be modulated by congruency. The only available evidence to date in this respect comes from Righart and De Gelder's studies with picture primes. However, it is not clear from these results whether similar effects should be expected with contexts that require a more complex, conceptual analysis, such as the sentence contexts used in the present study. There is no previous evidence that early face processing stages, such as that indexed by the N170, are sensitive to semantic or conceptual influences. In a relevant study with intracranial recording of ERPs (Puce, Allison, & McCarthy, 1999), it was found that the face-specific N200 component, recorded from the ventral occipitotemporal cortex, did not show semantic priming effects. These effects, however, did appear on two later components, P290 and N700, thought to reflect later face processing. Based on these considerations, our prediction was that congruency effects would not appear on the N170 component.

METHOD

Participants

Participants were 20 psychology students (15 female and 5 male) that took part in the experiment for course credit. Their ages ranged between 18 and 22 years (mean 19.4). All of them had normal or corrected vision, were right-handed, and Spanish was their native language.

Apparatus and stimuli

Software E-Prime 2.1 (Psychology Software Tools, Pittsburgh, PA, USA) was used for stimulus presentation and response registration. Stimuli were presented on a 23″ LCD screen. Responses were recorded using the keyboard. Sessions were carried out individually in an electrically and acoustically shielded room. The stimuli used as contexts consisted of 20 short sentences describing emotion-inducing daily situations (see Appendix A). Half of these sentences described happiness-inducing (positive sentences) and the other half, anger-inducing (negative sentences) situations. These types of situations were chosen based on two main criteria. First, the corresponding emotions can be easily differentiated because they have opposed valence and are related to clearly different, nonoverlapping evaluative patterns. For example, whereas happiness is usually associated with the perception of goal attainment and reward, the appraisal of goal blocking or frustration is the main determinant of anger (e.g., Kuppens, Van Mechelen, & Meulders, 2004; Scherer, 1997; Smith & Lazarus, 1993). Second, the prototypical facial expressions of happiness and anger are easily discriminated and their confusability is very low (e.g., Calvo & Lundqvist, 2008).

Positive and negative sentences were equated for number of words and had the same syntactic structure. Positive sentences described situations that would lead to a happy reaction due to either the fulfillment of a desired goal (e.g., “He has received the promotion he wanted at work”) or the presentation of a valued social or material reward (e.g., “His country’s soccer’s team has just won the world cup”). Negative sentences described situations that would lead to an angry reaction due to the obstruction of a goal (e.g., “He is informed at the airport that his luggage has been lost”) or because valued personal belongings have been taken away or voluntarily damaged (e.g., “He notices someone has vandalized his car”). These contents were chosen based on the characterization of the antecedents leading to the emotions of happiness and anger by appraisal theories of emotion (e.g., Scherer, 1999; Smith & Lazarus, 1993). The sentences finally used in the ERP study were selected from a larger set, based on the results obtained in a pilot study where the participants evaluated them in terms of emotion category and emotional intensity. Participants were given four different choices to categorize each sentence: “Happiness”, “anger”, “other emotion”, or “no emotion in particular”. After choosing one particular emotion label, participants were asked to rate, on a 1–9 scale, the intensity with which the sentence in question represented the chosen emotion. Those sentences that were identified by at least 75% of the participants in the pilot study as representing happiness or anger-inducing situations were selected for the present study. Mean emotional intensities were 7.22 (SEM = 0.75) and 7.50 (SEM = 0.56) for positive and negative sentences, respectively, $t(18) = -0.928$, $p = .36$. Ten additional sentences were selected for the practice phase that would not be used in the experimental phase.

Target stimuli were black and white pictures of the faces of 10 models (5 male, 5 female) showing either a happy or an angry expression and were taken from the NimStim set (Tottenham et al., 2009). Faces were cropped to remove hair and each model appeared showing both expressions, making for a total of 20 targets. These stimuli were selected based on the results of an additional pilot study with a structure similar to that of the sentence pilot study describe above. Percentage recognition of the represented emotion was above 80% for all selected faces and the two sets of faces did not differ in emotional intensity, $t(18) = 0.705$, $p = .49$. Mean emotional intensity for happy faces was 6.23 (SEM = 1.08), and for angry faces was 6.56 (SEM = 1.03). An additional set of 10 faces was selected to be used in the practice phase. Finally, the neutral, non-expressive faces of each model were used to accompany the sentence prime (see further details in the Procedure section).

Procedure

Instructions were presented self-paced on screen. Participants were informed that, on each trial, they would first see the expressively neutral face of a person along with a written description of a situation that she/he had lived through and that next, they would see the face of the same person showing her/his emotional reaction to that situation. The participants were instructed to read the sentence and then press the space bar, after which they would see the face of the same individual, but with a happy or an angry expression (see Appendix B for the complete text of the instructions as presented to the participants). This would be the target stimulus to which the participant had to respond. The task of the participant was simply to indicate whether the target face showed a happy or an angry expression.

During a previous familiarization phase, participants were presented with all the faces that would be later used in the experiment and asked to identify its expression. This phase was included with the aim of familiarizing the participants with the faces and to avoid possible effects of novelty or surprise during the experimental phase. Before the experimental phase, the participants received 20 practice trials. These trials had the same structure as those of the experimental phase, but with a different set of faces. Each trial started with a 1000 ms fixation point, followed by the prime or context sentence presented along with the corresponding neutral face. Participants were instructed to press the space bar upon reading the sentence, after which the fixation point was presented again during 1000 ms. Finally, the target was presented and the participant had to indicate its emotional expression using the keys "c" and "m" of the computer keyboard (the correspondence between keys and emotion labels was counterbalanced across participants). In order to embed each target face into a narrative, the context sentences were presented on the screen along with an expressively neutral face, followed then by the face of the same model showing a happy or an angry expression. With this procedure, we intended to model real situations in which we see people changing their expression in response to external events or to information provided by other people. The main manipulation was the congruency between the content of the context sentence and the following target face. In congruent trials, the target face showed an emotional expression that was congruent with the emotion suggested by the sentence (happy sentence followed by a happy face or angry sentence followed by an angry face), while in incongruent trials, the face showed an expression incongruent with the sentence (happy sentence followed by an angry face or angry sentence followed by a happy face). A flowchart showing the sequence of events in experimental trials is presented in Figure 1.

Each of the two expressions shown by each model was preceded by a positive or a negative sentence in different trials and each of these sentence–expression pairs was repeated eight times. Pairing of models with specific sentences was randomized across participants, so that different participants saw one specific face paired with different sentences. Eighty trials per condition (congruent/happy, congruent/angry, incongruent/happy, and incongruent/angry) were presented to each subject.

Electrophysiological recording

EEG activity was recorded from 32 Ag/AgCl electrodes mounted on an electrode cap (Compumedics Neuroscan's Quick-Cap; Neuroscan, Compumedics, Abbotsford, Australia). All scalp electrodes were referenced to the right mastoid and offline referenced to averaged mastoids. Electro-oculographic (EOG) data were recorded supra- and infraorbitally (vertical EOG), as well as from the left versus right orbital rim (horizontal EOG). Data were recorded with a bandpass filter from 0.1 to 50 Hz and digitization sampling rate was set to 1000 Hz. The continuous recording was divided into epochs ranging from –200 ms to 800 ms after target onset. Trials in which participants responded erroneously or did not respond were eliminated. The signal was baseline corrected and an offline low-pass filter was applied (30 Hz/24 dB). Ocular artifact correction was carried out through the method described by Semlitsch, Anderer, Schuster, and Preelich (1986). The remaining artifacts were removed after visual inspection. Mean number of trials per subject and condition after artifact rejection were 39.95 ($SD = 7.43$), 38.7 ($SD = 11.07$), 40.85 ($SD = 9.41$), and 39.8 ($SD = 10.36$) for the happy/congruent, angry/congruent, happy/incongruent, and happy/incongruent conditions, respectively. An ANOVA with Condition as a repeated measures factor did not show significant effects ($F(1,19) = 0.70$, $p = .795$).

Data analysis

Detection and quantification of N170, N400, and LPP effects were carried out through covariance matrix-based temporal principal component analysis (tPCA). This technique has been repeatedly recommended since the exclusive use of traditional visual inspection

Figure 1. Layout of the experimental procedure.
Publication of the faces included in this figure is permitted by authors of the NimStim set of facial expressions (Tottenham, N., Tanaka, J., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., Marcus, D. J., Westerlund, A., Casey, B. J., & Nelson, C. A. 2009. The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168(3)*, 242–249).

of grand averages and voltage computation may lead to several types of misinterpretation (Chapman & McCrary, 1995; Dien & Frishkoff, 2005). The main advantage of tPCA over traditional procedures based on visual inspection of recordings and on "temporal windows of interest" is that it presents each ERP component separately and with its "clean" shape, extracting and quantifying it free of the influences of adjacent or subjacent components. Indeed, the waveform recorded at a site on the head over a period of several hundreds of milliseconds represents a complex superposition of different overlapping electrical potentials. Such recordings can stymie visual inspection. In brief, tPCA computes the covariance between all ERP time points, which tends to be high between those time points involved in the same component, and low between those belonging to different components. The solution is therefore a set of factors made up of highly covarying time points, which ideally correspond to ERP components. Temporal factor (TF) scores, the tPCA-derived parameters in which extracted TFs may be quantified, are linearly related to amplitude. In the present study, the decision on the number of components to select was based on the scree test (Catell, 1966). Extracted components were submitted to promax rotation, as recently recommended (Dien, 2010, 2012; Dien, Khoe, & Mangun, 2007). As explained in detail later, the presence of N170, N400, and LPP effects was confirmed.

Signal overlapping may occur also at the space domain. At any given time point, several neural processes (and hence, several electrical signals) may concur, and the recording at any scalp location at that moment is the electrical balance of these different neural processes. While tPCA "separates" ERP components along time, spatial PCA (sPCA) separates ERP components along space, each spatial factor ideally reflecting one of the concurrent neural processes underlying each TF. Additionally, sPCA provides a reliable division of scalp into different recording regions, an advisable strategy prior to statistical contrasts, since ERP components frequently behave differently in some scalp areas than in others (e.g., they present opposite polarity or react differently to experimental manipulations). Basically, each region or spatial factor is formed with the scalp points where recordings tend to covary. As a result, the shape of the sPCA-configured regions is functionally based, and scarcely resembles the shape of the geometrically configured regions defined by traditional procedures. Moreover, each spatial factor can be quantified through the *spatial factor score*, a single parameter that reflects the amplitude of the whole spatial factor. Therefore, sPCAs were carried out for the relevant TFs (N170, N400, and LPP). Also, in this case, the decision on the number of factors to select was based on the scree test, and extracted factors were submitted to promax rotation.

Subsequently, repeated-measures ANOVAs on N170, N400, and LPP spatial factor scores and on the behavioral dependent measure (reaction time (RT)) were carried out with respect to Congruency (two levels: Congruent and Incongruent) and Target Emotion (two levels: Happy and Angry). In all statistical contrasts involving analyses of variance (ANOVAs), the Greenhouse–Geisser (GG) epsilon correction was applied to adjust the degrees of freedom of the F-ratios, and post hoc comparisons to determine the significance of pairwise contrasts were made using the Bonferroni procedure ($\alpha = 0.05$). Effect sizes were computed using the partial eta-square ($\eta^2{}_p$) method. Prior to ANOVAs, RT data (only for correct responses) were screened for statistical outliers based on each participant's distribution and subsequently log transformed to achieve a normal distribution. Nonsignificant Shapiro–Wilk test (all p-values $>.26$) demonstrated the Gaussian distribution of the RTs for each experimental condition. These analyses ensured the suitability of the RT data for parametric statistical testing.

Finally, to localize the cortical generators of the N170, N400, and LPP components, standardized low-resolution brain electromagnetic tomography (sLORETA) was applied to relevant TF scores. sLORETA is a 3D discrete linear solution for the EEG inverse problem (Pascual-Marqui, 2002). Although solutions provided by EEG-based source location algorithms should be interpreted with caution due to their potential error margins, LORETA solutions have shown good correspondence with those provided by hemodynamic procedures (such as fMRI and PET) in the same tasks (Dierks et al., 2000; Mulert et al., 2004; Pizzagalli, Oakes, & Davidson, 2003). Moreover, the use of tPCA-derived factor scores instead of direct voltages (which leads to more accurate source localization analyses, see Carretié et al., 2004; Dien, 2010; Dien, Spencer, & Donchin, 2003) contributes to reducing this error margin. In its current version, sLORETA computes the standardized current density at each of 6239 voxels (voxel size: 5 mm × 5 mm × 5 mm) in the cortical gray matter and the hippocampus of the digitized Montreal Neurological Institute (MNI) standard brain.

RESULTS

Behavioral data

Mean overall accuracy of target responses was 0.97 (SEM = .05). Mean RTs per condition are presented in Table 1. As already mentioned, RT data were log transformed to achieve normal distributions for all experimental conditions. The resulting data were subjected to a repeated-measures ANOVA, with Congruency and Target Emotion as factors. This analysis gave a significant effect of Congruency, $F(1, 19) = 4.66$, $p = .044$), with slower RTs on incongruent trials, and a marginal effect of Congruency × Emotion interaction, $F(1, 19) = 3.59$, $p = .074$).

Scalp ERP data

A selection of the grand averages is presented in Figure 2. The waveforms presented in the figure correspond to those scalp areas where experimental effects (described later) were most evident. As a consequence of the application of the tPCA, seven components[1] were extracted from the ERPs (see Figure 3). Factor

TABLE 1
Behavioral results

	Prime–target congruency	
	Congruent	*Incongruent*
Emotion	*RT (ms)*	
Happy	585.48 (32,83)	625.8 (42,59)
Angry	599.28 (38,45)	634.92 (46,15)

[1] Although the N170, N400, and LPC components were the focus of the present study, statistical analyses (ANOVAs) were conducted also on earlier PCA factors. The results of these analyses were not significant for either the main effects or their interaction.

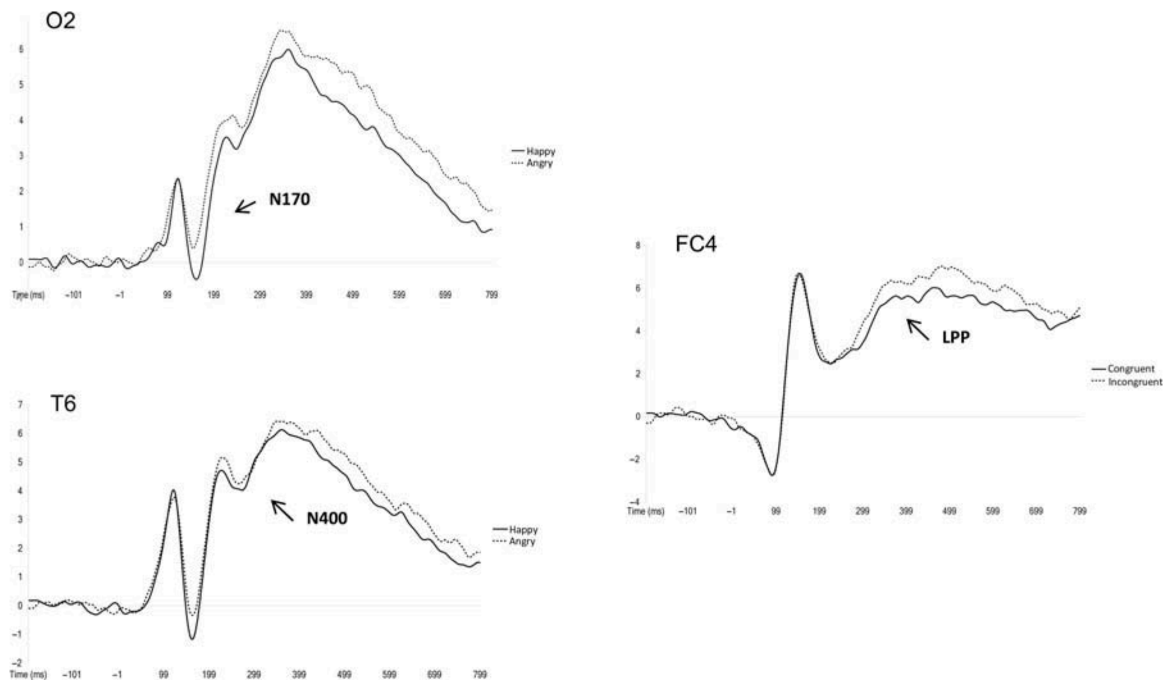

Figure 2. Grand average, target-locked event-related potential (ERP) waveforms at selected occipital, temporal, and central electrodes as a function of facial expression and sentence–expression congruency.

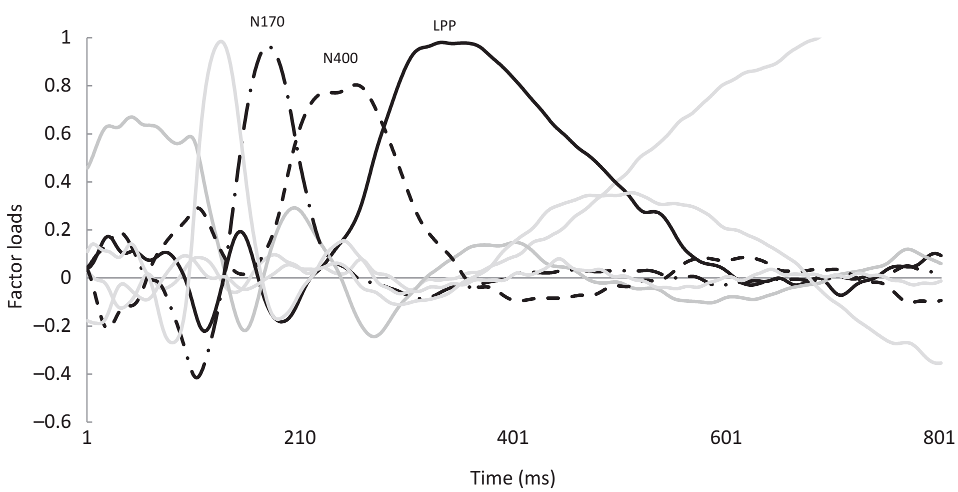

Figure 3. PCA-derived temporal factors. Temporal factors sensitive to experimental manipulations (N170, N400, and LPP) are marked in color.

latency and topography revealed the following TFs as the key components: TF5 (peaking around 160 ms), TF4 (peaking around 260 ms), and TF2 (peaking around 350 ms), corresponding to the N170, N400, and LPP components, respectively. These labels will be employed hereafter to make results easier to understand. The sPCA subsequently applied to TF scores extracted two spatial factors for the N170, N400, and LPP components, respectively.

Repeated-measures ANOVAs on N170, N400, and LPP spatial factors (directly related to amplitudes, as previously indicated) were carried out for the Congruency and Target Emotion factors. The results of this analysis are summarized in Table 2. A significant effect of Target Emotion was found in N170 both in parieto-occipital [$F(1, 19) = 14.17$, $p = .002$, $\eta^2 = 0.4$] and fronto-central [$F(1, 19) = 13.06$, $p = .001$, $\eta^2 = 0.42$] spatial factors, with larger amplitudes for happy targets as compared to angry faces. The main effect of Target Emotion was also observed in N400 in a temporo-parieto-occipital scalp factor [$F(1, 19) = 6.24$, $p < .05$, $\eta^2 = 0.24$], again with greater amplitudes for happy than for angry faces (see Figure 4). Finally, the main effect of Congruency

TABLE 2

Results of the ANOVA performed on relevant temporo-spatial PCA factors. An asterisk denotes that the factor is significant ($p < .05$, 2×2 ANOVA, see text for further details)

Temporal factor	*Spatial factors*	*Congruency*	*Emotion*	*Congruency × emotion*
TF6 (P100)	*Fronto-central*	$F(1, 19) = 0.389$	$F(1, 19) = 0.159$	$F(1, 19) = 0.002$
	Occipital	$F(1, 19) = 0.279$	$F(1, 19) = 1.552$	$F(1, 19) = 0.022$
	Temporo-parietal	$F(1, 19) = 0.019$	$F(1, 19) = 0.013$	$F(1, 19) = 0.157$
TF5 (N170)	*Fronto-central*	$F(1, 19) = 2.311$	$F(1, 19) = 13.06^*$ Anger > Happy	$F(1, 19) = 0.167$
	Parieto-occipital	$F(1, 19) = 0.629$	$F(1, 19) = 14.17^*$ Anger > Happy	$F(1, 19) = 0.167$
TF4 (N400)	*Fronto-central*	$F(1, 19) = 0.415$	$F(1, 19) = 0.111$	$F(1, 19) = 0.032$
	Temporo-parieto-occipital	$F(1, 19) = 0.186$	$F(1, 19) = 6.239^*$ Anger > Happy	$F(1, 19) = 0.094$
TF2 (LPP)	*Fronto-central*	$F(1, 19) = 12.46^*$ Incongruent > Congruent	$F(1, 19) = 2.79$	$F(1, 19) = 0.353$
	Temporo-parieto-occipital	$F(1, 19) = 0.817$	$F(1, 19) = 2.99$	$F(1, 19) = 0.095$

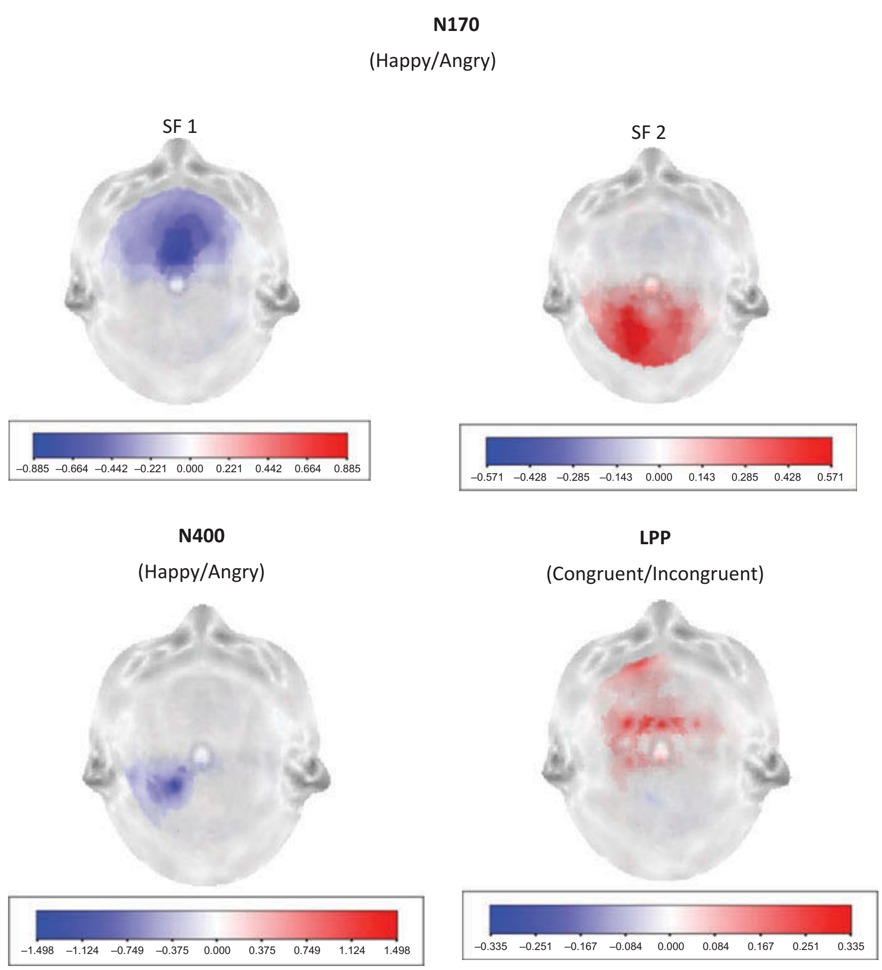

Figure 4. Scalp maps representing the differences between Happy and Anger, in the case of fronto-central N170, parieto-occipital N170, and temporo-parieto-occipital N400, and between Congruent and Incongruent in the case of fronto-central LPP.

was evident in the LPP in a fronto-central factor [$F(1, 19) = 12.46$, $p = .002$, $\eta 2 = 0.39$]. Amplitudes were maximal on trials where the target face was preceded by emotionally incongruent sentences (see Figure 2). Figure 4 shows scalp maps representing the distribution of difference waves for each of the significant main effects (Target Emotion and Congruency), corresponding to those spatial factors that reached statistical significance. In other words, these scalp maps reflect the differences between Happy and Anger, in the case of fronto-central N10, parieto-occipital N170, and temporo-parieto-occipital N400, and between Congruent and Incongruent in the case of fronto-central LPP.

Source localization data

The last step consisted of localizing the cortical sources underlying the main ERP components observed at the scalp level. To that aim, the sLORETA algorithm was applied to N170, N400, and LPP TF scores averaged across subjects and conditions. As shown in Figure 5, voxels in the middle temporal gyrus (BA 21, $x = 65$, $y = -55$, $z = 5$), precuneus (BA 19, $x = -30$, $y = -85$, $z = 40$) and intraparietal sulcus (BAs 40/7, $X = -45$, $Y = -55$, $Z = 55$) were maximally involved in the generation of N170, N400, and LPP, respectively.

DISCUSSION

In the present study, participants performed an emotion recognition task with target angry and happy faces preceded by short sentences describing daily situations that might be congruent or incongruent with the expression shown by the face. These sentences were intended to act as the context in which the faces would be perceived. Behaviorally, an effect of congruency was observed, with slower identification of the target expression in those trials where the expression was incongruent with the emotional meaning of the

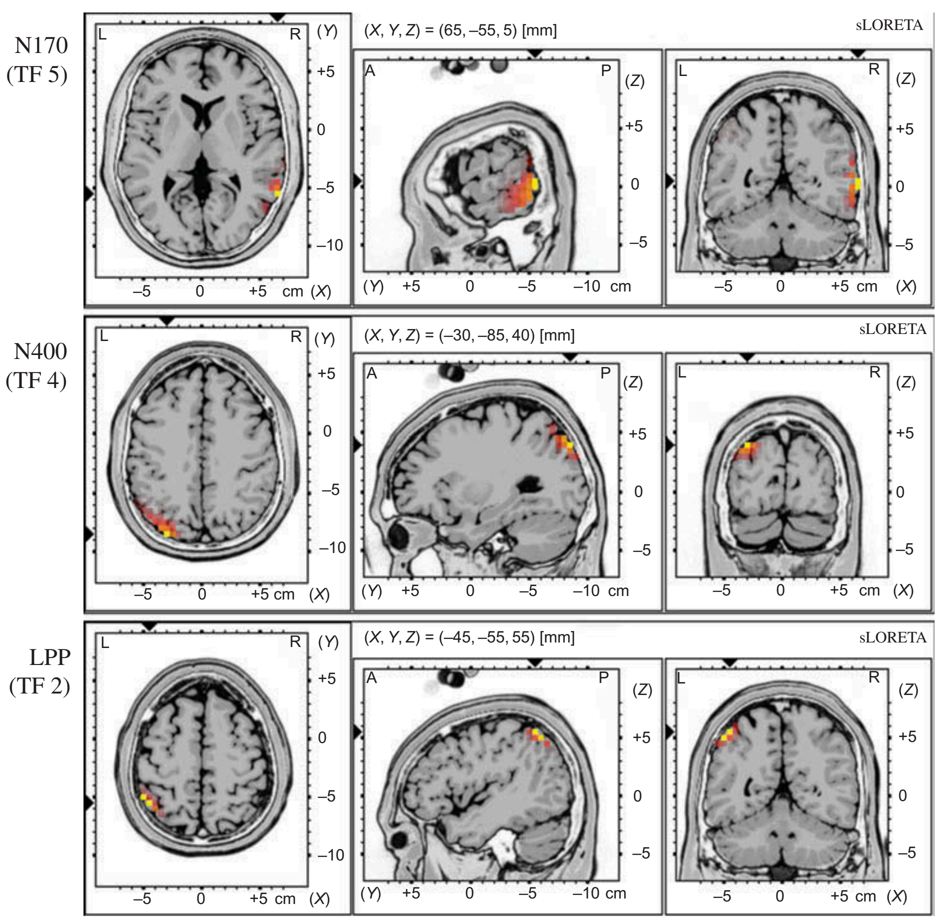

Figure 5. sLORETA solutions for N170, N400, and LPP temporal factor scores averaged across subjects and conditions. Coordinates are reported in MNI space.

preceding sentence. At the electrophysiological level, temporal-spatial PCA applied to activity recorded in the presence of the target faces revealed several components, three of which were sensitive to our experimental operations. These components were identified with the N170, the N400, and the LPP components according to their distribution and topography. Moreover, source analysis revealed probable neural generators for these components that are consistent with those found in previous studies (see discussion below). The main result obtained in the study was the differential sensitivity of these components to the two variables of interest, the expression shown by the target face and the congruency between that expression and the emotional meaning of the preceding sentence. N170 and N400 showed sensitivity to the first variable, as they were enhanced in the presence of happy faces. This effect was not modulated by the congruency between the expression and the preceding sentence context as it appeared in both congruent and incongruent trials. However, an effect of congruency was observed on the LPP. This later component showed larger amplitudes during the processing of target faces showing emotional expressions that were incongruent with the preceding context. This pattern of results reveals dissociable modulations of different ERP components by the emotional valence of faces and by the congruency between the facial expression and the preceding context.

N170

As was discussed in the introductory section, the N170 is the earliest ERP component identified in most studies as being differentially sensitive to faces. It appears as a negativity at occipitotemporal sites that is enhanced in the presence of faces compared to other types of objects. Source analysis and intra-cranial ERP recordings have revealed cortical sources in temporal cortices including the fusiform gyrus and the middle temporal gyri (e.g., Herrmann, Ehlis, Muehlberger, & Fallgatter, 2005; Itier & Taylor, 2004). In our study, source analysis at the N170 latency revealed a main source in the middle temporal gyrus, which is in line with previous research. Although there is still controversy regarding the possibility that N170 to faces can be modulated by emotion (Eimer & Holmes, 2002; Herrmann et al., 2002), there is now accumulating evidence that this component is sensitive to emotional expression and affective valence (Aguado et al., 2012; Batty & Taylor, 2003; Blau et al., 2007; Caharel et al., 2005). Moreover, the N170 component has been found, in some studies, to be modulated by the congruency between emotional faces and picture backgrounds (Righart & de Gelder, 2006, 2008b). This result is theoretically relevant because it suggests that integration of affective information from the face with contextual information takes place at early stages of visual processing. However, in our study, we failed to find evidence of N170 modulation by the congruency between the expression of the face and the content of the preceding sentence. In fact, what we observed was a main effect of emotion that was not modulated by affective congruency, as it appeared as an increased negativity elicited by happy faces in both congruent and incongruent trials. One main difference between our study and those by Righart and De Gelder is that while these authors used as contexts visual scenes presented simultaneously with the target face, we used verbal descriptions of emotion-inducing situations that the participants read just before seeing the faces. These differences might be important for several reasons. First, presenting simultaneously the visual context and the face might produce perceptual interactions that might explain by themselves the increased N170 amplitudes observed on congruent trials. Perhaps of more theoretical relevance are the differences that may derive from the different codes, visual and linguistic, in which the contexts were presented in ours and in Righart and De Gelder's studies. There is evidence that the affective gist is fast and effectively extracted from pictures even with very short exposure durations (Calvo, Nummenmaa, & Hyönä, 2008; Gutierrez, Nummenmaa, & Calvo, 2009), and ERP studies have indeed found modulation of early visual components by high-arousal pictures (e.g., Foti, Hajcak, & Dien, 2009; Junghöfer, Bradley, Elbert, & Lang, 2001). These early modulations probably reflect attentional capture, driven by general, basic affective stimulus properties such as arousal or affective gist. It is possible that the early face processing operations indexed by the N170 component are influenced by the output of systems performing a raw affective analysis of the background on which the face is presented. However, this may not be the case for the output of more conceptual analysis of complex linguistic messages, such as those conveyed by our sentence contexts. If this were so, it might explain why in the present study the N170 component was not sensitive to the congruency of the face with the context set by the preceding linguistic description of an emotional situation. There is, however, contradictory evidence on the possibility that linguistic information may modulate early face processing. On the one hand, enhanced N170 amplitudes have been reported by Landau, Aziz-Zadeh, and Ivry (2010, Experiment 1) to faces preceded by sentences describing facial features, compared to those trials where the preceding sentence described a place. On the other hand, and more pertinent to our results, Krombholz, Schaefer, and Boucsein (2007) failed to find an effect of the congruency between target schematic facial expressions and preceding emotional adjectives on this component. Together with the results from the present study, this last result suggests that the N170 component may not be sensitive to affective congruency, at least when affective meaning is expressed in an abstract, linguistic code.

N400

As was discussed in the introductory section, the N400 component is usually sensitive to semantic congruency in paradigms with verbal stimuli and has been found, in some studies, to be also modulated by the affective congruency between emotional prime and target stimuli. Previous studies have shown evidence that the left temporal lobe is a main contributor to the scalp-recorded N400 (see reviews by Lau, Phillips, & Poeppel, 2008; Van Petten & Luka, 2006). In the present study, source localization analysis gave the precuneus as the probable neural source of this component. Similar localization has been found in previous studies with faces (Jemel, George, Olivares, Fiori, & Renault, 1999) and verbal stimuli (Silva-Pereyra et al., 2003). The extent to which the N400 component responds to the affective congruency between a target stimulus and preceding primes or contexts is not well settled. Some studies have indeed found the usual N400 effect, that is, increased amplitudes on congruent trials (Morris, Squires, Taber, & Lodge, 2003; Zhang, Lawson, Guo, & Jiang, 2006; Zhang et al. 2010), while others have failed to obtain differential effects (e.g., Herring et al., 2011; Hinojosa et al., 2009; Taylor, 2010) or even have obtained inverse priming effects, with more negative amplitudes on congruent trials (Aguado et al., 2013; Paulmann & Pell, 2010). In the present study, no congruency effects were found on the N400 component. This result contrasts with that reported in the already mentioned study by Krombholz et al. (2007). These authors found enhanced N400 amplitudes on those trials where the faces were preceded by emotionally incongruent adjectives. Similarly, Paulmann and Pell (2010) observed the usual N400 effect in response to emotional faces when these were preceded by affectively incongruent voice intonations with a 400 ms stimulus onset asynchrony (SOA), though the effect was inverted (that is, the N400 component was enhanced on congruent trials) at a shorter, 200 ms SOA. However, the absence of congruency effects in our study was not completely unexpected, given the mixed evidence on the effects of affective congruency on the N400 component.

The main effect of emotion was found on the N400 component, with more negative-going deflections in the case of happy targets. Effects of emotion on the N400 component with face stimuli have been reported before (Eimer, 2000; Paulmann & Pell, 2009; Zhang, Li, & Zhou, 2008). Similar effects have also been obtained with visually presented words (Holt, Lynn, & Kuperberg, 2009; Schirmer, Kotz, & Friederici, 2005; Trauer, Andersen, Kotz, & Müller, 2012). These effects have been interpreted as reflecting enhanced processing of stimuli endowed with emotional meaning. According to this interpretation, the result obtained in the present study would suggest that happy faces were, in general, more deeply processed and that this effect was independent of the congruency between the face and the preceding context. Although modulations of ERP components by negative emotional expressions have been frequently reported, with enhanced amplitudes in the presence of negative faces (e.g., Aguado et al., 2012; Eimer & Holmes, 2002; Schupp et al., 2004), other studies have reported opposite results suggesting a “positivity bias” that favors the processing of happy faces. More specifically, increased amplitudes elicited by happy faces have been detected at different latencies corresponding to the N170 and to later components, such as the P300 and early posterior negativity (EPN) (e.g., Carretié et al., 2012; Marinkovic & Halgren, 1998; Schacht & Sommer, 2009). These enhanced amplitudes might reflect a processing bias, whose function might be to facilitate attention to highly relevant social information that communicates positive states and approach dispositions.

LPP

Affective congruency effects were detected on a later positive component with maximal amplitudes around 350 ms, corresponding to the LPP. This component showed larger amplitudes at fronto-central scalp regions for incongruent targets, that is, in those trials in which the target face showed an emotional expression that was incongruent with the content of the preceding sentence. This effect was not modulated by target valence, as it was evident with both happy and angry target faces.

As was mentioned in the introductory section, modulation of the LPP by prime–target congruency has been reported before in the affective priming paradigm (Herring et al., 2011; Hinojosa et al., 2009; Werheid et al., 2005; Zhang et al., 2010). It has been proposed that this effect and the similar effect observed in studies on violation of social expectancies might be related to the detection of evaluative incongruency (Baetens et al., 2011; Herring et al., 2011), that is, to the detection of a discrepancy between the valences of the target and the preceding prime or context. This contrasts to the functional meaning of the N400 component that would rather be related to processes of a more semantic nature, such as the integration of the target with the preceding semantic context (Kutas & Federmeier, 2011). Results supporting a similar distinction between the functional meaning of the LPP and N400 components have been obtained by Bartholow et al. (2001) in a study on social expectancies. In this study, the N400 component was found to be sensitive to semantic congruency but not to expectancy violations. In contrast, the LPP was sensitive to expectancy violations but not to semantic congruency. In paradigms using emotional stimuli, as in the present study, the distinction between semantic and evaluative congruencies would correspond to the detection of congruency in relation to two different levels of affect-related computations, the first one related to the evaluation of the stimulus as pleasant or unpleasant (affective valence computation) and the second one having to do with the analysis of the specific meaning of the stimulus as related to specific emotions (emotion content computation). Discrepancy between the valences of the target and the preceding prime or context would lead to the detection of evaluative incongruency. On the other hand, discrepancy in terms of emotion content (e.g., between a happy-related target and an anger context) would lead to the detection of incongruency in terms of specific emotional meaning. According to this account, the pattern of results obtained in the present study, with congruency effects on LPP but not on N400, might be interpreted as showing an effect of evaluative congruency in the absence of semantic congruency effects.

Two aspects of the LPP results obtained in the present study deserve special comment. First, although sPCA yielded two spatial factors for this component (temporo-parieto-occipital and fronto-central), significant effects of context–target congruency were found only in the fronto-central component. The correspondence of these positivities with the LPP is supported by both its scalp distribution and the location of its neural generators suggested by source analysis. Source analysis pointed to the intra-parietal sulcus as the cortical region maximally involved in the generation of the component. This is coincident with the results of functional imaging studies that have found a positive correlation between the amplitude of the LPP and blood oxygen level dependent (BOLD) signal changes in visual parietal areas (Sabatinelli, Keil, Frank, & Lang, 2012; Sabatinelli, Lang, Keil, & Bradley, 2007). Furthermore, extended positivities with anterior distributions, such as those observed here, have been previously observed in several studies on the effect of context–target or prime–target congruency with socio-emotional stimuli. For example, and enhanced frontal positivity in the LPP latency range has been observed in studies on the effects of violations of social expectancies (e.g., Baetens et al., 2011; Bartholow et al., 2001; Leuthold, Filik, Murphy, & Mackenzie, 2012). Modulations of frontal positivities in the same latency range are also documented in studies with emotionally arousing words (Hinojosa, Méndez-Bértolo, & Pozo, 2012; Méndez-Bértolo, Pozo, & Hinojosa, 2011) and in studies looking at the effects of semantic congruency (e.g., Federmeier, Wlotko, De Ochoa-Dewald, & Kutas, 2007; Molinaro, Carreiras, & Duñabeitia, 2012). Although there is at present no formal explanation for the possible functional basis of the frontally distributed LPP, results obtained in different paradigms using verbal stimuli suggest that it might reflect an increase in resource demands in cases where targets are especially difficult to integrate with immediately preceding contexts or primes (Federmeier et al., 2007; Hinojosa et al., 2012; Méndez-Bértolo et al., 2011; Molinaro et al., 2012). For example, Federmeier et al. (2007) found an enhanced positivity that was most prominent on frontal sites when unexpected target items were embedded in strongly constraining sentence contexts. Therefore, it might be speculated that, in our case, the enhanced frontal LPP could reflect the high constraint set by the sentence context in terms of the valence of the facial expression that would be more expected given the valence of the sentence. More specifically, while anger-related sentences would set a strong expectation that the person would react with a negative expression, happy-related sentences would set a strong expectation that the person would react with a positive expression. The enhanced LPP on incongruent trials would reflect the detection of a discrepancy between the expectation set by the context and the valence of the actual expression shown by the target face.

The second aspect of the LPP results obtained in the present study is the relatively early latency at which this component appeared, at least compared to what has been found in studies with emotional pictures (e.g., Cuthbert et al., 2000; Weinberg & Hajcak, 2010) that have reported LPP effects on the 400–700 ms range and longer. However, effects of emotion on the LPP at shorter latencies are not uncommon, with some studies describing effects that start at latencies shorter than 300 (Hajcak, 2006; Hajcak, Dunning, & Foti, 2009; Moser, Hajcak, Bukay, & Simons, 2006). This and the sustained character of the LPP, that may last after picture presentation (e.g., Cuthbert et al., 2000; Weinberg & Hajcak, 2010), is compatible with the description of the LPP as the sum of several overlapping positivities with different temporal properties rather than as a single component (Hajcak, Weinberg, MacNamara, & Foti, 2012).

CONCLUSIONS

In the present study, modulations of the amplitude of different ERP components at post-stimulus onset times were observed in the presence of target faces showing happy or angry expressions. There were two sources of these modulations, the emotional expression of the face and the affective congruency between that expression and the preceding sentence context. Emotion-related modulations appeared first, as enhancements of the amplitude of the N170 and N400 components in the presence of happy faces. The fact that this effect appeared in both congruent and incongruent trials suggests that it is the product of more automatic processes that are not under contextual modulation and that probably reflect an enhancement of perceptual and attentional processing driven by the affective valence of the stimulus. ERP effects suggestive of more flexible processing operations that probably reflect the computation of the congruency between the valences of the facial expression and the preceding context were evident only at a later latency and appeared as an enhanced amplitude of the LPP. This last result provides new evidence suggesting that processing of facial expressions of emotion is sensitive to situational contexts that simulate the complex emotional environments in whose presence we perceive facial expressions of emotion in everyday life.

The main conclusion that can be drawn from the present study concerns the timing of cognitive operations reflecting the initial processing of the affective valence of facial expressions and those involved in evaluating the congruency of the expression with the knowledge about the expresser's situation provided by the immediately preceding context. According to our results, these two types of cognitive operations can be dissociated and have a different temporal course. While the two earliest components that were sensitive to our experimental variables, the N170 and the N400, showed effects of emotion that were independent of congruency, the later component, LPP, was sensitive to affective congruency but did not respond to affective valence. The absence of congruency effects on the N170 component contrasts with the results from previous studies where the face targets appeared on the background of emotionally arousing pictures (Righart & de Gelder, 2006, 2008b). This discrepancy is probably due to the nature of the contexts used in each case. While pictures can be very effective to produce a strong emotional impact based on fast and automatic gist processing, the decoding of the meaning of our sentence contexts requires complex cognitive processes of a more conceptual nature. What we suggest is that the discrepancy between our results and those of Righart and De Gelder reflects the sensitivity of different stages of facial expression processing to modulation by different types of contexts. While early processing stages related to the initial perceptual coding of the face can be influenced by the output of nonconceptual processes that rapidly extract the affective gist of pictorial stimuli, interaction with the output of more conceptual and deliberate processes that decode the meaning of linguistic contexts takes place only at later, possibly post-perceptual stages. However, we must recognize that a more complete understanding of the contextual modulation of facial expression processing would require further studies along these same lines, explicitly contrasting the effects of different types of contexts of varying content and complexity.

Finally, we have to point some characteristics of our study that may limit the generalizability of our results. First, the sentences and faces used in the design contained only stimuli related to two emotions, happiness and anger. More definitive conclusions would require the use of a broader set of emotional stimuli. However, a complete design with several emotions would require an unmanageably large number of trials, especially taking into account the high number of samples per experimental condition needed when using ERPs as the dependent variable. This is perhaps the reason why, in previous related studies, a small number of expressions (two or three) have been also used (e.g., Righart & de Gelder, 2006, 2008a, 2008b). Second, our results were obtained with a sample composed mainly by females. This might be important given that research on gender differences in face perception and in the decoding of emotional expression has usually found higher proficiency in females (e.g., Biele & Grabowska, 2006; Lewin & Herlitz, 2002; for a meta-analysis study, see McClure (2000)). Moreover, some studies using the affective priming paradigm with different types of stimuli, such as odors (Hermans, Baeyens, & Eelen, 1998) and words (Schirmer et al., 2005), have found stronger behavioral priming in female than in male participants. Finally, there is some evidence that these effects are also manifest at the level of brain activity, at least in the case of word stimuli (Schirmer, Kotz, & Friederici, 2002). The extent to which these effects can be generalized to priming effects with facial expressions is not known. In any case, given the composition of the participant sample in the present study, caution should be taken when generalizing our conclusions to the male population.

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APPENDIX A

Negative, anger-inducing sentences		
Sentence	*Agreement (%)*	*Intensity*
Le comunican que han perdido su equipaje en el aeropuerto *(He is informed at the airport that his luggage has been lost)*	85,714	7,57
Le han despedido del trabajo sin avisarle *(He is fired without warning)*	82,143	8,33
Le han robado el móvil que acababa de comprar *(His brand new mobile phone has just been stolen)*	82,143	7,75
Lleva dos horas haciendo cola y alguien intenta colarse *(He has been queuing for two hours when someone tries to cut in before him)*	89,286	6,14
Se da cuenta de que han estado espiando en su ordenador *(He notices that someone has been spying on him through his computer)*	96,429	7,04
Se da cuenta de que unos gamberros le han rayado el coche *(He notices someone has vandalized his car)*	85,714	7,00
Se queda sin concierto porque le han vendido entradas falsas(He isn't allowed into the concert because he has been sold fake tickets)	92,857	7,67
Tiene que madrugar y el ruido de una fiesta le impide dormir *(He needs to wake up early the next morning and the noise from a party won't let him sleep)*	85,714	7,11
Una máquina dispensadora se ha tragado el poco dinero que tenía *(A vending machine has eaten the little money he has left.)*	82,143	5,89
Se ha quedado sin vacaciones porque los controladores están de huelga *(He has to miss his holidays because of an air traffic controller strike)*	78,571	7,71

Positive, happiness-inducing sentences		
Sentence	*Agreement (%)*	*Intensity*
Ha ganado dos entradas para asistir al concierto de su grupo favorito *(He wins two tickets to see his favorite band in concert)*	96,43	7,54
Ha ganado la oposición que había preparado con gran esfuerzo *(He passes the board exam he has studied very hard for)*	92,86	8,18
Ha conseguido que le den el ascenso que tanto deseaba en el trabajo *(He receives the promotion he wanted at work)*	85,71	7,78
Ha conseguido reunir el dinero para comprar el coche que deseaba *(He manages to raise the money he needs to get the car he always wanted)*	82,14	6,86
Por fin le han entregado las llaves de su primer piso *(He is finally given the keys to his first house.)*	100,00	7,33
Está disfrutando del primer día de vacaciones que tanto necesitaba *(He is enjoying the first day of his much-needed holidays)*	82,14	7,46
Ha conseguido que le seleccionen para un casting muy importante *(He is selected for a very important casting)*	89,29	7,54
Por fin ha conseguido la cita que tanto ansiaba con la persona de sus sueños *(He finally gets a date with the person of his dreams)*	85,71	7,89
El equipo de fútbol de su país acaba de ganar el mundial *(His country's soccer team has just won the world cup)*	85,71	6,32
Le han concedido una importante beca para estudiar en el extranjero *(He is given an important grant to study abroad.)*	85,71	8,07

APPENDIX B[2]

Screen 1

You will see faces and sentences in each trial of this task
The sentences describe what has just happened to the person whose face you will see along with the sentence
On each trial you will see
(1) The face of the person
(2) The sentence describing what has just happened to her/him
(3) The face that the person puts when after finding out what happened
Press the space bar to continue

Screen 2

When the sentence appears, please read it and then press the space bar
Your task will be to indicate which expression) the face shows (happy or angry, pressing the following keys:
c = angry m = happy
Press the space bar when you're ready

[2] Original text in Spanish.

CAPÍTULO 5. LA ATENCIÓN EXPLÍCITA A UN CONTEXTO SITUACIONAL MODULA EL PROCESAMIENTO DE LA EXPRESIONES FACIALES DE LA EMOCIÓN

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To whom it may concern

Re Biological Psychology ms # BIOPSY-D-15-00206R3.

To whom it may concern,

This is to confirm that the paper authored by Teresa Dieguez Risco, Luis Aguado, Jacobo Albert, & Jose Antonio Hinojosa entitled 'JUDGING EMOTIONAL CONGRUENCY: EXPLICIT ATTENTION TO SITUATIONAL CONTEXT MODULATES PROCESSING OF FACIAL EXPRESSIONS OF EMOTION' has been accepted for publication in Biological Psychology.

Please do not hesitate to contact me should further information be required.

Yours sincerely

Ottmar Lipp, PhD, FASSA, FAPS

Editor

Biological Psychology

JUDGING EMOTIONAL CONGRUENCY: EXPLICIT ATTENTION TO SITUATIONAL CONTEXT MODULATES PROCESSING OF FACIAL EXPRESSIONS OF EMOTION

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Abstract

The influence of explicit evaluative processes on the contextual integration of facial expressions of emotion was studied in a procedure that required the participants to judge the congruency of happy and angry faces with preceding sentences describing emotion-inducing situations. Judgments were faster on congruent trials in the case of happy faces and on incongruent trials in the case of angry faces. At the electrophysiological level, a congruency effect was observed in the face-sensitive N170 component that showed larger amplitudes on incongruent trials. An interactive effect of congruency and emotion appeared on the LPP (Late Positive Potential), with larger amplitudes in response to happy faces that followed anger-inducing situations. These results show that the deliberate intention to judge the contextual congruency of facial expressions influences not only processes involved in affective evaluation such as those indexed by the LPP but also earlier processing stages that are involved in face perception.

KEYWORDS: CONTEXT, CONGRUENCY, FACIAL EXPRESSION, N170, LPP

INTRODUCTION

In the course of our daily life we use the facial expressions of the people we interact with to understand intuitively their inner states and how these are related to ongoing events. However, facial expressions are not always consistent with the context in which we perceive them and sometimes we feel puzzled by expressions that reveal emotions that seem contextually inappropriate. On these occasions we may try to deliberately ascertain the extent to which the emotion we see in a face matches the current situation. A theoretically relevant issue is the way in which decoding of facial expressions by the brain is influenced by the context in which they are perceived and by our explicit attempt to evaluate their appropriateness to that context. This is related to the more general issue of the relative flexibility of brain processing of facial expressions of emotion and the extent to which it can be influenced by top-down cognitive operations.

A number of recent studies using behavioral and electrophysiological measures have shown that contextual congruency has a significant impact on the way in which facial expressions of emotion are processed (for a review see Wieser & Brosch, 2012). Contextual congruency refers here to the matching of a target facial expression with the situational context in which it appears. At least two broad types of contextual influences can be distinguished according to whether the origin of influence resides in the sender herself (e.g. affective prosody, body posture) or in the external environment (the situational context in which the expression is perceived). The focus of the present study is the influence of situational context on the processing of facial expressions of emotion. In the few studies that have addressed this issue, pictures or sentences with different affective content were presented prior to or along with faces showing positive or negative emotions. Under these conditions it has been shown that the context facilitates behavioral responses to affectively congruent facial expressions (Righart & De Gelder, 2008). Moreover, congruency also modulates expression processing at the level of brain activity. Using the event-related potentials (ERP) technique it has been shown that components that index different aspects of affective and perceptual processing are modulated by the congruency between contexts and expressions (Righart & De Gelder, 2006, 2008; Dieguez-Risco, Aguado, Albert & Hinojosa, 2013; Hietanen & Astikainen, 2013). For example, the amplitude of the N170, an ERP component that is linked to the perceptual stage of structural coding of faces (e.g., Bentin, Allison, Puce, Perez & McCarthy, 1996; Rousselet Husk, Bennett & Sekuler, 2008; see the review by Rossion & Jacques, 2012), is modulated by contextual congruency at least when pictures are used as contexts (Righart & De Gelder, 2006, 2008; Hietanen & Astikainen, 2013). This result indicates that what is considered to be the earliest electrophysiological marker of the differentiation between faces and other visual objects is already sensitive to higher-order contextual influences. This is important because it shows that processing of faces and their emotional expression at this early stage is not fixed and encapsulated but can be modulated in an interactive manner by situational information. However, the generality and precise interpretation of these early effects is not well established. In a study that used short sentences that described emotion-inducing situations as affective contexts (Dieguez-Risco et al., 2013), congruency effects with larger positive amplitudes on incongruent trials were only observed at later latencies on a fronto-central late positive potential (LPP) that is usually enhanced in the presence of affectively meaningful stimuli (e.g., Cuthbert, Schupp , Bradley, Birbaumer & Lang, 2000; Hajcak & Olvet, 2008; Schupp, Öhman, Junghöfer, Weike & Stockburger,2004) and that is also sensitive to affective congruency in the affective priming paradigm (Herring, Taylor, White & Crites,2011; Werheid,Alpay, Jentzsch & Sommer, 2005; Zhang, Lia, Gold & Jiang,2010). In a different study (Krombholz, Schaefer, & Boucsein, 2007), N170 to target faces was modulated by the valence of their emotional expression, with larger amplitudes in response to angry than happy faces, but not by their congruency with immediately preceding word primes. However, congruency did influence a later component, the N400, that has been traditionally associated to the computation of semantic congruency in the context of sentence processing (see the review by Kutas & Federmeier, 2011). More specifically and in line with the usual effect of congruency on the N400, larger negative amplitudes were observed on incongruent trials.

In the studies mentioned above the processing of facial expression was modulated by the preceding contexts or primes in spite of the fact that the instructions did not require or even discouraged attention to them or to their relationship with the target expression. This seems to indicate that the information provided by the context or prime is automatically encoded and integrated with that provided by the expression itself and that emotional congruency can be processed implicitly. In the present study we were interested in establishing whether processing of facial expressions of emotion is also sensitive to the top-down influence of strategic processes engaged by tasks that involve explicit reasoning about their contextual congruency. Evidence from previous studies suggests that automatic processes linked to the encoding of expressive faces and other affective stimuli can be influenced by explicit and deliberate cognitive processes. For example, neuroimaging research has shown that explicitly labeling the emotion shown by a face can suppress the response of brain systems involved in affective processing (e.g., Hariri, Bookheimer & Mazziotta, 2000; Lieberman et al., 2007). Also, some ERP studies have shown that modulation of the face-sensitive N170 component by emotional expression depends on the strategic set imposed by different task demands (e.g., Rellecke, Sommer & Schacht, 2012; Wronka & Walentowska, 2011). Moreover, ERP components that are sensitive to the motivational relevance of pictures or faces such as the LPP are modulated by task demands and by deliberate attempts to regulate emotion (e.g., Hajcak &Nieuwenhuis, 2006; Krolak-Salmon, Fischer, Vighetto, & Mauguiere, 2001; see the review by Hajcak, MacNamara, & Olvet, 2010). What all these studies show is that the implicit processing mechanisms engaged by emotional stimuli are not impervious to the influence of deliberate processes of reasoning and emotion regulation. However, none of these studies has focused on the influence of explicit reasoning about the contextual congruency of facial expressions. In the task used in the present study we asked the participants to indicate whether the expression shown by a target face matched the situation described in an immediately preceding sentence. Given that the participants were informed that the face belonged to the person experiencing the situation described in the sentence, the task required an inference about the emotional experience of that person and the degree to which her facial expression matched that experience. The main question of interest in the present study is the way in which ERP components indicative of cognitive operations related to the perceptual and affective processing of faces are modulated under the conditions of an explicit congruency task. Specifically, we were interested in three target components –N170, N400 and LPP- that have been found to be modulated by emotion and affective congruency in previous studies.

In spite of the absence of N170 effects in the study by Dieguez-Risco et al. (2013) with sentence contexts, modulation of this component under the task conditions of the present study cannot be ruled out due to its sensitivity to task-related and strategic factors (Rellecke, Sommer & Schacht, 2012; Wronka & Walentowska, 2011). More important, further exploration of the effects of contextual congruency on the N170 component is warranted in view of the nature of the current evidence from previous studies. Research on the contextual modulation of facial expressions has usually shown larger N170 amplitudes in congruent trials. This stands in contrast to the most frequent finding in priming studies (e.g., Herring et al., 2011; Werheid et al.,2005; Zhang et al., 2010), that report enhanced component amplitude on incongruent trials. For example, in the studies by Righart and De Gelder, N170 amplitudes were larger to fearful faces presented on fear backgrounds than to fearful faces presented on happy (Righart & De Gelder, 2008) or neutral (Righart & De Gelder, 2006) backgrounds. Evidence for larger N170 amplitudes on incongruent trials was only obtained with happy faces (Righart & De Gelder, 2008). Similarly, in the study by Hietanen and Astikainen (2013), larger N170 amplitudes were observed to sad and happy faces presented immediately after affectively congruent picture primes. This effect was interpreted by the authors as showing the facilitated encoding of emotional expressions by the congruent primes in line with the spreading activation account of affective priming. This account assumes that affective stimuli automatically activate the associated affective evaluation and that this in turns facilitates encoding of affectively congruent stimuli for a brief period of time (Hietanen & Astikainen, 2013). However, it is by no means clear that facilitated encoding should result in enhanced N170 amplitudes. An alternative explanation can be proposed in term of the additive effects of the conjoint activation of the affective valence of the context and the prime on congruent trials. For example, the enhanced N170 in the presence of a fearful face presented in a negative context would reflect the higher overall negative valence activated in these trials. The enhanced N170 amplitude under these conditions would be similar to the effect of emotional intensity shown in other studies (Sprengelmeyer & Jentzsch, 2006; Utama, Takemoto, Nakamura & Koike, 2009). This mechanism, of course, does not require that the congruency of the expression with the context is computed. The issue we address in the present study is if the usual congruency effect (that is, enhanced amplitudes on incongruent trials) is obtained when the task requires an explicit judgment of the congruency of the expression with the preceding context. Under these conditions, it is clear that deliberate processes involved in the detection of contextual congruency have to be activated and the specific question is if they can have an influence on the early stage of perceptual processing indexed by the N170. Our prediction was that modulations of the N170 similar to those usually found on later components in other priming and context studies and that are indicative of enhanced processing or increased attention to incongruent targets would appear under these conditions. More specifically, we predicted that the N170 would show larger amplitudes in trials in which the expression shown by the target is incongruent with the preceding sentence context. It can be argued that under the conditions of an explicit congruency task a more detailed representation of the emotional meaning of the context and of the expected reactions from the person involved would be active at target time, thus increasing the likelihood of observing ERP modulations when these expectations are violated. We assume that unexpected expressions on incongruent trials require enhanced perceptual processing and that this would be reflected in larger N70 amplitudes. This result would provide evidence that early processing of faces is effectively influenced by contextual congruency.

A focus on the N400 and LPP components is also pertinent because modulations of these waveforms have been related to different aspects of affective processing. The N400 is a negative deflection observed usually in the 250-500 ms range (Kutas & Hillyard,1980) related to semantic congruency (Kutas & Federmeier, 2011). The LPP is a centro-parietal positive deflection that usually appears between 300 and 700 ms, related to affective congruency (Herring et al., 2011). More specifically, it has been proposed that while the N400 effects reflect semantic integration of affective targets with preceding primes or contexts based on the effort to access relevant information from long-term memory, the LPP indexes the processing of affective or evaluative congruency, that is, the congruency between the affective valence of the prime and the target (Herring et al., 2011). Effects of affective congruency on the LPP component have been reported in priming studies with different types of targets such as faces (Hietanen & Astikainen, 2013; Werheid, et al., 2005) pictures (Herring et al., 2011, experiments 1 and 2) and words (Herring et al., 2011, experiment 3; Zhang et al., 2010). Studies with the affective priming paradigm have also reported amplitude modulations of the N400 component, with enhanced amplitudes on incongruent trials (Eder,Leuthold, Rothermund & Schweinberger, 2011; Hamm, Johnson & Kirk, 2002; Paulman & Pell, 2010) although the direction of the effect is sometimes reversed (Aguado et al., 2013) and may vary depending on prime duration (Paulman & Pell, 2010). Finally, there are also cases in which no effects of affective congruency have been found on this component (Dieguez-Risco et al., 2013).

Apart from other procedural differences, the variation in task demands is a potential source of variability in the results of previous priming and context studies with affective stimuli that have used the ERP technique. Valence judgments (e.g. Herring et al, 2011; Zhang et al., 2010) and emotion recognition (Dieguez-Risco et al., 2013; Hietanen &Astikainen, 2013; Righart & De Gelder, 2008a, b; Werheid et al., 2005) have been the most common tasks assigned to the participants in these studies although other, more unspecific tasks, have also been employed (e.g., identifying the target as emotional or not in Paulman and Pell, 2010) or even tasks unrelated to the emotional expression (an orientation decision -face upright or inverted- in Righart & De Gelder´s, 2006 study). It seems reasonable to assume that there may be important variations in the way in which targets and contexts are processed under task conditions that impose different demands on the participant. Evaluative tasks involve only a valence judgment and thusrequire a categorization of the target at a level that is broader and more basic than that required by emotion recognition tasks. For example, although explicit consideration of the congruency between the target face and its context is not required in either evaluative or emotion recognition tasks, the relevance of the context might be higher in this latter case and some participants might explicitly take into account the context when giving their responses. The absence of a clear pattern of results associated to different task assignments might be related to the variability of the processing set that each participant adopts with respect to the relationship between the context and the target face in this type of tasks. Assigning the participants a task in which the congruency between the context and the target face has to be judged has the advantage of reducing much of this variability by requiring explicit joint consideration of the emotional meaning of the context and the face. Under these conditions, results that could be clearly attributed to the influence of context on the processing of facial expressions should be obtained. We predicted that the influence of context on later, post-perceptual processing stages should be manifest as modulations of the N400 and LPP components, with enhanced amplitudes on incongruent trials. In fact, this was the result reported in a recent study by Dozolme, Brunet-Gouet, Passerieux and Amorim (2015) in which an explicit congruency task was assigned to the participants, using a sentence-face procedure similar to the one employed here and in the study by Dieguez-Risco et al. (2013). Although no effects were detected in earlier components, the results showed the expected congruency effects on both the N400 and LPP components. The study by Dozolme et al. (2015) was aimed at studying the influence of empathy on the processing of emotional congruency and the sample included only high and low empathy participants selected on the basis of questionnaire measures. It is interesting that this personality variable modulated only the N400 but not the LPP effect as this is consistent with the idea that these two components are associated with different processing mechanisms (e.g., Werheird et al., 2005). Moreover, the modulatory effect of empathy on the N400 points to an additional source of variability and indicates that the precise effects of affective congruency on this component can vary depending on the specific personality characteristics of the participant.

Our predictions about the effects of the explicit congruency task at the behavioral and electrophysiological levels do not differentiate in principle between affectively positive and negative targets. For example, at the behavioral level our predictions were based in the most usual result in priming and context studies, that is, less accurate and/or slower responses on incongruent trials. However, most prior studies with emotional stimuli have used valence or emotion recognition tasks and their results may not be generalizable to our explicit congruency task. For example, there may be differences in the difficulty to judge the congruency of positive and negative emotional expressions. While a smiling face seems an appropriate response to a wide variety of positive situations, there are specific facial expressions appropriate to different types of negative situations (for example, those related to fear or to anger). On this account, we cannot exclude the possibility that context-expression congruency could influence in a different way the processing of positive and negative targets, leading to different results in each case. In fact, different behavioral and electrophysiological congruency effects have been reported in some studies depending on the valence of the target (e.g., Aguado et al., 2013; Paulman & Pell, 2010; Righart & De Gelder, 2008). Thus, we leave open the possibility that differences between positive and negative targets might appear at either the behavioral or electrophysiological levels.

To summarize the methodology and aims of the present study, behavioral and electrophysiological measures were taken while the participants performed an explicit congruency task. On each trial, the subjects were instructed to read a short sentence that described an emotionally relevant situation (the context). This sentence was presented along with the neutral, non-expressive face of the same individual that would subsequently look happy or angry and the participant was informed that the situation described in the sentence had happened to that individual.Thereafter, a target-face showing either a happy or an angry expression was presented (see Dieguez-Risco et al., 2013). This explicit congruency task allowed us to study the effects of deliberate, top-down processes of emotional reasoning on the early stages of processing of facial expressions of emotion. We predicted that this influence should be manifest at both the behavioral and electrophysiological levels. Behaviorally, less accurate and/or slower responses were expected on incongruent trials. Electrophysiologically, modulations of ERP components in the form of enhanced amplitudes on incongruent trials were expected for the N170, LPP and N400. Although our predictions did not in principle differentiate between positive and negative targets we cannot exclude the possibility that, for the reasons discussed above, there might be some variations in the effects of congruency with target faces showing happy or angry expressions.

METHOD

Participants

Participants were 24 Psychology students (14 females) from the Universidad Complutense (Madrid, Spain) with ages between 18 and 27 (mean 18.72) who took part for course credit. All of them gave written informed consent to participate. All participants had normal or corrected-to-normal vision and two of them were left handed.

Apparatus and Stimuli

Stimuli were presented on a 23'' screen using Software E-Prime 2.1 (Psychology Software Tools, Pittsburgh, PA, USA). Participants entered their responses through a computer keyboard. The experimental sessions took place in an electrically and acoustically shielded room.

Short sentences written in Spanish and describing relatively simple and easy to understand situations were used as contexts (between 7-13 words). Twenty sentences were selected for the present experiment from a larger set based on the results of a pilot study carried out with 34 participants. Each sentence described from a third-person point of view a situation that would normally provoke a happy or angry reaction in the person undergoing it. Ten of those sentences described happiness-inducing situations and the other ten anger-inducing situations. Participants in the pilot study were given four different options to categorize each sentence: "happiness", "anger", "other emotion" or "no emotion in particular". After choosing one particular emotion label, participants were asked to rate on a 1-9 scale the intensity with which the sentence in question represented the selected emotion. The sentences selected for the present study had been recognized as representing the intended emotion by at least 75% of the participants in the pilot study. The sentences were equated in terms of emotional intensity (that is, the extent to which a given sentence represented the corresponding emotion) and syntactic complexity (see Diéguez-Risco et al., 2013). Mean emotional intensities were 7.22 (SEM = 0.75) and 7.50 (SEM = 0.56) for positive and negative sentences, respectively, $t(18) = -0.928$, $p = .36$.Ten additional sentences were selected for the practice phase. Examples of the used sentences can be found in Table 1.

TABLE 1 ABOUT HERE

TABLE 1.

Examples of positive and negative sentences.

Positive	Negative
He receives the promotion he wanted at work	His brand new mobile phone has just been stolen
He manages to raise the money he needs to get the car he always wanted	He has been queuing for two hours when someone tries to cut in before him

The target stimuli were twenty black and white pictures of models showing angry and happy expressions, taken from the NimStim set (Tottenham et al., 2009). There were five male and five female models, each one showing both expressions. Face stimuli were selected based on the responses of the same sample that participated in the pilot study for the sentences and using a similar procedure. The expressions included in the final set met the requirement of a minimum recognition rate of 80%. Happy and angry expressions were equated in terms of emotional intensity (the intensity with which a given face showed the corresponding emotion), $t(18) = 0.705$, $p = .49$. Mean emotional intensity was 6.23 (SEM = 1.08) and 6.56 (SEM = 1.03) for happy and angry faces, respectively. Neutral expressions of each model were also selected and presented altogether with the prime. The pictures were equated in terms of contrast and luminance and the faces were cropped to remove hair.

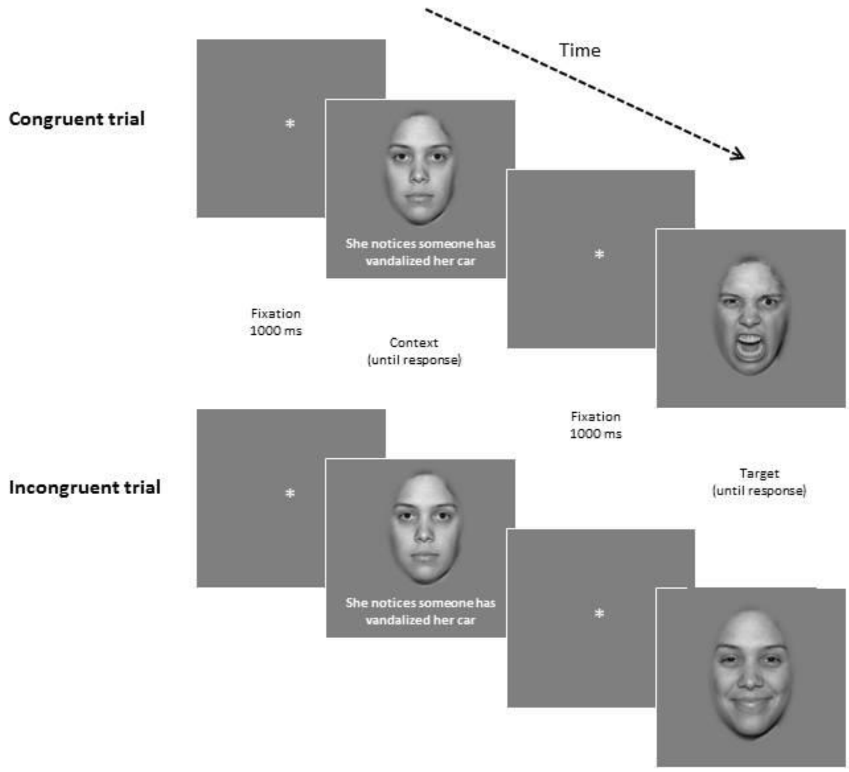
Procedure

In order to ensure that the participant understood the task, instructions were presented self-paced on the screen and explained verbally when necessary. Each trial started with a 1000 ms fixation point. Then the sentence context was presented along with the neutral face of the corresponding model. The participant was instructed to press the space bar after reading the sentence. Presentation of the sentence plus face slide was terminated by the response or after a maximum of 2000 ms had elapsed. Immediately after this a second fixation point appeared during an additional 1000 ms and finally the target face, showing a happy or an angry expression, was presented replacing the neutral face. The participants were instructed to indicate if the expression shown by the target face was congruent with the situation described in the preceding sentence. The participants had to consider if someone in that situation would normally show that expression. The responses were entered pressing the keys "c" or "n" of the computer´s keyboard. No indications about accuracy or speed were given.

The main experimental manipulation was the emotional congruency between the sentence context and the expression shown by the target face. Thus, the context and the target face could be congruent (happy sentence followed by a happy face or angry sentence followed by an angry face) or incongruent (happy sentence followed by an angry face or angry sentence followed by a happy face). The final number of trials was 320 per condition.

In order to familiarize the participants with the faces that they would see during the experiment, a familiarization phase was given in which they were asked to indicate the model's gender. Finally, practice trials were given with stimuli different to those that would be used in the experimental phase. A diagram showing the sequence of events on experimental trials is presented in Figure 1.

Figure 1



Layout of the experimental procedure. Publication of the faces included in this figure is permitted by authors of the NimStim set of facial expressions (Tottenham, N., Tanaka, J., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., Marcus, D. J., Westerlund, A., Casey, B. J., & Nelson, C. A. 2009. The NimStim set of facial expressions: Judgments from untrained research participants. Psychiatry Research, 168(3), 242–249).

Electrophysiological recording

Electroencephalographic (EEG) activity was recorded from 62 Ag/AgCl electrodes mounted on an electrode cap (Compumedics Neuroscan`s Quick-Cap). All scalp electrodes were referenced to averaged mastoids. Electrooculographic (EOG) data were recorded supra- and infraorbitally (vertical EOG), as well as from the left versus right orbital rim (horizontal EOG). Data were recorded with a band-pass filter from 0.1-100 Hz and digitization sampling rate was set to 1000 Hz. Offline, the sampling rate was decreased to 500Hz and an average reference was computed. The continuous recording was divided into epochs ranging from -200 ms to 800 ms after target onset. Trials in which participants responded erroneously were eliminated. The signal was baseline corrected (pre-stimulus activity, from -200 to 0 ms) and filtered with an offline low-pass filter (30 Hz/24 dB). Ocular artifact correction was carried out through an Independent Component Analysis (ICA) (Jung et al., 2000). Finally, a visual inspection was carried out and trials with artifacts were removed. Participants with less than 20 trials were removed. There were no significant differences between conditions in the average number of valid trials (see Table 2), $F(1,23) = 0.447$, $p > .05$, $\eta_p^2 = .019$.

Table 2.

Average trials per condition

Condition	Trials
Congruent-Happy	47.5 (15.37)
Congruent-Angry	48.04 (13.36)
Incongruent-Happy	47.62 (15.20)
Incongruent-Angry	48.875 (12.87)

Data analysis

Based on previous findings on the N170, N400 and LPP, and after visual inspection of the grand-average waveforms, four time intervals were selected for further analysis. Activity in these regions of interest (ROIs) was computed by averaging together activities at neighbor electrodes sites. For the N170, mean amplitudes we calculated between 155 and 180 ms post-stimulus onset at electrodes P5, P6, P7 and P8 (e.g., Batty and Taylor, 2003). For the N400 and LPP, mean amplitudes were calculated for different subsets of electrodes in which these components have been previously found to be more evident (e.g., Kutas & Federmeier, 2011; Liu, Huang, McGinnis-Deweese, Keil and Ding, 2012). The N400 was measured between 250 and 350 ms post-stimulus onset at centroparietal sites in two scalp ROIs: right centro-parietal (comprising TP8, CP6, P8, and P6) and left centro-parietal (comprising TP7, CP5, P7, and P5). The LPP showed a temporally broad distribution, so we divided the corresponding time window into an early (350-550 ms) and a late (550-700 ms) LPP component as in prior research (e.g., Choi et al., 2014; Frühholz, Fehr, & Herrmann, 2009; Johnston, Miller, & Burleson, 1986). Average amplitudes were calculated over these time windows at right (CP2, CP4, P2 and P4) and left (CP1, CP3, P1 and P3) centro-parietal ROIs.

Behavioral data (accuracy and correct reaction time) were subjected to a repeated measures 2 x 2 ANOVA with Congruency (congruent vs. incongruent) and Emotion (happy expression vs. angry expression) as factors. For the reaction time (RT) measure, outliers that exceeded the mean in three standard deviations were excluded. Scalp ERP data (N170, N400 and LPP mean amplitudes) were also submitted to a repeated 2x 2 x 2 ANOVA with Hemisphere (left vs right), Congruency (congruent vs. incongruent) and Emotion (happy vs. angry) as factors. Post-hoc pairwise comparisons were carried out using the Bonferroni procedure (α =.05). Effect sizes were computed using the partial eta-squared method (η^2_p)

RESULTS

Behavioral results

Mean overall accuracy of responses to the target was 0.94 (*SEM* = 0.01). A main effect of Emotion was obtained, $F(1, 23) = 13.82$, $p = .001$, η^2_p =.38, with higher accuracy for happy targets. The main effect of Congruency was not significant, $F(1, 23)=3.02$, $p > .05$, η^2_p = .014. However, there was a significant effect of the Congruency x Emotion interaction, $F(1, 23) = 16.65$, $p < .001$, η^2_p = .43. Analysis of the interaction showed more accurate responses to happy targets in congruent trials.

Mean overall RT was 748 ms (*SEM* = 13.61). The Shapiro-Wilk test for normality showed that RTs data were normally distributed. Response speed results corresponding to the four Congruency x Emotion conditions are presented in Figure 2. The analysis gave significant main effects of Congruency, $F(1, 23) = 23.55$, $p < .001$, η^2_p = .503, with slower RTs on incongruent trials, and Emotion, $F(1, 23) = 70.94$, $p < .001$, η^2_p =.755, with slower RTs for angry targets, as well as their interaction, $F(1,23) = 285.27$, $p < .001$, η^2_p = .92. Analysis of this interaction showed opposite effects of congruency for happy and angry targets. Responses to happy targets were faster on congruent trials. On the contrary, responses to angry targets were faster on incongruent trials.

Figure 2. Mean reaction times. Error bars represent SEM.

Electrophysiological results

The statistical analysis showed a significant main effect of Congruency in the N170 component, $F(1,23) = 4.34$ p =.048, η^2_p =.16, with more negative amplitudes on incongruent, compared to congruent trials. Significant main effects of Emotion were also found in this component, $F(1,23) = 5.53$, p = .028, η^2_p =.19, with larger amplitudes in the presence of happy faces. The Congruency by Emotion interaction did not reach significance in this component [F(1,23)=0.000, p = 0. 995, η^2_p = 0.000]. Grand-average waveforms showing the effects of congruency and emotion are showed in Figure 3. No other main effects or interactions were significant[1].

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[1] One reviewer suggested the possibility that main effects of Congruency and/or Emotion effects that were observed in the N170 effects already emerged in prior components. In order to explore this possibility, we conducted three additional repeated-

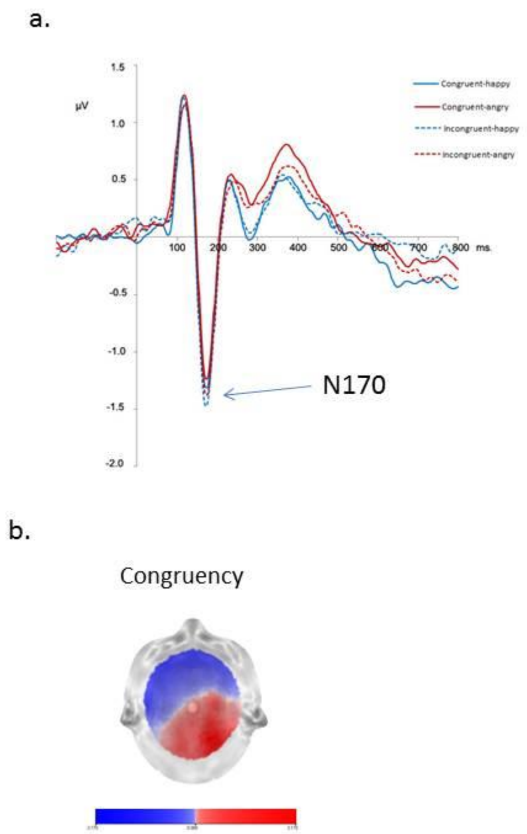

Figure 3. a. Grand average, target-locked event-related potential (ERP) waveform as a function of facial expression and sentence–expression congruency. ERPs were collapsed across electrode positions within the scalp region used for N170 analysis: P5, P6, P7 and P8. b. Difference topographical maps (in µV) showing the Congruency (larger amplitude for incongruent than congruent trials) and Emotion effects (larger amplitude for happy than angry trials) during the N170 time range

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measure ANOVAs in consecutive 25- ms time windows, (80-105 ms; 105-130 ms, which corresponds to the P1 component; and 130-155 ms). None of these analyses reached significance for the factor Congruency, $\boldsymbol{F}(1,23)$ =.003. Main effects of Emotion were observed in 130-150 ms the time window, $F(1,23) = 10.28$; $p = 0.004$), indicating that emotional effects started by the time that the N170 developed. In contrast, no effects of Emotion were found in the P1 component between 105-130 ms, $F(1,23)$ =.13or in the 80-105 ms time interval that preceded the P1, $F(1,23) = 2.37$.

A main effect of Emotion was observed on the N400 component, $F(1, 23) = 5.18$, $p = .03$, $\eta^2_p = .19$, showing larger amplitudes for happy than for angry faces. Figure 4 displays the waveforms corresponding to this effect. No other main effects (Congruency [$F(1,23)=0.124$, $p = 0.728$, $\eta^2_p = 0.005$]) or interactions (Congruency by Emotion [$F(1,23)=2.496$, $p = 0.128$, $\eta^2_p = 0.098$)] reached statistical significance

(FIGURE 4 ABOUT HERE)

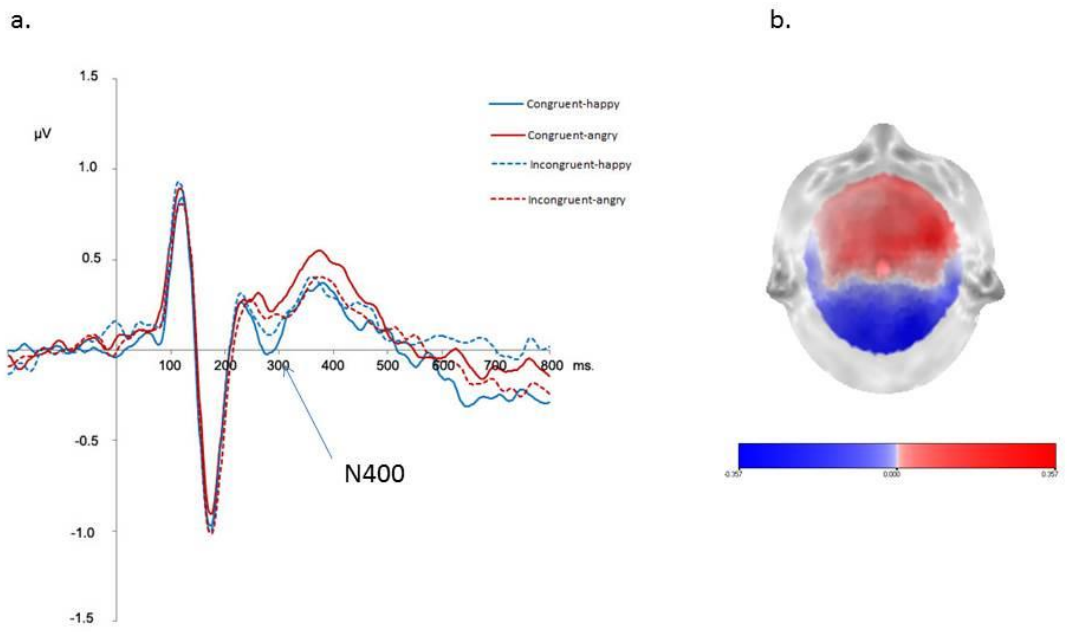

Figure 4. Grand average, target-locked event-related potential (ERP) waveform as a function of facial expression and sentence–expression congruency and difference topographical maps (in µV) showing the Emotion effect (larger amplitude for happy than congruent trials) during the N400 time range. ERPs were collapsed across electrode positions within the scalp region used for N400 analysis: TP8, CP6, P8, P6, TP7, CP5, P7 and P5.

No main effects of Emotion [$F(1,23)=2.011$, $p = 0.170$, $\eta^2_p = 0.071$], Congruency [$F(1,23)=0.055$, $p = 0.817$, $\eta^2_p = 0.002$] or Hemisphere were found on the early LPP component (350-550 ms). The corresponding interactions (Congruency by Emotion [$F(1,23)=0.354$, $p = 0.557$, $\eta^2_p = 0.015$]) were also not significant. However, the results of the analysis for the late LPP component (550-700 ms) showed a significant Congruency x Emotion interaction, $F(1, 23) = 5.24$, $p = .03$, $\eta^2_p = .18$. Pairwise comparisons indicated that incongruent happy faces elicited enhanced LPP amplitudes, $M = .581$, SEM =.027, compared to congruent happy faces, $M = .273$ SEM = .018, $p = .002$. In contrast, congruency did not have a significant effect in the case of angry faces. These effects are shown in Figure 5. No effects of Congruency [$F(1,23) = 3.494$, $p = 0.074$, $\eta^2_p = 0.132$], Emotion [$F(1,23) = 1.003$, $p = 0.327$, $\eta^2_p = 0.042$], Hemisphere or the remaining interactions were obtained.

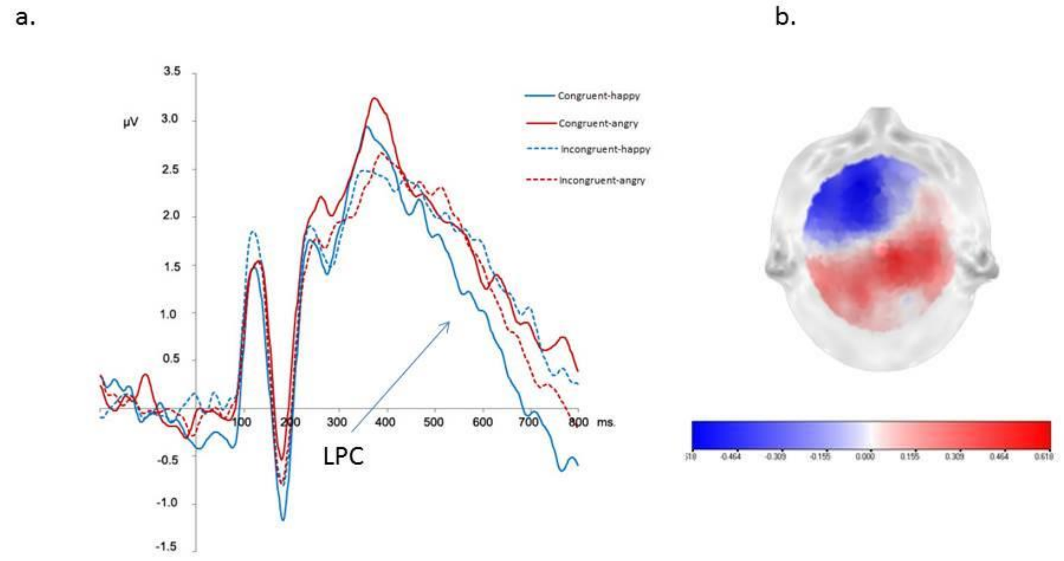

Figure 5. Grand-average event-related potential (ERP) waveform and difference topographical maps (in µV) showing the interaction of Congruency and Emotion during the LPP time range (incongruent happy faces elicited enhanced amplitudes compared to congruent happy faces, whereas no differences were found in angry faces). ERPs were collapsed across electrode positions within the scalp region used for LPP analysis: CP2, CP4, P2, P4, CP1, CP3, P1 and P3.

DISCUSSION

Using behavioral and electrophysiological dependent measures we investigated variations in the processing of facial expressions of emotion under conditions that required explicit attention to the situational context in which they were presented.

At the behavioral level, explicit judgments of the congruency between contexts and expressions were faster on congruent trials in the case of happy targets and on incongruent trials in that of angry targets. At the neural level, modulations of three main components (N170, N400 and LPP) associated to the processing of the target face were observed. The earliest effects of congruency appeared on the latency range of the N170 component (155-180 ms post-target onset) and this for both happy and angry target faces. An effect of congruency appeared also in a late LPP component (550-700 ms post-target onset) but in this case the effect was limited to the happy face targets.

Simple effects of the valence of the target face were also observed on the N170 and N400 components that showed enhanced negative amplitudes in the presence of happy faces. In what follows we describe in more detail the results and discuss their possible functional meaning and theoretical implications. The discussion will concentrate on the context-target congruency and its effects on neural processing, processing, as these effects were the focus of our study, although some consideration will also be given to the effects of emotion observed at different post-stimulus onset latencies as a secondary result.

The earliest effect of congruency on ERP components appeared in the N170 component. This component showed enhanced amplitudes on incongruent trials, that is, on trials in which the expression shown by the target face did not match the emotional content of the preceding sentence context. Amplitude modulations of the N170 have been reported in prior studies that have looked at the effects of picture contexts on the processing of facial expressions (Righart & De Gelder, 2006, 2008; Hietanen & Astikainen, 2013). However, these studies have most usually found larger negative amplitudes on congruent trials in which the context and the target face were of similar valence (e.g., a fearful face in a threatening context). A main difference is that while in the studies mentioned above the participants had to identify the emotional expression shown by the target face in the present study they had to judge its congruency with the preceding context. The specific direction of the effect in each study might be indicative of variations in the processing mechanisms that underlie context effects under these different task conditions. For example, Hietanen and Astikainen (2013) interpreted their N170 effects in terms of the spreading activation account, according to which presentation of the context activates automatically the corresponding affective evaluation and facilitate the encoding of affectively congruent facial expressions. However, as we mentioned in the introductory section, it is not clear that this can explain the enhanced N170 amplitudes in congruent trials in which processing of the target was supposedly facilitated. In studies on the effects of prime-target congruency, enhanced amplitudes of ERP components are usually observed on incongruent trials and are interpreted as reflecting an increased engagement of attentional or cognitive resources due to the more difficult integration of the target with the preceding context (see the review by Kutas & Federmeier, 2011, for the classical example of the N400 component in semantic processing). An alternative explanation of the N170 effects observed in previous studies with expression targets is that its enhanced amplitude on congruent trials is due to the additive effect of the conjoint activation of the affective valence of the context and the target. In fact, the amplitude of the N170 has been shown to be sensitive to emotional intensity, with increased amplitudes in response to more intense expressions (Sprengelmeyer & Jentzsch, 2006; Utama, Takemoto, Nakamura & Koike, 2009).

The N170 effects observed in the present study were in the same direction as those usually found in priming studies and can be interpreted as reflecting the enhanced perceptual processing of the target on incongruent trials. More specifically, we propose that these effects reflect the influence of deliberate top-down processes engaged by the explicit congruency task and that involve the interaction of face processing systems with previous knowledge about the emotional reactions that are to be expected in different situations. In this case, perceptual processing would be enhanced for those signals that involve a violation of these expectations because their valence or their specific emotional meaning is not consistent with the context. If larger N170 amplitudes reflect enhanced processing aimed at increasing the gain of perceptual signals (e.g., Hillyard, Vogel & Luck, 1998), then larger amplitudes should be expected precisely on incongruent targets in which the target expression is contextually inappropriate.

While the contexts used in the present study were short sentences describing emotion-inducing situations, picture contexts were used in the studies by Righart and De Gelder (2006, 2008) and Hietanen and Astikainen (2013). Given the different mechanisms involved in sentence and picture processing, processing of facial expressions of emotion might be differentially sensitive to the influence of contexts presented in visual and linguistic codes. In a previous study with a procedure similar to that used in the present one and with the same sentence contexts (Diéguez-Risco et al., 2013) we did not find modulation of the N170. We reasoned then that this might be reflecting the insensitivity of early visual processing of faces to the output of the conceptual processes involved in the decoding of complex linguistic messages. However, this interpretation cannot be maintained in view of the modulation of the N170 by contextual congruency that was observed in the present study. We might thus conclude that the discrepancy between the results of the present study and that of Diéguez-Risco et al. (2013) was due to the different task demands of each study. However, this interpretation is also problematic in view of the absence of N170 effects in a recent paper by Dozolme et al. (2015) in which the participants were also assigned an explicit congruency task. We can also point to the procedural differences between the two studies (e.g., the inclusion of different emotional expressions, one positive and one negative in our study versus one positive, three negative plus neutral in Dozolme et al.´s) as a potential explanation for this discrepancy. In any case, if the N170 effects found in the present study are truly indicative of a modulation of perceptual processing by the congruency of emotional expressions, this discrepancy highlights the need to specify the conditions under which top-down influence is produced.

A word must be said about the characteristics of the N170 in the present study. The amplitude of this component was relatively small, compared to the amplitudes found in many studies, although there are also cases in which amplitudes similar to those found here have been reported (e.g., Dalrymple et al., 2011; Heisz, Watter & Shedden, 2006). Differences in the magnitude of N170 across studies can be attributed to several factors such as the type of reference used (Rellecke, Sommer, Schacht, 2013), the number of electrodes used or the method employed to measure the amplitude (Handy, 2005). Beside these general considerations, a relevant factor in the present study might be the repetition of the face of the same model, that appeared twice in each trial, first with a neutral expression when presented along with the sentence context and then with an emotional expression as the target face. Repetition effects that lead to reduced N170 amplitudes have been described previously in the literature (e.g., Itier & Taylor, 2002; Jemel et al., 2003) and might have also occurred in the present case.

In the present study, no effects of congruency were found on the N400 component. This component shows enhanced amplitudes with improbable or anomalous sentence endings in studies on linguistic processing and is usually interpreted as an electrophysiological marker of semantic congruency (see Kutas and Federmeier, 2011, for a review). Target faces showing emotional expressions that violate the expectation generated by a preceding sentence context are semantically incongruent and thus should also elicit larger N400 responses. In fact, a recent study by Dozolme et al. (2015) found an effect of affective congruency on the N400 employing a procedure similar to that used in the present study. Two factors can be pointed to as a possible explanation of this discrepancy. One is the number of emotions that had to be discriminated in each study. While in our study the contexts and the target faces were only happy or angry, a wider variety of emotions was sampled in that of Dozolme et al. More specifically, the contexts described situations associated to joy, sadness, fear or anger and the target faces could show the corresponding expressions or be neutral. Given that each sentence was paired with each facial expression it is clear that the task was much more difficult that the one assigned to the participants in our study. This increased difficulty should have increased the cognitive effort needed to judge the congruency of the target expressions, contributing to produce enhanced N400 effects. An additional factor that might explain the discrepancy between Dozolme et al.´s (2015) results and ours is the composition of the sample. Given the relationship shown between empathy level and the size of the N400 effect, the inclusion of participants that were in the two extreme ends of the empathy dimension might have contributed to the finding of a congruency effect. In a more general sense, Dozolme et al.´s findings point to personality differences as a potential contribution to the variability of the results of previous evaluative or affective priming studies.

Effects of context-target congruency were found on a later positive component appearing with a broad centro-parietal distribution in the 550-700 ms time-range after target onset. This component showed larger positive amplitudes on incongruent trials in which happy target faces followed anger-related contexts. Enhanced LPP amplitudes on incongruent trials have also been reported in previous priming studies with facial expressions of emotion (Diéguez-Risco et al.,2013; Hietanen & Astikainen, 2013; Werheid et al., 2005) and other types of affective stimuli (Herring et al., 2011; Zhang et al., 2010). Given that in all these studies processing of the primes or contexts was irrelevant for the target task it can be assumed that modulation of the LPP reflected the operation of implicit evaluative processes. This assumption especially applies to those studies in which short SOA (stimulus-onset asynchrony) durations have been used (300 ms or less in the studies by Herring et al., 2011, Werheid et al., 2005 and Zhang et al., 2010), as it is well known that implicit priming effects disappear when this duration is increased (e.g., Hermans, DeHouwer & Eelen, 2001; Hermans, Spruyt & Eelen, 2003). The sensitivity of the LPP to affective congruency shown in the present study indicates that the processes indexed by this component can also be influenced by deliberate evaluative processes such as those engaged by an explicit congruency task. This interpretation is consistent with previous studies that have described LPP modulations associated to different attentional sets to attend emotional stimuli (Ferrari, Codispotti, Cardinale & Bradley, 2008; Hajcak, Dunning & Foti, 2009) or to voluntary reappraisal attempts (Hajcak & Nieuwenhuis, 2006). Finally, and in a more general sense, our results are in accordance with studies that suggest that the emotional LPP is influenced by top-down processes (Moratti, Saugar & Strange, 2011) and that its modulation in complex situations is mainly under the control of explicit cognitive processes (Daltrozzo, Wioland & Kotchoubey, 2012).

Following the proposal by Herring et al. (2011), the differential sensitivity of the N400 and LPP components in studies with emotional stimuli might reveal the dissociation between the processes underlying the detection of semantic and affective congruency that would be indexed by the N400 and the LPP, respectively. According to this account, LPP effects in the absence of N400 effects, as in the present study, would reflect modulation of expression processing by evaluative or affective congruency, that is, by the mismatch between the affective valence of the context and the target. The functional process underlying these LPP effects would be related to the increased demand for sustained attention when facial expressions are unexpected or do not match the affective meaning of the situational context in which they are perceived.

Congruency effects on the LPP were only observed with happy face targets. This might not be so surprising given the opposite behavioral results that were obtained with happy and angry targets. The usual behavioral result, with more accurate and faster responses on congruent trials, was indeed obtained only with happy targets. In contrast, an inverse priming effect was shown in the case of angry targets, with significantly faster responses on incongruent trials. It seems then that angry expressions were easily recognized as an inappropriate reaction to happy situations and that it was comparatively harder to recognize that an angry expression was appropriate in an anger-inducing context. This relatively unexpected result might explain why enhanced LPP amplitudes on incongruent trials were not observed with angry targets. A different matter is the explanation of the opposite behavioral priming effects found with happy and angry targets. Although the inverse priming effect observed with the angry targets may seem counterintuitive it can be more easily understood if we take into account the differential specificity of the facial expressions of positive and negative emotions. We follow here the account proposed by Aguado et al. (2013) to explain the inverse priming effects observed on the N400 component in a face-word priming study. This account proposes that contextual integration of facial expressions of emotion requires a double check in terms of stimulus valence and specific emotional content and that this process proceeds in a different way for positive and negative expressions due to their different specificity. Although there may be qualitative differences between different positive emotions in terms of experience and appraisal (e.g., Cohn & Fredrickson, 2009; Morrone-Strupinsky & Lane, 2007), a smiling face is the canonical expressive hallmark of all of them. In consequence, a smiling face will fit easily with a variety of situations inducing different positive emotions. When it comes to judging the contextual congruency of a happy face, a valence check suffices to decide if it matches or not the preceding context. Recognizing the match of a happy face with a congruent happy context is relatively easy because a happy face "goes" with any positive context. On the other hand, on incongruent trials the unexpected presentation of a happy face in a negative context would result in slower judgments. In contrast to this, the fact that there are different configurations of facial movements corresponding to different negative emotions may make the response more difficult precisely on congruent trials. In this case, a valence check is not enough (not all negative expressions are valid in all negative contexts) and further consideration of the matching between the specific expression of the face and the specific emotional meaning of the context is required.

Judging the congruency of angry faces on incongruent trials would be comparatively easier because in this case a valence check is enough (no negative expressions “go” with a positive context). A corollary of this account is that given the differences between the processes involved in detecting the contextual congruency of positive and negative facial expressions different congruency effects should be expected at both the behavioral and neural levels.

The rationale developed in the previous paragraph to explain the different behavioral results obtained with happy and angry targets might also explain the discrepancies in the electrophysiological results. While a similar N170 congruency effect was obtained with both targets, the LPP effect was observed only with happy faces. Together with what was observed at the behavioral level, this pattern of results indicates that there were both common and specific contextual influences on the processing of these two types of targets. While the N170 effect can be attributed to a common mechanism influencing in a similar way the processing of happy and angry faces, the enhancement of the LPP observed in the presence of contextually incongruent happy faces must reflect a process that operated only with positive targets. One possibility is that the N170 and LPP effects reflect the effects of evaluative congruency at the level of affective valence (Herring et al., 2011) but that these effects have a different impact on each expression depending on the processing stage. At the early stage indexed by the N170 evaluative congruency would impact in a similar way processing of happy and angry faces in coincidence with the earlier check in terms of affective valence. In contrast, evaluative congruency would influence the later stage indexed by the LPP for happy but not for angry faces. While a check of evaluative congruency is sufficient in the case of happy faces, the angry targets require an additional emotion checking in order to judge their congruency with the context. A likely candidate marker for the effects of emotional congruency that we hypothesize for angry faces would be the N400 component. However, no significant effects of congruency were observed in this component and we have to recognize that this interpretation is only speculative and that confirmation requires further evidence.

Although investigating the separate influence of emotion on ERP components was not the main objective of this study, an effect of emotion was observed as early as 130 ms when the N170 component started, with larger negative amplitudes in the presence of happy faces. Several studies have reported sensitivity of this component to facial expression (e.g., Aguado et al., 2012; Batty & Taylor, 2003; Blau, Maurer, Tottenham, & McCliss, 2007; Caharel, Courtay, Bernard, Lalonde, & Rebäi, 2005; for a recent meta-analysis see Hinojosa, Mercado & Carretié, 2015). However, specific effects for different facial expressions are not so clear. Some studies have found an increased negativity for angry in comparison to happy and neutral faces (Tamamiya & Hiraki, 2013; Wieser, Pauli, Reicherts & Mühlberger, 2010) while others have reported the inverse pattern (e.g. Rossignol et al., 2012; Astikainen & Hietanen, 2009; Schacht & Sommer, 2009) or no differences between different emotional expressions (e.g., Eimer & Holmes, 2002; Santesso et al., 2008). A main effect of emotion was also found on the N400 component, with more negative going deflections also in the case of happy targets. Effects of emotion on the N400 component with face stimuli have been reported before (Paulman & Pell, 2009) and have been interpreted as reflecting enhanced or deeper processing of emotional stimuli. Following this interpretation, the emotion effects observed in the present study would suggest that happy faces were in general more deeply processed. Although modulations of ERP components by negative emotional expressions have been frequently reported, other studies have reported opposite results that might be interpreted in terms of a "positivity offset" effect by which positive evaluation is enhanced for stimuli of relatively mild affective intensity (e.g., Ito & Cacioppo, 2005). More specifically, increased amplitudes elicited by happy faces have been detected at different latencies corresponding to the N170 and to later components, such as the P300 and EPN (early posterior negativity), (e.g., Carretié et al., 2013; Marinkovic & Halgren, 1998; Schacht & Sommer, 2009). These enhanced amplitudes might reflect a processing bias that would have the function of facilitating attention to relevant social information that communicates approach dispositions by other agents.

In summary, the results of the present study confirmed that processing of facial expressions of emotion is modulated by the situational context in which they are perceived and that this modulation takes place since the earliest stages of perceptual processing such as those indexed by the face-sensitive N170 component. Moreover, we showed that this modulation can be driven by the strategic, top-down processes engaged by the deliberate attempt to judge the extent to which the expression is contextually appropriate. These results indicate that far from being rigid and encapsulated, processing of affective stimuli is flexible and sensitive to contextual influences and higher-order processes.

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CAPÍTULO 6. DISCUSIÓN Y CONCLUSIONES

6.1 DISCUSIÓN

El objetivo principal de esta investigación es el estudio de la actividad cerebral en respuesta a las expresiones faciales de la emoción. Este objetivo se ha abordado desde dos perspectivas diferentes. En primer lugar se ha investigado el papel de la expresión facial como moduladora del procesamiento afectivo. En segundo lugar, se ha explorado la actividad cerebral relacionada con la percepción de expresiones faciales precedidas por un contexto. Asimismo, se ha estudiado el papel de las demandas de la tarea en esta modulación contextual. Para ello se han realizado tres estudios en los que se ha empleado la técnica de los ERPs.

La modulación del procesamiento afectivo por las expresiones faciales de la emoción

En el Experimento 1 se estudiaron los efectos del *priming* afectivo producido por expresiones faciales emocionales. A nivel conductual sólo se obtuvo un efecto marginal, y únicamente en los ensayos con targets positivos, en los que se observó una tendencia a tiempos de reacción menores. La literatura sobre *priming* habitualmente reporta tiempos de reacción mayores en los ensayos incongruentes; y en el caso del *priming* afectivo la tendencia es similar, es decir, cuando la valencia del *prime* y el *target* difiere el tiempo de reacción aumenta (ver revisiones en Bargh, 1997; Fazio, 2001). No obstante, en este tipo de tareas no siempre se produce el efecto de *priming*. En primer lugar, el efecto parece ser altamente sensible al intervalo entre estímulos (IEE o SOA –stimulus onset asynchrony-), y no ocurriría cuando el SOA es elevado (1000ms) pero sí cuando es corto (300ms) (De Houwer, Hermans & Eelen, 1998). Esto se ha interpretado como un indicador de que el *priming* afectivo se basa en el procesamiento automático de los estímulos en términos de positivo/negativo, al margen de las demandas de la tarea (Bargh, 1997). Sin embargo, este factor por sí sólo no es suficiente para que aparezca este efecto. Diversos autores han llevado a cabo estudios sobre *priming* afectivo y semántico bajo diferentes condiciones y con distintos estímulos, donde no se han obtenido efectos de *priming* afectivo, aun en presencia de efectos de *priming* semántico (De Houwer, Hermans, Rothermund & Wentura, 2002; Klauer & Musch, 2001; Storbeck & Robinson, 2004).

La primera aproximación teórica propuesta para explicar el mecanismo del *priming* afectivo se basa en la propagación de la activación (p.ej. Spruyt, Hermans, De Houwer & Eelen, 2002; Bargh, Chaiken, Raymond & Hymes, 1996). Esta hipótesis asume la existencia de una red asociativa de nodos, en los que se halla representada la valencia afectiva. Cuando se procesa un *prime* con valor afectivo, se preactivan las representaciones de targets relacionados, produciendo un codificación más rápida de los *targets* con la misma valencia que el *prime*.

Alternativamente, algunos autores (p.ej. Klauer, Roßnagel & Musch, 1997; Wentura, 1999) han propuesto que el *priming* afectivo podría deberse a la competencia de respuesta ante el estímulo diana: al procesar el *prime* se produce una tendencia de respuesta que facilitaría la respuesta al *target* en caso de ser congruente, lo que no ocurriría si se trata de un target incongruente. Esta explicación daría cuenta de algunos resultados donde se han encontrado efectos de congruencia afectiva con tareas evaluativas de valencia pero no con otras tareas, como la denominación (naming) o la categorización del *target* como neutro o emocional (p. ej. Klauer &Musch, 2002; Werner & Rothermund, 2013).

Sin embargo, Spruyt, De Houwer, Hermans, y Eelen (2007) sugirieron otra posible explicación para estos efectos, apelando al concepto de foco atencional. Según estos autores, una diferencia consistente entre las tareas evaluativas y las de categorización de otros elementos es el foco atencional inducido por la tarea, postulando que el atender a la valencia del estímulo es la clave para explicar el *priming* afectivo. Sin embargo, algunos autores han sugerido ciertas dificultades metodológicas en sus diseños (Werner & Rothermund, 2013), entre ellas las relacionadas con la doble tarea que debían realizar los sujetos. Estos autores sugieren que la especificación del *target* como irrelevante en una de las tareas podría interferir con la identificación del mismo como estímulo relevante en la otra. Este resultado sugiere un mayor consumo de recursos en el caso de la tarea evaluativa, lo que podría haber reducido la influencia del *prime*.

Werner y Rothermund (2013) llevaron a cabo una serie de estudios tratando de arrojar luz sobre este fenómeno, por medio de la implementación de un diseño donde la tarea consistía en indicar si el *target* era emocional o, por el contrario, era neutro. Con este diseño se pretendía descartar la hipótesis de la competencia entre respuestas, ya que tanto en el caso de la congruencia afectiva como en el de incongruencia el *target* y el *prime* serían categorizados como "emocionales", al mismo tiempo que se forzaba a los participantes a dirigir el foco atencional a la valencia del estímulo, tal como sugieren Spruyt et al., (2007). De manera sistemática, estos estudios no encontraron efectos de congruencia afectiva, lo que va en contra de la hipótesis del foco atencional como determinante del *priming* afectivo.

Otros trabajos (Steinbeis & Koelsch, 2009; Werheid et al., 2005) han identificado efectos de *priming* afectivo únicamente en respuesta a *targets* positivos, en la misma línea que la tendencia obtenida en el presente estudio. En suma, la literatura existente sobre este fenómeno dista mucho de ser consistente, mostrando resultados heterogéneos y, en muchos casos, contradictorios. Parece claro que es necesaria una mayor investigación en este campo antes de poder delimitar con precisión los factores que intervienen en este proceso.

En cuanto a los resultados electrofisiológicos, en el Experimento 1 se halló un efecto principal de valencia del *target* en el LPP, con mayores amplitudes ante la presencia de estímulos positivos en electrodos parietooccipitales, frontocentrales y temporales, en este último caso en el hemisferio izquierdo. Este resultado está en consonancia con la literatura existente (Herbert, Junghofer & Kissler, 2008; Kissler, Herbert, Winkler & Junghofer, 2009).

El resultado más complejo es el correspondiente a los efectos de congruencia afectiva en el N400, con amplitudes más negativas en electrodos parietooccipitales y frontocentrales en los ensayos congruentes con *targets* negativos. Es decir, ante la presencia de una palabra con valencia negativa precedida por una cara con valencia también negativa, la amplitud de este componente es mayor que ante palabras positivas precedidas de expresiones faciales positivas (ensayos congruentes con *targets* positivos) y que ante palabras negativas precedidas de caras con valencia positiva (ensayos incongruentes con *targets* negativos). Habitualmente, en estudios de *priming* semántico, el patrón obtenido es el inverso, con mayores amplitudes en ensayos incongruentes (ver revisión de Kutas & Federmeier, 2011). Este mismo resultado se ha obtenido también en estudios sobre *priming* afectivo (Eder et al., 2011; Morris, Squires, Tabes & Lodge, 2003; Schirmer, Kotz & Friederci, 2005; Steinbeis & Koelsch, 2009; Zhang et al., 2010), si bien en la literatura se encuentran diversos estudios en los que no se han observado efectos de congruencia afectiva en este componente (Herring et al., 2011; Kissler & Koessler, 2011). Asimismo, existe evidencia de efectos invertidos en el N400 (Paulmann & Pell, 2010)

Como posible explicación de este efecto invertido proponemos la hipótesis del *double checking,* según la cual el procesamiento afectivo está compuesto por dos niveles, uno inicial en el que se procesa la valencia de forma general, y un segundo nivel en el que se evalúa el contenido emocional específico, produciendo resultados diferentes para estímulos positivos y negativos. Siguiendo esta línea de razonamiento, todas las emociones positivas tienen asociada una misma expresión facial: la alegría. Por el contrario, las emociones negativas tienen una variedad mucho más amplia de expresiones faciales (miedo, ira, tristeza…). Esto provocaría que la evaluación de la congruencia afectiva entre dos estímulos positivos sea mucho más rápida y sencilla, dado que no es necesario evaluar el contenido emocional específico. Esto se debe al hecho de que la cara sonriente es congruente con cualquier palabra de valencia positiva y, por tanto, habrá facilitado su procesamiento. En cambio, la evaluación de la congruencia existente entre una expresión facial negativa y un *target* igualmente negativo resultará mucho más demandante, al hacerse necesario identificar si la emoción específica expresada por la cara se corresponde con el contenido emocional asociado a la palabra. Esta mayor dificultad tendría su reflejo en el incremento de la amplitud del N400 ante este tipo de ensayos.

Es importante señalar una posible limitación de este estudio, referida a la muestra, constituida básicamente por mujeres. Este aspecto es de potencial importancia dado que algunas investigaciones han reportado efectos diferentes en hombres y mujeres con una mayor sensibilidad a la congruencia afectiva en el caso de las mujeres, tanto a nivel conductual (Hermans, Baeyens, & Eelen, 1998; Schirmer et al., 2005), como electrofisiológico (Schirmer, Kotz & Friederici, 2002).

En resumen, este estudio pone de manifiesto la diferente sensibilidad de los componentes N400 y LPP a la valencia y a la congruencia afectiva. Este patrón sugiere que el fenómeno de *priming* afectivo no se explica únicamente mediante los mecanismos propuestos de propagación de la activación, competición de la respuesta o foco atencional, en consonancia con lo que ya ha sido propuesto por otros autores (Goerlich et al., 2012; Werner & Rothermund, 2013). Tal como sugieren nuestros datos, el contenido emocional específico podría jugar un papel importante en este ámbito, y resultaría de gran interés la realización de futuros estudios en los que se tenga en cuenta, además de la valencia, la emoción discreta asociada.

Influencia implícita del contexto en el procesamiento de las expresiones faciales de la emoción

En este segundo estudio se ha tratado de seguir explorando el ámbito relacionado con las expresiones faciales de la emoción cuando constituyen el *target*, en lugar de como estímulo modulador. Además, se ha querido investigar cómo se ve influenciado su procesamiento por un la presencia de un contexto previo.

Como se expuso con anterioridad, es llamativa la falta de estudios en la literatura que tomen en consideración los posibles estímulos circundantes que pueden estar presentes durante el proceso de percepción e identificación de las expresiones faciales de la emoción. En nuestro día a día lo habitual es que el procesamiento de una cara tenga lugar en el contexto más amplio de una interacción social. Esta situación puede proporcionar claves que faciliten o incluso modifiquen la identificación de la emoción expresada, como sugieren algunos estudios (Carroll & Russell, 1996; Kim et al., 2004).

Con el fin de disminuir la ambigüedad relativa al contenido emocional específico, se emplearon frases describiendo situaciones cotidianas asociadas a ira, seguidas por una cara que podía ser congruente con ellas o no; esta congruencia podría producirse tanto a nivel semántico como afectivo. En la literatura se ha asociado el componente N400 con el procesamiento de la congruencia semántica, mientras que el LPP reflejaría el procesamiento de la congruencia afectiva (Baetens et al., 2011; Bartholow et al., 2001; Herring et al., 2011), por lo que se podrían esperar efectos en ambos componentes.

Los resultados obtenidos muestran un efecto de congruencia a nivel conductual, con tiempos de reacción mayores en ensayos incongruentes. En cuanto a los resultados de ERPs, se identificaron tres componentes de interés: N170, N400 y LPP.

Si bien a nivel conductual los efectos pueden ser similares a los obtenidos con *priming* semántico, algunos autores (p.ej. Herring et al., 2011) señalan que hay evidencias de que los procesos cognitivos subyacentes son diferentes. Una de las principales razones para esta idea es la sensibilidad a la tarea. Como se vio anteriormente, el *priming* afectivo no se produce en todos los casos y la tarea parece ser un factor determinante (siendo necesaria una tarea de evaluación afectiva), mientras que el *priming* semántico se produce con tareas muy diversas, desde categorización semántica hasta la mera pronunciación del *target* (Van den Bussche, Van den Noortgate & Reynvoet, 2009). Esta hipótesis se ve apoyada por los estudios de Bartholow et al. (2001), en los que encontraron efectos de incongruencia semántica en el N400 pero no en el LPP, y viceversa.

En cuanto al componente N170 se observó un efecto principal de emoción con amplitudes más negativas ante caras de alegría, lo que apoya numerosos estudios sobre expresiones faciales de la emoción que encuentran efectos diferenciales en este componente (Batty & Taylor, 2003; Blau et al., 2007; Caharel et al., 2005). El análisis de localización de fuentes arrojó un resultado acorde con la literatura localizando el origen neural de este componente en el giro temporal medial (Itier & Taylor, 2004). Por otra parte, no se han encontrado efectos congruencia ni interacción entre emoción y congruencia. Este resultado contrasta claramente con los obtenidos por Righart y De Gelder (2006, 2008b). Esto podría deberse a las diferencias en los estímulos y en el diseño experimental; mientras que Righart y De Gelder emplearon imágenes como contextos y una presentación simultánea de la imagen y la expresión facial, en nuestro estudio se utilizó información verbal como contexto y la presentación fue secuencial. En primer lugar, las imágenes constituyen estímulos que llevan a una rápida extracción del contenido emocional (Calvo, Nummenmaa & Hyönä, 2008; Gutierrez, Nummenmaa & Calvo, 2009), lo que no ocurre con tanta rapidez en el caso de la información verbal (Hinojosa et al., 2009). Además, la presentación simultánea de la imagen y la cara superpuesta sobre ella genera un estímulo cmpuesto con características perceptivas diferentes de las de la expresión facial aislada. Estos dos factores podrían estar detrás de la falta de efectos de congruencia en el N170 en el presente estudio.

En el N400 se encontró también un efecto principal de emoción, en ausencia de efectos de congruencia o de interacción. Numerosos estudios han mostrado sensibilidad del N400 a la emoción, tanto con caras como con estímulos verbales (Eimer, 2000; Paulmann & Pell, 2009; Zhang, Li & Zhou, 2008; Schirmer, Kotz, & Friederici, 2005; Trauer, Andersen, Kotz & Müller, 2012). El análisis de localización de fuentes situó en el precúneo el origen neural de este componente, en consonancia con estudios previos (Jemel, George, Olivares, Fiori & Renault, 1999; Silva-Pereyra et al., 2003).

Se debe señalar que tanto en el N170 como en el N400, los efectos de emoción han mostrado amplitudes más negativas ante caras de alegría. Si bien varios estudios han reportado amplitudes mayores ante caras de ira que ante caras neutras o de alegría (Blechert, Sheppes, Di Tella, Williams & Gross, 2012; Tamamiya & Hiraki, 2013; Wieser, Pauli, Reicherts & Mühlberger, 2010), otros no han hallado diferencias entre estas emociones (Tortosa, Lupiáñez & Ruz, 2013; Eimer & Holmes, 2002; Santesso et al., 2008) o han mostrado un patrón inverso, en consonancia con los resultados del presente estudio (p.ej. Rossignol et al., 2012; Schacht & Sommer, 2009). Este resultado sugiere un procesamiento más profundo de las expresiones faciales positivas, con independencia de la congruencia entre dichas expresiones y la frase precedente.

Como se expuso con anterioridad, la literatura sobre el procesamiento de la congruencia afectiva arroja resultados contradictorios y poco claros, habiéndose encontrado modulación en unos casos (Eder et al., 2011; Morris et al., 2003; Schirmer, Kotz & Friederci, 2005; Steinbeis & Koelsch, 2009; Zhang et al., 2010), mientras que en otros estudios no hay efectos o éstos presentan un patrón invertido (Herring et al., 2011; Hinojosa et al., 2009; Taylor, 2010; Paulmann & Pell, 2010).

Por el contrario, la sensibilidad del N400 al *priming* semántico parece bien establecida en la literatura, habiéndose encontrando efectos ante distintos tipos de estímulos (palabras, imágenes, etc.) (Kiefer, 2002; Kutas & Van Petten, 1994; Kutas & Federmeier, 2000).

Al contrario que en el caso del componente N400, se observaron efectos de congruencia en el LPP, con amplitudes mayores ante ensayos incongruentes, en zonas frontocentrales, sin que hubiese una interacción con la emoción. Esta sensibilidad a la congruencia afectiva en el LPP está en la línea con los hallazgos de numerosos estudios, con expresiones faciales (Hietanen & Astikainen, 2013; Werheid et al., 2005) y con otros estímulos afectivos (Herring et al., 2011; Zhang et al., 2010).

En suma, nuestros datos muestran que la incongruencia afectiva afecta a varios niveles de procesamiento. Además, los resultados del presente estudio indican la presencia de incongruencia afectiva pero no semántica, al no haber efectos en el N400.

Influencia explícita del contexto en el procesamiento de las expresiones faciales de la emoción

En este experimento se investigó el papel de la atención explícita en la percepción y procesamiento de las expresiones faciales en relación a un contexto verbal. El diseño fue similar al empleado en el Experimento 2 pero en este caso se pedía a los participantes que evaluasen si la emoción expresada por una persona se correspondía con la situación por la que aquella acababa de pasar. Con este diseño se pretendía que los participantes evaluasen de forma deliberada la congruencia afectiva entre ambos estímulos.

A nivel conductual se encontraron efectos de la emoción de la cara y de congruencia frase-cara, además de una interacción entre ambos factores. Esta interacción se tradujo en un tiempo de reacción menor en los ensayos congruentes con caras positivas, mientras que ante caras negativas se encontraron tiempos de reacción menores en los ensayos incongruentes. Este efecto es similar al encontrado en el primer experimento, en consonancia con la idea expuesta anteriormente del *double checking* ante la incongruencia afectiva. En cuanto a los resultados electrofisiológicos, se analizaron los mismos tres componentes que en los experimentos 1 y 2: N170, N400 y LPP, si bien este último se dividió en dos: LPP temprano (350-550 ms) y LPP tardío (550-700 ms), debido a la gran amplitud del mismo, siguiendo el procedimiento de otros estudios (Choi et al., 2014; Frühholz, Fehr & Herrmann, 2009; Johnston, Miller & Burleson, 1986).

En relación a los efectos debidos a la emoción de la expresión facial, se replicaron los resultados del experimento 2, encontrando mayores amplitudes ante caras positivas tanto en N170 como en N400, lo que proporciona un apoyo adicional a la hipótesis de un mayor procesamiento de estas expresiones.

En el N170 se encontró también una modulación por la congruencia entre el prime y el target, con mayores amplitudes ante ensayos incongruentes. Existen estudios previos que han hallado efectos de congruencia en este componente (Righart & De Gelder, 2006, 2008b; Hietanen & Astikainen, 2013). Sin embargo, en estos trabajos se encontraron mayores amplitudes en ensayos congruentes, es decir, cuando contexto y *target* presentan la misma valencia. La principal diferencia entre estos estudios y el nuestro reside en la tarea: en este caso debían evaluar de manera explícita si el contexto y la emoción expresada eran congruentes, mientras que en los otros estudios únicamente debían indicar la emoción de la cara. La dirección opuesta de los efectos podría estar reflejando procesos diferentes, siendo una posible explicación la presencia de un efecto de sumación de valencias y no un efecto de congruencia propiamente dicho. Es decir, los resultados de los estudios mencionados podrían deberse a que los efectos de la valencia del *target* se suman a los del prime cuando ambos estímulos tienen la misma valencia, produciendo un incremento de la amplitud del N170. Tal y como han señalado algunos autores, la amplitud de este componente se ve modulada por la intensidad emocional, lo que podría explicar este posible efecto de sumación (Sprengelmeyer & Jentzsch, 2006; Utama, Takemoto, Nakamura & Koike, 2009).

En el presente estudio, los efectos de congruencia van en la misma dirección que los efectos clásicos de *priming* semántico. El incremento de amplitud ante ensayos incongruentes sugiere un mayor procesamiento de los mismos, el cual parece estar mediado por procesos top-down de evaluación de expectativas, como sugiere la ausencia de efectos cuando la tarea no obliga a realizar dicha evaluación (ver Experimento 2). Aún más importante, este resultado indica que el procesamiento perceptivo temprano no está influenciado únicamente por procesos automáticos, sino que presenta sensibilidad a procesos top-down, siendo modulado por ambos.

También hemos observado efectos debidos a la congruencia contexto-target en latencias más tardías, en concreto en el LPP (550-700 ms). Se encontraron amplitudes mayores en ensayos incongruentes, en consonancia con la literatura previa (Hietanen & Astikainen, 2013; Werheid et al., 2005). Sin embargo, estos efectos solo eran evidentes en el caso de los *targets* positivos. Por tanto, la mayor amplitud del LPP cuando el ensayo es incongruente se produjo únicamente cuando el contexto negativo iba seguido de una expresión facial de alegría, pero no cuando un contexto positivo aparecía seguido de una cara de ira.

De nuevo, la principal diferencia entre la literatura y el presente experimento la encontramos en la tarea: en los estudios previos no se requería explícitamente la evaluación del contexto. Por tanto, los efectos encontrados trabajos anteriores indican que el LPP se ve afectado por la congruencia contexto-*target* de forma automática, lo que se ve apoyado por la desaparición de estos efectos en aquellos estudios que han empleado SOA elevados (p.ej. Hermans, DeHouwer & Eelen, 2001; Hermans, Spruyt & Eelen, 2003). Estos resultados sugieren que este componente se ve afectado también por procesos top-down (Moratti, Saugar & Strange, 2011; Daltrozzo, Wioland & Kotchoubey, 2012).

En este experimento, tal como ocurrió en el Experimento 2, no se han encontrado efectos de congruencia en el N400 pero sí, en el LPP. De nuevo, estos resultados parecen indicar la presencia de incongruencia afectiva pero no semántica, en línea con la hipótesis propuesta por Herring et al., (2011). Por tanto, la atención explícita a la concordancia entre contexto y *target* no parece influir en el componente N400 de un modo que sugiera un efecto de congruencia semántica.

6.2 CONCLUSIONES

En la presente tesis, se ha investigado el papel de las expresiones faciales de la emoción en el procesamiento afectivo a lo largo de tres estudios, desde dos enfoques diferentes: primero se ha explorado su función como contexto: qué procesos activan y cómo se afectan al procesamiento de otros estímulos; en segundo lugar, se ha investigado en qué medida y de qué manera se ven afectadas por un contexto. Para ello se ha empleado la técnica de potenciales evocados, y se han analizado aquellos componentes que en trabajos previos, han mostrado sensibilidad a los procesos de identificación de expresiones faciales de la emoción y a aquellos otros relacionados con la congruencia afectiva y semántica. En los tres estudios se analizaron los componentes N400 y LPP, mientras que en los dos últimos se estudiaron también los efectos producidos en el componente N170.

Lo primero que se observa en estos tres estudios es que el procesamiento de las expresiones faciales de la emoción puede modificar y, a su vez, verse modificado, por otros estímulos afectivos. Si bien el hecho de que las expresiones faciales pueden modular la respuesta a otros estímulos se ha reportado en numerosas ocasiones en la literatura, los mecanismos implicados no están claros todavía. Resulta de interés el hecho de que estos componentes mostraron diferente sensibilidad ante los diferentes procesos implicados en los tres estudios. En el primero de ellos se encontraron efectos de congruencia en el N400, algo que no se replicó en los estudios 2 y 3. Asimismo, mientras que en el primer estudio el LPP no mostró sensibilidad a la congruencia entre la valencia del *prime* y el *target*, sí lo hizo en los otros dos experimentos. Como se expuso con mayor detalle anteriormente, algunos autores (Herring et al., 2011) han sugerido una disociación del procesamiento de la incongruencia semántica y afectiva, donde la primera modularía la amplitud del componente N400 y la segunda la del LPP. Siendo así, la falta de efectos en el LPP en el primer experimento indicaría que se produjo un efecto de incongruencia semántica (reflejado en el N400) pero no afectiva. Por el contrario, se encuentra el patrón opuesto en los experimentos 2 y 3, donde los resultados se podrían interpretar en términos de incongruencia afectiva (al producirse en el LPP) pero no semántica.

El diseño fue diferente en estos dos casos, ya que en el Experimento 1 se empleó un paradigma de priming con expresiones faciales (positivas o negativas) como estímulos *prime* y palabras (positivas o negativas) como estímulos *target*, mientras que en los Experimentos 2 y 3 se presentó un contexto verbal seguido por una cara que podía ser congruente o no con dicho contexto. El empleo de palabras como targets parece ser consistente en los estudios que han encontrado efectos de incongruencia afectiva en el componente N400 (Eder et al., 2011; Morris et al., 2003; Schirmer et al., 2005; Zhang et al., 2006, 2010), si bien Herring et al., (2011), en un estudio sobre prosodia con palabras como *targets*, no encontraron dichos efectos. Estos mismos autores sugieren como posible explicación de la falta de efectos la integración del contexto con el target, señalando que en los estudios habituales de prosodia se requiere una mayor integración para evaluar el significado afectivo del estímulo en su conjunto (Nygaard & Queen, 2008).

Teniendo en cuenta las evidencias aportadas por la literatura y los resultados de nuestros estudios, una posible explicación sería que el empleo de palabras como estímulos *target* favorece el procesamiento de la congruencia semántica, lo que no ocurre con otro tipo de estímulos. Además, este procesamiento semántico se ve influenciado por las demandas de la tarea. Es decir, el target por sí solo no es suficiente para que se produzca un efecto de incongruencia semántica, sino que debe producirse también una alta integración entre contexto y *target*. Dado el alto valor afectivo y el rápido procesamiento de las expresiones faciales de la emoción, es posible asumir que esta integración se produjo en el primer experimento. En los dos siguientes experimentos, en cambio, el *target* consistió en expresiones faciales de la emoción en lugar de palabras, lo que podría explicar por qué no se obtuvieron efectos de incongruencia semántica.

En resumen, los resultados de los tres experimentos tomados en conjunto sugieren una disociación en los mecanismos que subyacen al procesamiento de la congruencia afectiva y semántica, así como una gran influencia de factores como el tipo de estímulo o las demandas de la tarea en la utilización de uno, otro o ambos mecanismos. No obstante, sería necesario ahondar más en este campo, ya que los resultados en la literatura son poco consistentes y difíciles de integrar. Este hecho se debe en gran medida a la variabilidad de diseños experimentales con los que se ha explorado este fenómeno.

Es importante destacar también la gran influencia que han mostrado tener los procesos top-down en el procesamiento de las expresiones faciales de la emoción en lo experimentos de esta tesis. Habitualmente, los estudios sobre la modulación de dicho procesamiento por el contexto han empleado tareas de evaluación centradas en el *target*, donde la atención al contexto no era necesaria. La postura tradicional en relación a este tema se basa en un procesamiento rápido y automático de las expresiones faciales de la emoción, dirigido por las características perceptivas de los estímulos y con escasa o nula permeabilidad a procesos de mayor nivel. Los resultados obtenidos en el Experimento 3, y especialmente en contraste con los encontrados en el Experimento 2, muestran que esta asunción no es correcta y que la identificación de las expresiones faciales de la emoción está afectada por factores ajenos a los propios estímulos, como las demandas de la tarea, en momentos muy tempranos del procesamiento (N170).

Otra conclusión a tomar en consideración, a la vista de los resultados obtenidos en los Experimentos 2 y 3, es un posible sesgo de procesamiento hacia las expresiones faciales positivas, teniendo en cuenta las mayores amplitudes en los componentes estudiados. Esto se ha reportado previamente en la literatura, en diferentes momentos temporales (p.ej. Carretié et al., 2013; Marinkovic & Halgren, 1998; Schacht & Sommer, 2009) y podría relacionarse con la relevancia social de estos estímulos.

Un resultado que reviste bastante interés lo encontramos en los efectos de *priming* inversos, ya sea a nivel conductual o electrofisiológico. Como se expuso con anterioridad, esto podría indicar un doble procesamiento de la congruencia afectiva. Todas las emociones positivas (orgullo, alegría, satisfacción) tienen en común una misma expresión facial: la sonrisa. Por tanto, esperaremos ver dicha expresión ante cualquier situación positiva, del mismo modo que la percepción de una cara de alegría nos predispondrá a esperar un estímulo positivo. Por el contrario, las emociones negativas se encuentran más diferenciadas y las expresiones faciales representativas de cada una son diferentes (asco, ira, tristeza…). Ante una situación de tristeza no esperamos ver una cara expresando asco, del mismo modo que una cara de tristeza no generará la expectativa de ir seguida por un estímulo relacionado con la ira. Por tanto, resultará más complicado identificar la congruencia entre un estímulo negativo y una expresión facial de la misma valencia que entre un estímulo positivo y su correspondiente expresión facial. De esta forma, en caso de producirse una doble comprobación de la congruencia, se observarían resultados diferentes en estímulos positivos y negativos. Durante la primera comprobación de la valencia, si ambos estímulos son positivos, no será necesario realizar una segunda comprobación del contenido emocional específico, ya que también será congruente. Por ello, es suficiente con parar el procesamiento en esta primera comprobación de valencia. En caso de ser un estímulo positivo y otro negativo tampoco será necesario evaluar la congruencia emocional dado que ya han resultado incongruentes en esta primera etapa de procesamiento. Cuando el contexto es negativo y el siguiente estímulo positivo tampoco es necesario realizar una comprobación del contenido emocional, ya que sabemos que en este caso son incongruentes. Pero si estamos ante un contexto negativo y aparece tras él un estímulo también negativo, será necesario evaluar la emoción asociada a cada uno de ellos tras la comprobación inicial de la valencia. Este paso adicional se traducirá en un mayor tiempo de procesamiento.

En resumen, creemos que los estudios realizados aportan un mayor conocimiento sobre el papel de las expresiones faciales de la emoción como estímulos afectivos, abarcando por una parte su influencia sobre otros estímulos y por otra parte el grado y modo en que se ve afectado su procesamiento en función del contexto en que son percibidas. Los estudios realizados han proporcionado algunas claves que pueden ayudar a la hora de continuar la investigación sobre algunos efectos poco establecidos en la literatura.

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