Mecanismos Corticales y Periféricos del Procesamiento Afectivo de Caras Familiares: Estudio de la Emoción Asociada a la Identidad

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A Luz

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Mis cuatro años que han pasado desde que comencé a trabajar en el laboratorio de Psicofisiología Humana y de la Salud de la Universidad de Granada han estado cargados de experiencias humanas y profesionales que me han hecho aprender un poquito y cambiar otro tanto.

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Gracias a su templanza, amabilidad, confianza e intuición, Jaime ha conseguido crear un grupo de investigación en el que además de excelencia científica existen personas todas ellas formidables. Con la gran mayoría de ellas he podido compartir momentos de intimidad y comunicación, aprendiendo un poquito cada vez. Con algunas de ellas he desarrollado relaciones de amistad, mujeres a las que admiro y a las que quiero tener cerca de mi. Cada sonrisa en cada encuentro con alguna de estas personas forman parte de mi repertorio de circunstancias emocionales positivas que guardo en algún lugar de mi universo. Sólo mencionaré el nombre de Marlen, que por ser la que más lejos se encuentra no podrá estar presente en la gran fiesta de celebración que acompaña la defensa de toda tesis que se precie. Te echaré de menos, sé que te echaremos de menos, pero estamos unidas por esas redes invisibles que nos enlazan desde nuestro centro a las personas que amamos. Tengo pendiente un viaje a tu tierra así que puede que aparezca pronto en tu puerta.

Entre el ámbito académico y el personal se encuentra el doctor caos, al que le debo algunas taquicardias asociadas a eventos emocionales complejos e innumerables aumentos de conductancia eléctrica de la piel. Además, le debo innumerables respuestas del músculo cigomático que por su amplitud hubiesen sido incapaces de ser registrados por cualquier polígrafo al uso.

Saliendo del ámbito académico, pienso también en mis amigas que desde diferentes lugares del mundo han escuchado y acompañado mis tormentas, mis calmas y mis alegrías. Ellas saben quienes son y ellas saben cuánto las admiro y las necesito. Sólo volveré a mencionar a aquella que se encuentra más lejana pero con la cual existen redes invisibles tan amplias que nada ni nadie podría romper. María, no sé qué tienes que me hace sentir tan viva, tan sensible, tan frágil y tan fuerte cuando hablo contigo. Tengo otro viaje pendiente, así que prepárate para enseñarme las maravillas de tu nuevo país. También quiero mencionar a Lara por traer de nuevo el baile a mi vida y llevar mi vida al movimiento. Espero que sigamos compartiendo escenario en muchos lugares del mundo.

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Resumen

En los últimos años, el interés por el estudio de las bases neurales y fisiológicas del procesamiento de estímulos familiares con relevancia social y emocional ha aumentado considerablemente. Dentro de este ámbito de investigación, las caras de personas familiares queridas (pareja, hijos, padres, amigos, etc.) se han utilizado en condiciones de laboratorio con el fin de inducir un estado emocional positivo asociado con el procesamiento de la identidad de la persona. Por este motivo, la investigación acerca de los procesos subyacentes a las emociones de apego y amor converge con la línea de estudio sobre el reconocimiento de caras familiares. A pesar de los avances que se han realizado en ambos ámbitos, todavía quedan bastantes fenómenos que requieren ser clarificados. El primero de ellos tiene que ver con la diferenciación entre los fenómenos de valencia afectiva (procesamiento apetitivo vs. aversivo), arousal indiferenciado y familiaridad.

En el primer capítulo de esta tesis se presentan una serie de estudios cuyo objetivo fue investigar el procesamiento afectivo de caras queridas, intentando desentrañar los efectos debidos al procesamiento de la valencia, de aquellos relacionados con el arousal indiferenciado y con la familiaridad. Con este objetivo se utilizó el paradigma de visualización pasiva de P. Lang durante la visualización de caras que diferían en familiaridad (estudios 1 y 2) y en valencia afectiva (estudio 3). Los resultados de los tres estudios presentados en el capítulo 1, señalan que las caras queridas provocaron una fuerte reacción emocional positiva que no puede ser explicada únicamente por un efecto del arousal o de la familiaridad. Las reacciones emocionales positivas provocadas por la presencia de seres queridos pueden tener una relación con los efectos beneficiosos del apoyo social sobre la salud. Nosotros defendemos la hipótesis de que las caras queridas podrían estar actuando

como señales de seguridad activando el sistema motivacional apetitivo e inhibiendo el defensivo. En el estudio 2 pusimos a prueba esta hipótesis utilizando el paradigma de sobresalto durante el visionado pasivo de caras queridas, neutrales y desagradables. El resultado más llamativo de este estudio fue la clara inhibición del reflejo de sobresalto durante la visualización de caras queridas, dato que confirma la fuerte reacción emocional positiva que provocan estas caras. Esta capacidad inhibidora puede estar relacionada con el efecto positivo que el apoyo social tiene sobre la salud. Después de comprobar que las caras queridas provocan unas respuestas emocionales intensas no atribuibles a un simple procesamiento del arousal o de la familiaridad, surgió la pregunta sobre el curso temporal y la localización cerebral de estos procesos.

La técnica de potenciales evocados ha mostrado ser extremadamente útil a la hora de identificar los patrones temporales de diferentes fenómenos cognitivos y emocionales. En el estudio 3 presentamos los datos de potenciales evocados y localización de fuentes cerebrales durante el procesamiento de caras queridas (padres, pareja y amigo/a), neutrales (desconocidos) y desagradables (mutiladas). El componente P3a, de latencia inferior al clásico P3 y localización frontal, mostró estar modulado en función de la valencia afectiva de los estímulos faciales. Las caras queridas provocaron una mayor positividad en este componente en comparación con las caras neutrales y desagradables. Los análisis de permutaciones mostraron que la onda de potenciales evocada por las caras queridas comienza a diferenciarse de la onda asociada a las caras neutrales en latencias muy tempranas (inferiores a 200 ms), lo que refleja el acceso rápido a los recuerdos y emociones positivas asociados a las caras familiares. Los análisis de fuentes, utilizando el método de promediación bayesiano, mostraron que las áreas asociadas con la generación del P3a estuvieron localizadas en estructuras relacionadas con el reconocimiento de caras familiares (corteza temporal inferior) y con el procesamiento del valor hedónico y reforzador de los estímulos (corteza orbitofrontal y cíngulo anterior). Estos resultados mostraron que las caras familiares queridas modulan las respuestas neuronales en función de su valor social y emocional.

A pesar de la novedad de estos resultados, una limitación del estudio presentado en el capítulo 3 consiste en la utilización de caras desagradables por la apariencia física (mutiladas) y no por su identidad. El estudio presentado en el capítulo 4 tuvo como objetivo investigar la modulación central y periférica provocada por la emoción asociada a la identidad del rostro. A su vez estuvimos interesados en comprobar una posible modulación en función de la valencia afectiva de los rostros. Para ello registramos las evaluaciones subjetivas, las respuestas autonómicas, somáticas y centrales (IRMf) de un grupo de hombres y mujeres durante la visualización de caras pertenecientes a cuatro categorías: familiares queridas, familiares desagradables, desconocidas atractivas y desconocidas desagradables. Los resultados de este estudio mostraron que las caras familiares son estímulos que implican de forma masiva a una amplia red de estructuras cerebrales así como a los sistemas de respuesta autonómico y somático. Las áreas activadas durante el procesamiento de caras familiares están relacionadas con la modulación y procesamiento emocional (ínsula, operculum frontal y giro frontal inferior), con el reconocimiento de caras familiares (giro fusiforme, giro temporal inferior y polos temporales) y con el control motor (giro frontal medial, área motora suplementaria y cerebelo). Por otro lado, las caras familiares queridas fueron las únicas en activar la corteza orbitofrontal medial, un área relacionada con el procesamiento de estímulos placenteros y que forma parte de los circuitos de recompensa cerebrales.

En conclusión, los resultados de los estudios presentados en esta tesis aportan la siguiente información novedosa: (1) las caras familiares queridas elicitan una serie de cambios periféricos y centrales reflejo haber inducido un estado emocional positivo intenso, diferenciable del efecto del arousal y de la familiaridad; (2) las caras queridas inhiben respuestas defensivas tal y como muestra la inhibición del reflejo de sobresalto, y este mecanismo inhibitorio puede estar en la base de los efectos beneficiosos del apoyo social sobre la salud; (3) las caras queridas provocan una P3a de menor latencia y mayor amplitud que el inducido por las caras neutrales y desagradables, reflejando el acceso rápido a recuerdos sociales y emocionales relevantes;

(4) el procesamiento de caras familiares depende de una amplia red de estructuras cerebrales encargadas de reconocer la identidad y recuperar el conocimiento acerca de la persona, de procesar la emoción evocada por la identidad de la cara y de preparar una posible acción motora. Por último, tal y como muestra la activación de la corteza orbito-frontal medial ante las caras queridas en comparación con las caras atractivas, las caras de familiares queridos constituyen estímulos cuyo valor reforzador supera al de otros estímulos muy gratificantes.

Abstract

In recent years, interest in studying the neural and physiological correlates of the processing of familiar social and emotional relevant stimuli has increased significantly. In this area of research, faces of loved familiar people (partners, children, parents, friends, etc.) have been used in laboratory conditions with the aim of inducing a positive emotional state related to the person's identity. Therefore, research on the processes underlying the emotions of attachment and love converges with the line of study that focuses on the recognition of familiar faces. In spite of the progress made in these areas, there are still a number of phenomena that need to be clarified. The first one is related to the distinction between the phenomena of affective valence (appetitive vs. aversive processing), undifferentiated arousal and familiarity.

In Chapter 1 we present a series of studies aiming at studying the affective processing of loved faces, trying to distinguish the effects caused by the processing of the valence from those related to undifferentiated arousal or familiarity. With this aim in mind, we used P. Lang's passive viewing paradigm during the visualization of faces differing in familiarity (studies 1 and 2) and valence (study 3). The results of the three studies presented in Chapter 1 show that loved faces prompted a strong positive emotional reaction that cannot be attributed solely to the arousal or familiarity effect.

Positive emotional reactions caused by the presence of loved ones may be related to the beneficial effects of social support on health status. We defend the hypothesis that loved faces could be acting as safety cues activating the motivational appetitive system and inhibiting the defensive system. In study 3, presented in Chapter 2, we tested this hypothesis using the startle paradigm during the passive viewing of loved faces, neutral faces and unpleasant faces. The most striking result of this study was a clear inhibition of the startle reflex during visualization of loved familiar faces. This result

confirms the strong positive emotional reaction evoked by these faces. This inhibiting effect may be related to the positive effect of social support on health. After having confirmed that familiar faces provoke an intense emotional reaction that cannot be attributed to a mere arousal or familiarity effect, the next question that came up referred to the temporal course and brain location of these processes.

Event-related potentials have proven to be very useful in identifying temporal patterns of different cognitive and emotional phenomena. In Chapter 3 we presented event-related and source analysis data related to the processing of loved faces (parents, partner and friend), neutral faces (unknown) and unpleasant faces (mutilated). We saw that component P3a, of a lower latency than the classical P3 and a frontal distribution, was modulated as a function of the affective valence of facial stimuli. Loved faces prompted a higher P3a positivity than neutral and unpleasant ones. Permutation analysis showed that the ERPs evoked by loved familiar faces starts to differentiate itself from the ERPs associated to neutral faces at very early latencies (lower than 200 ms), which shows the quick access to positive memories and emotions related to familiar faces. Source analyses using the Bayesian averaging method showed that those areas associated with the generation of the P3a where located in structures related to recognition of familiar faces (inferior temporal cortex) and with the processing of the hedonic value and pleasantness of the stimuli (orbitofrontal cortex and anterior cingulate). These results showed that loved familiar faces modulate neural responses depending on their social and emotional value.

In spite of the novelty of these results, a limitation of the study presented in Chapter 3 is the use of faces that are unpleasant due to their physical appearance (mutilation) and not due to their identity. The aim of the study presented in Chapter 4 was to research on the central and peripheral modulation caused by the emotion associated to the identity of the face ("emotion from identity"). We were also interested in finding a possible modulation depending on the affective valence of faces. To this end, we recorded the subjective assessments and the autonomic, somatic and central responses

(IRMf) of a group of men and women during the viewing of faces belonging to four categories: loved familiar, unpleasant familiar, attractive unknown and unpleasant unknown. The results of this study showed that familiar faces are stimuli that massively engage a large network of brain structures as well as autonomous and somatic response systems. The areas activated during the processing of familiar faces are related to emotion modulation (insula, frontal operculum and inferior frontal gyrus), with the recognition of familiar faces (fusiform gyrus, inferior temporal gyrus, and temporal poles) and with motor control (medial frontal gyrus, supplementary motor area and cerebellum). On the other hand, loved familiar faces were the only ones activating the medial orbitofrontal cortex, an area related with the processing of pleasant stimuli and which is part of the brain's reward circuits.

We can therefore conclude that the results of the studies presented in this thesis offer the following novel information: (1) loved familiar faces elicit a series of peripheral and central changes as a consequence of having induced an intense positive emotional state; (2) loved faces inhibit defensive responses, as is shown by the inhibition of the startle reflex, and this inhibitory mechanism could be at the origin of the benefitial effect of social support on health; (3) loved faces provoke a P3a of a lower latency and higher amplitude than that induced by neutral and unpleasant faces, which shows that there is a very fast access to relevant social and emotional memories and (4) the processing of familiar faces depends on an large network of brain structures in charge of recognizing the identity and recovering the knowledge about the person, processing the emotion evoked by the identity of the face and preparing a possible motor action. Last but not least, as is shown by the activation of the medial orbitofrontal cortex when seeing loved faces as opposed to attractive faces, faces of familiar loved people constitute a stimulus that has a higher reinforcing value than that of other very gratifying stimuli.

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Chapter 1

Introducción

1.1 El amor como constructo psicológico

"Love is such a tissue of paradoxes, and exists in such an endless variety of forms and shades that you may say almost anything about it that you please, and it is likely to be correct."

Henry Finck (1902)

El Simposio de Platón, escrito hace aproximadamente 2.400 años, versa sobre la naturaleza, expresiones y efectos del amor. La disparidad de opiniones defendidas por los diferentes actores del diálogo platónico refleja la complejidad de un fenómeno que todavía hoy es objeto de debate y de desarrollo de multitud de aproximaciones teóricas. Pausanias defiende la diferenciación entre el amor pasional, que involucra de forma activa al cuerpo y sus pulsiones y el amor sereno, comprometido e intelectual que puede definir las relaciones a largo plazo. Erixímaco centra su discurso en el poder creador y sanador del amor, como fuente de toda felicidad. Tanto la distinción entre amor apasionado y amor compañero que matiza Pausanias como la función protectora de la salud que Erixímaco otorga al amor, son temas de gran actualidad en el estudio psicológico del amor.

La vivencia subjetiva del amor, su expresión y su conceptualización, tanto en el ámbito popular como científico, está interrelacionada con factores históricos, culturales y económicos. Pero más allá de los diferentes matices que la cultura y la historia individual pueden conferirle a la experiencia amorosa, nos encontramos ante un fenómeno que en sus diferentes formas ha estado presente a lo largo de la historia del ser humano.

1. INTRODUCCIÓN

Un estudio transcultural realizado en 166 sociedades contemporáneas, encontró evidencia sobre la existencia de amor romántico en 147 de ellas (Jankowiak y Fischer, 1992; Aron et al., 2005).

En la breve historia de la psicología moderna, el amor se ha conceptualizado desde diferentes perspectivas. Se ha entendido como fuerza o impulso que lleva a la unión con el otro, a la preservación y la reproducción de la especie, se ha estudiado como una respuesta emocional ante estímulos reforzadores, se ha equiparado con el apego y, más recientemente, se ha conceptualizado como parte del repertorio emocional y motivacional humano.

A principios del siglo XX Freud plantea diferentes cuestiones fundamentales con respecto a la naturaleza y función del amor. En cuanto a su naturaleza, apunta a la existencia de dos corrientes internas, la afectuosa y la sensual, que unidas constituyen el amor normal (Freud, 1912). En Psicología de las masas y análisis del yo, Freud discurre sobre la función del amor, otorgándole un lugar principal como “el primer factor de civilización” en el origen de la cultura, aquello que nos permite pasar del egoísmo al altruismo (Freud, 1921). En el desarrollo último de su teoría psicoanalítica, el amor –Eros- aparece de nuevo como la fuerza primaria asociada con la preservación de la especie, reproducción, cuidado y creatividad (Freud, 1940). Después de Freud, el amor ha seguido siendo un objeto de análisis central dentro del psicoanálisis. Uno de sus discípulos, Erich Fromm, dedicó una obra completa al estudio del amor desde una perspectiva filosófica y psicológica. En El arte de amar, Fromm señala la importancia del cuidado, la responsabilidad, el respeto y el conocimiento como factores que constituyen el “amor verdadero” (Fromm, 1956).

Mientras en Europa el psicoanálisis estaba sentando sus bases, en Estados Unidos comienza a desarrollarse y tomar fuerza el conductismo, corriente psicológica que se centra en el estudio de la conducta observable como único método objetivo para acercarse al conocimiento del comportamiento humano. Para Watson, las emociones son respuestas observables que surgen ante determinados estímulos incondicionados, e identifica tres formas de respuestas emocionales: el miedo, la ira y el amor. Las reacciones de amor en el niño estarían asociadas a los estímulos táctiles (mecer, acariciar, estimular) provenientes de la madre (Watson, 1924). A pesar de la importancia central que tiene el aprendizaje en su teoría, Watson asume que el amor es una emoción innata, acercándose en este punto más al posterior desarrollo de la teoría del apego, que a gran parte de los psicólogos experimentales de esa época. Desde la perspectiva experimental se defendía la ausencia de emociones innatas en el neonato humano, defendiendo el origen aprendido, a través de las leyes del reforzamiento, de toda reacción afectiva (Harlow, 1958).

A mediados del siglo XX, el horror de la Segunda Guerra mundial deja a millones de niños huérfanos o víctimas de episodios de separación de sus personas y lugares familiares. En este contexto histórico surgen los trabajos de autores tan influyentes en la psicología moderna como John Bowlby y Harry Harlow. Los estudios clásicos de René Spitz sobre niños criados en orfanatos, comienzan a cambiar la creencia de que el amor surge de un mero intercambio de reforzadores primarios. Spitz demostró cómo la carencia de contacto físico afectivo que sufrían los niños institucionalizados alteraba en tal medida el desarrollo, que llevaba en muchos casos a provocar la muerte prematura. Con sus estudios señaló la importancia del contacto físico afectuoso para el crecimiento infantil, más allá de la satisfacción de necesidades básicas como el hambre y la sed (Spitz, 1949). A los trabajos de Spitz se unieron los esfuerzos de Bowlby por entender las secuelas físicas y psicológicas originadas por la separación y privación durante la primera infancia. Como consultor sobre salud mental de la Organización Mundial de la Salud, se le solicita en 1951 escribir un artículo en el que informa sobre las secuelas de la privación materna y la importancia del cuidado materno en el desarrollo del niño (Bowlby, 1951). Este artículo supone la base sobre la que se comienza a desarrollar la influyente Teoría del Apego, teoría que supone un cambio paradigmático en la concepción del amor. Bajo la influencia de teorías biologicistas y evolucionistas, Bolwby plantea la existencia de un sistema biológico innato que predispone al niño a la creación de vínculos afectivos (Bowlby, 1958). En paralelo a los trabajos de John Bowlby, Harry Harlow lleva a cabo estudios experimentales con crías de primates, en los que muestra la importancia para el desarrollo físico y social de la presencia constante de una figura con la que establecer un contacto físico cálido (Harlow, 1958). La difusión de los resultados de estos autores supusieron un cambio en la concepción de la educación, los derechos de los niños y la importancia del afecto, que aún hoy sigue en vigencia.

En los años 70 y 80 del siglo pasado, el amor y el fenómeno del enamoramiento empiezan a ser estudiados por los psicólogos sociales que, desde posicionamientos relativamente reconciliables, desarrollan taxonomías, cuestionarios y teorías sobre el amor. Rubin, por ejemplo, defiende la entidad diferenciada del amor romántico en relación a otros fenómenos estudiados por los psicólogos sociales como la atracción y el agrado ("liking"). Para este autor, el amor es una actitud que predispone hacia una forma de pensar, sentir y actuar, señalando los diferentes componentes cognitivos, emocionales y conductuales asociados a la experiencia amorosa (Rubin, 1970). Lee desarrolla la primera taxonomía del amor en la que diferencia seis estilos, Eros, Storge, Ludus, Mania, Agape y Pragma, en un intento por clasificar la complejidad de las emociones, pensamientos y conductas que surgen dentro de un relación amorosa (Lee, 1973). Esta taxonomía sirvió posteriormente a Hendrick y Hendrick para desarrollar un cuestionario, el Love Attitudes Scale, que supone un apoyo empírico a la clasificación de los diferentes tipos de amor de Lee (Hendrick y Hendrick, 1986). Berscheid y Walster retoman el concepto de emoción acuñado por Schachter para definir el amor romántico como una emoción con un componente de activación fisiológica inespecífica unida a una interpretación cognitiva de su causa (Berscheid y Walster, 1974). Berscheid propone la distinción entre amor pasional, amistad, apego y cuidado (Berscheid, 1988). En 1986, J. Sternberg postula su teoría triangular del amor, señalando la intimidad, la pasión y el compromiso como los tres vértices del amor, que, en diversas combinaciones constituyen diferentes clases de amor. En 1988 se publica el primer manual de revisión que aúna la investigación sobre el amor realizada en las últimas dos décadas (Sternberg, 1988). La diversidad de enfoques sobre la naturaleza del amor que se observa en este manual también está presente en la versión más actual del manuscrito "The new Psychology of love" (Sternberg, 2006). Llama la atención, al comparar las dos versiones del manual, el considerable incremento que ha tenido lugar en los últimos años en la cantidad de teorías neuropsicológicas y psicobiológicas que intentan explicar el fenómeno del amor.

1.2 El estudio neurocientífico y psicobiológico del amor

"We must study love; we must be able to teach it, to understand it, to predict it, or else the world is lost to hostility and to suspicion"

Abraham H. Maslow

El fin del siglo XX y el comienzo del siglo XXI está marcado por un aumento drástico en el conocimiento de las bases biológicas y cerebrales de la conducta, la emoción y la motivación humana. Este avance viene dado por un lado por la proliferación de la investigación animal sobre los mecanismos cerebrales subyacentes a la motivación y emoción y, por otro, por el desarrollo y aplicación de las novedosas técnicas de neuroimagen no invasivas al estudio del funcionamiento del cerebro humano. En los últimos años ha aumentado de forma espectacular el conocimiento acerca de las bases biológicas de procesos tales como la búsqueda de placer, el impulso sexual, la atracción y el establecimiento de vínculos afectivos. La proliferación de datos neurocientíficos y psicofisiológicos en este área de conocimiento está ayudando a superar la tendencia a considerar el amor como una experiencia íntima y personal impropia de la investigación científica. Desde mediados del siglo XX, diferentes autores han señalado la similitud entre la relación de apego entre la cría y la madre en primates no humanos y el amor romántico experimentado entre humanos adultos (Harlow, 1958; Rosemblum, 1981, 1985). Tanto la relación entre una cría y su madre como la relación entre dos amantes está caracterizada por el placer asociado a la cercanía y contacto físico y la desesperación y angustia ante la separación. Desde una perspectiva biologicista, estos dos sistemas básicos de búsqueda de proximidad y pánico ante la separación estarían en la base del desarrollo de los diferentes y complejos tipos de amor que experimentamos los humanos (Shaver et al., 1988; Panksepp, 1998). La inmadurez de los mamíferos al nacer, estado que en el ser humano se mantiene durante un período más largo que en el resto de especies, lleva consigo la búsqueda de la cercanía física de individuos maduros como mecanismo de protección y seguridad. Desde esta perspectiva, la reacciones defensivas de miedo y las reacciones apetitivas de búsqueda de cercanía tendrían en los mamíferos un origen común y una importancia similar a nivel evolutivo (Panksepp, 1998).

1.2.1 El amor como emoción

A la pregunta sobre la naturaleza emocional del amor se antepone la pregunta sobre la naturaleza de la emoción. La concepción moderna de la emoción está claramente influida por los trabajos de Darwin sobre el origen de las emociones. En su obra La expresión de las emociones en el hombre y el animal, Darwin arguye la función adaptativa de las emociones a la hora de posibilitar la comunicación y ayudar a la supervivencia. Darwin defiende que al igual que los rasgos morfológicos, las emociones han evolucionado según la teoría de la selección natural (Darwin, 1872). Pocos años después, William James publica su famoso artículo en el que defiende que la percepción subjetiva de la emoción, el sentimiento, es secundario a los cambios fisiológicos experimentados (James, 1884). Según James, la emoción es un fenómeno discreto asociado con un patrón único de eventos fisiológicos periféricos. Esta concepción de la emoción, en la que la respuesta fisiológica determina la vivencia emocional subjetiva y en la que las diferentes emociones se corresponden con diferentes patrones de activación central y periférica, ha sido retomada por las teorías neurocientíficas y psicofisiológicas contemporáneas.

Uno de los teóricos de la emoción más influyentes del siglo XX, Paul Ekman, defiende el origen de la emoción desde un punto de vista evolucionista y realiza importantes estudios transculturales sobre la universalidad de las expresiones emocionales (Ekman et al., 1969). Ekman acuña el término "emoción básica" para referirse a aquellas emociones que (1) son discretas e identificables en base a sus diferencias en cuanto a expresión facial, evaluación cognitiva, respuestas conductuales, fisiología, etc. y (2) tienen un valor adaptativo en el sentido de que han evolucionado para mejorar la consecución de tareas fundamentales para la vida (enfrentarse a un peligro, conseguir una meta, etc.) (Ekman, 1992). Este autor sitúa la función de la emoción dentro del ámbito interpersonal señalando que, aunque las emociones también aparecen en ausencia de otras personas, su función esencial es la de movilizar al organismo para enfrentarse a encuentros interpersonales importantes en función de aquello que ha resultado adaptativo tanto para la especie como para el individuo a lo largo de su historia personal. La concepción de la emoción como mecanismo desarrollado a partir de las demandas de relación con los otros, abre las puertas al estudio de las denominadas "emociones sociales", aquellas que surgen a partir de la socialización y de la interiorización de las necesidades de los demás (Adolphs, 2002). Ekman (1992) entiende el amor como una mezcla de diferentes emociones y lo define como una actitud emocional que se prolonga a lo largo del tiempo. Esta postura es defendida por otros teóricos de la emoción, que reconocen el amor como uno de los fenómenos emocionales más poderosos pero cuya naturaleza difiere de la de las emociones básicas. Así por ejemplo, Izard (1991) reconoce la multitud de emociones contrapuestas que pueden surgir dentro de una relación de amor (deseo, felicidad, tristeza, rabia, etc.).

Para Bowlby, es también en el campo de las relaciones personales, en concreto en la formación, mantenimiento y ruptura de los vínculos afectivos, donde surgen las emociones más intensas (Bowlby, 1979). A finales de los años 80, Hazan y Shaver elaboran una aproximación teórica a la naturaleza del amor romántico enmarcada dentro de la teoría del apego de Bowlby (Shaver y Hazan, 1988). Según estos autores, el amor romántico y el apego infantil a los padres, son variaciones de un mismo proceso subyacente. Los estilos de apego infantil observados por Ainsworth y colegas (1978) (apego seguro, ansioso y evitativo) son también observables en las diferentes formas de relación de los adultos con sus parejas (Hazan y Shaver, 1987). En la base del amor romántico estarían actuando tres de los principales sistemas conductuales propuestos por Bowlby, el apego, el cuidado y el sexo. Estos sistemas conductuales consisten en programas neuronales universales dentro de una especie que rigen la elección, activación y terminación de secuencias conductuales que provocan un cambio funcional en la relación de la persona con el ambiente teniendo ventajas para la supervivencia y la reproducción (Shaver y Mikulincer en Sternberg, 2006). Estos autores defienden la inclusión del amor dentro de las taxonomías de la emoción. Para ellos existe una diferenciación entre la emociones como tendencia estable, por ejemplo tristeza o rabia mantenida y las emociones como impulso. De esta forma matizan la diferencia entre el amor relacional o apego y el amor como impulso equiparable con otras emociones básicas como el miedo o la rabia puntual. Shaver y Hazan (1996) citan a Darwin en su descripción de las expresiones faciales asociadas con dos tipos de amor, el amor romántico y el amor materno. La expresión maternal se diferenciaría por una “sonrisa dulce y mirada cariñosa” mientras que la cara del enamorado se determinaría por su rubor (Darwin, 1872/1965). La existencia de diferentes estudios que demuestran la universalidad y transculturalidad del amor romántico, así como estudios en los que se han podido diferenciar las expresiones faciales, tono de voz y postura corporal asociadas a la emoción de amor, lleva a estos autores a formular la hipótesis de que el impulso de amor cumple con los criterios determinados por Ekman para ser considerado una emoción básica (Jankowiak y Fischer, 1992; Wu y Shaver, 1993; Morris, 1971; Rapson, 1993; Hatfield et al., 1996; Santibanez, 1987). En su forma disposicional, el amor sería equiparable al apego, pudiendo evocar sentimientos tanto de felicidad, tranquilidad y bienestar como de angustia, sufrimiento o pánico.

1.2.2 El amor como motivación

En su influyente trabajo realizado a partir de 1980, el psiquiatra Michael Liebowitz dividió el amor romántico humano en dos estados básicos, atracción y apego, y propuso que determinados procesos fisiológicos estaban involucrados en cada uno de estos estados (Liebowitz, 1983). A partir de su trabajo con pacientes “enfermos de amor” relacionó el fenómeno de la atracción con la acción de los neurotransmisores feniletilamina, norepinefrina, dopamina y serotonina. Por otro lado, conectó el fenómeno del apego y sus emociones de tranquilidad y paz con la actuación de las endorfinas. Datos posteriores mostraron que la oxitocina y la vasopresina tienen una función mediadora en la creación de diferentes vínculos afectivos en diferentes especies de mamíferos, postulando la hipótesis de la posible función mediadora de estos neurotransmisores en la creación del apego humano (Pedersen et al., 1992).

A comienzos de los años 90 la bio-antropóloga Helen Fisher comienza a interesarse por el fenómeno del amor, su función adaptativa y sus bases neurofisiológicas. Partiendo de los datos acumulados hasta el momento sobre los análogos de la atracción y el apego en aves y mamíferos, propone que estas emociones son tan primitivas y universales como el miedo, el enfado o la sorpresa (Fisher, 1994). Los sistemas cerebrales encargados de mediar las conductas y emociones relacionadas con el apego habrían evolucionado a partir de los mecanismos neurofisiológicos que controlan la conducta reproductiva en mamíferos y otras especies menos evolucionadas. La evolución de las especies va de la mano del nacimiento de crías cada vez más inmaduras y necesitadas de cuidado, por lo que los sistemas de apego habrían evolucionado a partir de la necesidad de la creación y mantenimiento de un vínculo afectivo que asegurase el cuidado de las crías. Evidencia a favor de esta hipótesis se encuentra, por un lado, en la similitud de las conductas y emociones asociadas a ambos tipos de procesos y, por otro, por la existencia de mecanismos neuroquímicos, como la oxitocina y la vasopresina, que median tanto la conducta reproductiva como el apego (Carter, 1998; Panksepp, 1998; Fisher, 1998). Más allá de su origen compartido, los sistemas de deseo, atracción y apego parecen haber evolucionado hasta convertirse en fenómenos en parte independientes y en parte interrelacionados. Por un lado, el deseo o impulso sexual habría evolucionado para motivar a mantener relaciones sexuales con cualquier miembro apropiado de la especie a través de la mediación de los esteroides sexuales (testosterona y estrógenos). La administración de testosterona en hombres y mujeres de mediana edad, aumenta el deseo sexual pero no la pasión romántica o el apego (Sherwin y Gelfand, 1987; Sherwin, Gelfald and Brender, 1985). La atracción, caracterizada por aumento de energía y atención focalizada, habría evolucionado para motivar a los individuos a seleccionar entre potenciales parejas. Parte de los síntomas asociados con altos niveles de atracción o “amor romántico” (euforia, falta de apetito, poca necesidad de sueño, etc.) están relacionados con los efectos provocados por aumentos de dopamina en el sistema nervioso humano (Wise, 1988; Colle y Wise, 1988; Kruk y Pycock, 1991). Estos datos han llevado a hipotetizar la intervención de los sistemas dopaminérgicos en las emociones asociadas con la atracción en humanos (Fisher, 1998; Fisher et al., 2002). Por último, el apego se caracteriza por el mantenimiento a medio o largo plazo del contacto social y la proximidad física, conductas que tanto en humanos como en otros animales se han visto mediadas por los péptidos vasopresina y oxitocina (Carter, 1998; Williams et al., 1994) y que están asociadas a emociones de calma, confort y unión emocional (Fisher, 1998).

En los últimos años, diferentes estudios han utilizado técnicas de neuroimagen, en concreto resonancia magnética funcional, durante el visionado pasivo de caras de personas queridas con el fin de registrar las áreas cerebrales más sensibles al procesamiento de estímulos relacionados con el vínculo y el apego social. En concreto, las dos emociones que más se han investigado han sido el amor romántico (Bartels y Zeki, 2000; Aron et al., 2005; Acevedo et al., 2011) y el amor materno (Bartels y Zeki, 2004; Leibenluft et al., 2004; Swain et al., 2008; Strathearn et al., 2008). Estos estudios han mostrado la activación de determinadas áreas subcorticales (por ejemplo, núcleo caudado, putamen, nucleo acumbens) y corticales (por ejemplo, ínsula, corteza orbito-frontal) relacionadas con el procesamiento de contextos altamente emocionales y gratificantes. Parte de las regiones activadas en estos estudios presentan una alta densidad en receptores dopaminérgicos (área ventral tegmental y núcleo caudado) y en receptores de vasopresina y oxitocina (núcleo caudado, sustancia gris periacueductal, sustancia negra). En conjunto, estos datos vuelven a señalar el nexo entre los procesos asociados a la creación de vínculos afectivos y aquellos involucrados en las experiencias reforzadoras, mostrando que la experiencia de conexión social es fundamentalmente reforzante (Cacioppo et al., 2009). La otra cara de la moneda -los efectos de la soledad y de la carencia de conexión social- empezó a ser estudiada por los psicólogos sociales y cada vez más ocupan el interés de los psicofisiólogos y neurocientíficos. La literatura sobre apoyo social aporta información a tener en cuenta en el desarrollo de teorías que vinculen el funcionamiento fisiológico con las emociones de amor, apego y cuidado.

1.3 Amor, apoyo social y salud

"... researchers should recognize the importance of love as a provision that can help people get through times of stress and crisis. For this reason, research on love needs to be connected with the booming research literature on social support"

Rubin (1988)

A mediados del siglo XX se comenzó a investigar la influencia del apoyo social en la salud y hoy en día es uno de los factores psicosociales cuya influencia sobre la salud está mejor documentada (Uchino, 2009). El concepto de apoyo social se ha operacionalizado de diferentes formas atendiendo a sus componentes estructurales (por ejemplo, ser parte de una red social, estado civil, participación social, etc.) o a sus componentes funcionales (por ejemplo, tipos de transacciones entre individuos) (Reblin y Uchino, 2008). Los tipos de transacciones entre individuos pueden ser de tipo emocional, en el que el apoyo provendría a través del afecto positivo (amor, cuidado, empatía, confianza y aceptación por parte de los demás), o de tipo instrumental en el que el apoyo se presta a través de ayuda tangible (económica, material, servicios, etc.) (Thois, 1995; House, 1981). Por lo tanto, en una de sus acepciones, el apoyo social es un fenómeno muy cercano al amor.

La cantidad y calidad de las redes sociales tiene un impacto directo sobre la salud física y psicológica (Uchino, Cacioppo y Kiecolt-Glaser, 1996). El apoyo social es un factor protector ante la enfermedad, mientras que el aislamiento social supone un factor de riesgo para la salud comparable con el consumo de tabaco, la falta de actividad física o los niveles elevados de presión arterial (Berkman y Syme, 1979; Ortmeyer, 1974; Nuckolls, Cassel y Kaplan, 1972; Gore, 1973; Berkman, Glass, Brissette y Seeman, 2000; House, Landis y Umberson, 1988). La influencia del apoyo social se ha investigado en relación con el funcionamiento de los tres sistemas fisiológicos que median las respuestas de estrés a corto, medio y largo plazo: el sistema cardiovascular, el sistema endocrino y el sistema inmune (Berkman et al., 2000; Kemeny, 2003). Pero, ¿a través de qué mecanismos ejerce el apoyo social su efecto amortiguador sobre las respuestas de estrés? Una de las hipótesis más secundada defiende que el apoyo social influye beneficiosamente en la salud reduciendo la reactividad fisiológica ante circunstancias estresantes (Uchino et al., 1996; Eisenberger et al., 2007). Las respuestas fásicas ante estímulos estresantes son adaptativas, por ejemplo un aumento rápido de la reactividad cardiovascular y del eje hipotálamo-hipófisis-pituitaria, porque permiten la movilización del organismo ante una fuente posiblemente dañina. Sin embargo, el mantenimiento a largo plazo de estas reacciones, por ejemplo niveles crónicos elevados de cortisol, tiene efectos nocivos en la regulación de los sistemas fisiológicos (Blalock, J. E., & Smith, E. M., 1985). La menor reactividad fisiológica puede deberse bien a una evaluación de la situación como menos amenazante antes de que se pongan en marcha las respuestas fisiológicas ante el estrés, o bien a una serie de procesos autorreguladores y de reevaluación que interfieren en las respuestas de estrés a largo plazo (Eisenberger et al., 2007). Algunos autores también han defendido la hipótesis de que el apoyo social ejerce su influencia positiva sobre la salud a través de promover conductas saludables (mejor alimentación, más ejercicio físico, etc.). Esta hipótesis se vería rebatida por el hecho de que la asociación entre apoyo social y salud sigue siendo significativa después de controlar diferentes variables relacionadas con la salud, incluyendo el peso y la masa corporal (Bland et al., 1991 en Uchino et al., 1996). Los efectos directos de la presencia de una persona familiar sobre el funcionamiento cardiovascular, hormonal, neuronal e incluso genético también representan datos que refutan la hipótesis de una influencia indirecta del apoyo social sobre la salud. Por ejemplo, Spitzer, Llabre, Ironson, Gellamn y Schneiderman (1992) mostraron que la presencia de un familiar, en comparación con un amigo o un desconocido, estuvo asociada con niveles más bajos de presión arterial sistólica y diastólica medidos de forma ambulatoria. Un estudio más reciente (Heinrichs et al., 2003) ha mostrado que la presencia de una persona familiar querida reduce la actividad del eje hipotálamo-hipófisis-adrenal encargado de la segregación del cortisol. Así mismo, Eisenberger et al. (2011) presentaron fotografías de la cara de la pareja a un grupo de mujeres durante una tarea experimental de inducción de dolor. Las mujeres evaluaron como menos dolorosa la estimulación dolorosa durante la visualización de la cara de su pareja, a la vez que las áreas cerebrales encargadas de procesar el dolor estuvieron menos activadas. Un estudio sobre expresión genética, mostró la capacidad de un entorno cariñoso y cuidadoso de modificar determinados genes relacionados con la propensión a desarrollar depresión y otros tipos de psicopatologías (Way y Taylor, 2010). Por otro lado, algunos autores defienden que los entornos caracterizados por la ausencia de apoyo social se procesan a nivel básico como una amenaza severa a la propia seguridad activando el sistema motivacional defensivo e inhibiendo el apetitivo (McDonald y Leary, 2005). Un entorno cariñoso y comprensivo actuaría de forma opuesta proporcionando claves de seguridad que activarían el sistema apetitivo e inhibirían el defensivo. El estudio psicofisiológico y de los reflejos defensivos durante el procesamiento de caras queridas puede aportar información relevante a la hora de comprender los mecanismos fisiológicos a través de los cuales el apoyo social, en concreto su componente emocional, repercute positivamente sobre la salud.

1.4 Procesamiento afectivo de caras

La cara aporta una gran cantidad de información que es utilizada, tanto por los humanos como por diferentes especies animales, para transmitir información relevante durante la interacción social. Transmite información sobre la identidad de una persona (rasgos físicos) y sobre su estado emocional (expresiones faciales). También comunica información social relevante como el género, la edad, el atractivo y posibles actitudes, intenciones y pensamientos (Adolphs, 2009; Dekowska, Kuniecki, y Ja?kowski, 2008). En consecuencia, la cara ha sido el objeto de estudio de numerosas investigaciones en las últimas décadas, principalmente centradas en delinear los mecanismos cognitivos a través de los cuales se logra la percepción y el reconocimiento facial (Bobes, Quiñonez, Perez, Leon, & Valdés-Sosa, 2007; Bruce & Young, 1986; Gobbini & Haxby, 2007; LaBar, Crupain, Voyvodic, &McCarthy, 2003).

Desde el clásico modelo propuesto por Bruce y Young (1986), la percepción facial se ha conceptualizado como un fenómeno dependiente de múltiples etapas especializadas en el procesamiento de información diferenciada. De este modo, el modelo neuroanatómico propuesto por Haxby, Hoffman y Gobbini (2000) describe una primera etapa de reconocimiento visual de los rasgos faciales variantes e invariantes y una segunda etapa en la que se accedería a otro tipo de información más compleja (recuerdos acerca de la persona, inferencia de rasgos de personalidad, emociones asociadas a la cara, etc.). El sistema de procesamiento visual, o sistema central, estaría compuesto por áreas cerebrales especializadas en el análisis de rasgos invariantes (giro fusiforme y occipital inferior) y de rasgos dinámicos (giro parietal superior). La información acerca de la persona, sus posibles estados mentales, rasgos de personalidad y recuerdos biográficos asociados a ella estarían relacionados con la actividad de otros sistemas neurales distintos del visual (corteza prefrontal, cortex temporal, giro cingulado, etc.) que, en conjunto con las áreas encargadas de procesar la información emocional asociada a la identidad de la persona (amígdala, ínsula y estriado), formarían el sistema extendido. En las últimas revisiones del modelo (Gobbini y Haxby, 2007; Haxby y Gobbini, 2011) estos autores hacen especial hincapié en los procesos asociados con el reconocimiento de caras familiares. Siguiendo este modelo, la recuperación de recuerdos asociados con la persona (por ejemplo, estados mentales, rasgos de personalidad y recuerdos biográficos) y la emoción evocada por la visualización de un rostro familiar ("emoción asociada a la identidad") son dos componentes fundamentales a la hora de garantizar un reconocimiento exitoso de la cara. Parte de los datos utilizados en el desarrollo de estos modelos neuroanatómicos sobre reconocimiento facial provienen de estudios de neuroimagen que han comparado caras familiares de diferente naturaleza con caras desconocidas. Así, por ejemplo, se han utilizado caras de famosos (Gorno-Tempini, 1998; Leveroni, 2000; Sergent, 1992), caras aprendidas en laboratorio (Dubois, 1999; Rossion, 2001), caras de conocidos (Nakamura, 2000) y, más recientemente, caras de familiares con relevancia social y emocional (Gobbini et al., 2004; Leibenluft et al., 2004; Taylor et al., 2009). Estos últimos estudios han estado interesados en mostrar la implicación del conocimiento acerca de la persona visualizada así como de las respuestas emocionales asociadas a ella en el reconocimiento del rostro.

A pesar de la mencionada importancia de las respuestas emocionales en el proceso de reconocimiento facial, la gran mayoría de los estudios citados anteriormente no utilizaron el registro psicofisológico de variables del sistema nervioso periférico, perdiendo así una valiosa fuente de información acerca de las reacciones emocionales. Un ámbito de estudio en el que sí ha sido más común la utilización de medidas del sistema nervioso autónomo, aunque restringida en la mayoría de los casos al registro de la conductancia eléctrica de la piel, ha sido el de pacientes neuropsicológicos con una alteración en el reconocimiento de rostros. El trastorno neuropsicológico más conocido asociado con un déficit en el reconocimiento de caras familiares es la prosopagnosia. Estos pacientes, a pesar de tener intacta la capacidad de reconocer otro tipo de objetos e incluso de reconocer a sus familiares a través de la voz o del cuerpo, son incapaces de reconocer un rostro familiar. Durante el estudio experimental de algunos pacientes con prosopagnosia, se pudo observar que, a pesar de que informaban no conocer ninguna de las caras familiares a las que eran expuestos, sus respuestas en conductancia eléctrica de la piel aumentaban considerablemente ante las caras familiares (Bauer, 1984; Tranel y Damasio, 1985). Estos datos llevaron a Bauer (1984, 1986) a desarrollar su modelo teórico que describe la posible existencia de una doble vía de procesamiento facial: la vía ventral, encargada del reconocimiento consciente y la vía dorsal, encargada del reconocimiento inconsciente. El modelo de Bauer puede explicar otro tipo de síndromes en los que el procesamiento del rostro se ve alterado. El síndrome de Capgras consiste en una alteración psiquiátrica, normalmente acompañada de otro tipo de sintomatología cognitiva y afectiva, en el que las caras de personas familiares son reconocidas a nivel cognitivo ya que se puede recuperar la información acerca de la persona, pero existe la creencia de que se trata de un impostor. Siguiendo el modelo de la doble ruta de Bauer, en la prosopagnosia se encontraría dañada la ruta cognitiva (Bauer, 1984; Tranel y Damasio, 1985), mientras que en el síndrome de Capgras, sería la información emocional la que no se estaría procesando correctamente. Uno de los datos utilizados a favor a esta hipótesis es que pacientes con síndrome de Capgras no muestran un aumento en las respuestas fásicas en conductancia eléctrica de la piel durante la visualización de caras familiares (Ellis et al., 1979; Hirstein y Ramachandran, 1997).

Además de la valiosa información que aportan tanto los estudios con pacientes como los estudios de neuroimagen sobre la localización cerebral de determinadas funciones asociadas con la percepción facial, las técnicas de registro de la actividad eléctrica cerebral (electroencefalografía y magnetoencefalografía), por su parte, han aportado información temporal muy relevante. Los potenciales evocados corticales han demostrado ser especialmente útiles en este contexto habiéndose encontrado varios componentes que reflejan las sucesivas etapas en el procesamiento de la información facial: el N170, el N250, P300, N400 y N600 (Bentin et al., 1996; Bruce y Young, 1986; Eimer, 2000; Herrmann et al., 2005; Bobes et al., 2007; Schweinberger, 2011). Estos potenciales se localizan fundamentalmente en zonas temporales del hemisferio derecho. Los primeros aparecen ante cualquier tipo de cara, independientemente de la familiaridad, siendo reflejo de procesamientos de tipo estructural. Los potenciales más tardíos permiten diferenciar las caras conocidas de las desconocidas, tanto a través de la familiaridad visual como reflejando la recuperación de información biográfica y emocional.

La utilización de técnicas de registro de la actividad central con buena resolución espacial (IRMf) y con buena resolución temporal (potenciales evocados) junto a técnicas de registro de la actividad periférica (tasa cardíaca, conductancia eléctrica de la piel, electromiografía) puede aportar una visión muy completa sobre la naturaleza y función de los procesos que subyacen al reconocimiento de caras familiares con relevancia social y emocional.

1.5 Estudio psicofisiológico de los procesos emocionales

"El cerebro dotado de una mente consciente de tener un cuerpo es en realidad cautivo del cuerpo y de las señales que éste le envía."
Antonio Damasio (2010)

Hoy en día existe un cierto consenso entre los psicólogos experimentales, psicofisiólogos y neuropsicólogos a la hora de considerar las respuestas corporales como parte esencial de la experiencia emocional. Autores relevantes en el estudio de la emoción diferencian a nivel teórico entre la reacción emocional, descrita como una serie de cambios fisiológicos, y la sensación emocional descrita como la integración y significación de esos cambios corporales por parte de la consciencia (Adolphs, 2002; Damasio, 2010).

Otro punto en común entre las diferentes aproximaciones teóricas al fenómeno de la emoción es su conceptualización como mecanismo desarrollado a través de la evolución cuya función original tiene que ver con una mejor adaptación al medio. Uno de los modelos teóricos contemporáneos sobre la emoción que mayor evidencia empírica ha aportado en este sentido es el desarrollado por Peter J. Lang y colaboradores (Lang, 1995; Bradley, 2000; Lang y Bradley, 2010). Este modelo conceptualiza las emociones como disposiciones para la acción que se han ido desarrollando a lo largo de la evolución a partir de reacciones de carácter adaptativo ante situaciones relevantes para la supervivencia y que están relacionadas con los dos sistemas motivacionales primarios: el apetitivo, relacionado con las emociones positivas y con conductas de aproximación, y el aversivo, relacionado con las emociones negativas y comportamientos defensivos. La emoción se produciría cuando se activa cualquier estructura de información en el cerebro que conecte con estos sistemas motivacionales.

Este modelo se ha puesto a prueba en humanos utilizando como principal paradigma de estudio la visualización pasiva de imágenes afectivas superpuestas a la evocación del reflejo de sobresalto junto con el registro simultaneo de diversas respuestas psicofisiológicas (frecuencia cardiaca, conductancia eléctrica de la piel, electromiografía de los músculos orbicular, corrugador y cigomático, y potenciales corticales). El paradigma de visualización de imágenes afectivas requiere el uso de un instrumento -el 'Sistema

Internacional de Imágenes Afectivas' o IAPS- elaborado por el grupo de Lang en la Universidad de Florida y adaptado a la población española en las Universidades de Granada y Castellón (Lang, Bradley y Cuthbert, 2008; Moltó et al., 1999; Vila et al., 2001). Actualmente incluye más de mil fotografías en color pertenecientes a diversas categorías semánticas: animales, escenas de la naturaleza, objetos caseros, desnudos, parejas eróticas, caras humanas, cuerpos mutilados, armas, comida, deportes, etc. El instrumento proporciona datos normativos para cada imagen, obtenidos a partir de escalas psicométricas pictográficas (Self Assessment Manikin) relativos a tres dimensiones afectivas generales: valencia (agradable-desagradable), arousal (excitado-relajado) y dominancia (dominador-dominado) (Bradley y Lang, 1994).

Los resultados de numerosas investigaciones utilizando este paradigma muestran que la amplitud del reflejo de sobresalto, provocado por estimulación acústica repentina (normalmente un ruido blanco presentado durante 50 ms a una intensidad de 105dBs y con un tiempo de subida virtualmente instantáneo), se potencia cuando el organismo se encuentra procesando información emocionalmente desagradable o aversiva, mientras que la amplitud de dicho reflejo se inhibe cuando el organismo se encuentra procesando información emocionalmente agradable o apetitiva (ver Dawson et al., 1999). Lang y colaboradores explican este fenómeno de acuerdo con su modelo de 'priming motivacional': los reflejos apetitivos y defensivos se potencian cuando existe congruencia entre el tipo de reflejo y el estado emocional en que se encuentra previamente el organismo, mientras que se inhiben cuando existe incongruencia entre ambos (Lang, 1995).

El paradigma de visualización de imágenes afectivas, pese a haberse centrado en el procesamiento de emociones negativas, también ha utilizado estímulos altamente positivos, generalmente por contraposición a los negativos, orientados a estudiar el efecto de la valencia afectiva (agradable frente a desagradable) sobre los reflejos defensivos y las respuestas psicofisiológicas. El 'Sistema Internacional de Imágenes Afectivas' en el que se basan estos estudios cubre una amplia gama de fotografías que, distribuidas en el espacio bidimensional definido por las dimensiones de valencia y arousal, presenta una forma de boomerang con dos brazos que salen de una misma zona afectivamente neutra y de mínimo arousal hacia los dos extremos separados de máximo agrado y desagrado y máximo arousal. Estos dos brazos representan los dos sistemas motivacionales primarios: el apetitivo y el defensivo. El brazo correspondiente al sistema motivacional apetitivo tiene una menor inclinación y mayor dispersión que el brazo correspondiente al sistema motivacional defensivo (Vila et al., 2001). Esta menor inclinación sugiere una menor fuerza motivacional para el sistema apetitivo. Su principal implicación es que existe un número menor de imágenes afectivas altamente positivas que de imágenes afectivas altamente negativas. Además, existen importantes diferencias de género con respecto a las imágenes evaluadas como altamente positivas: los hombres asignan mayores puntuaciones a las imágenes eróticas y de deportes mientras que las mujeres consideran como las más agradables las imágenes de bebés y de parejas románticas (Bradley et al., 2001; Moltó et al., 1999).

Los estudios psicofisiológicos que han utilizado el paradigma de visualización de imágenes han intentado identificar los patrones de respuesta que permiten diferenciar las emociones positivas de las negativas (efecto de valencia) controlando el efecto del arousal afectivo. Para ello, resulta metodológicamente imprescindible seleccionar imágenes desagradables y agradables que estén perfectamente igualadas en sus niveles altos de arousal, comparándolas con imágenes neutras de bajo arousal. Esta tarea ha resultado, por lo general, más difícil de lo que pudiera parecer, siendo las imágenes eróticas las que terminan siendo seleccionadas como las imágenes positivas que mejor cumplen los criterios de igualación. En el polo negativo, sin embargo, la selección de imágenes desagradables es más amplia siendo las categorías más estudiadas las imágenes de amenaza, sangre/mutilaciones, y objetos/animales fóbicos. Los resultados de los estudios psicofisiológicos utilizando estas imágenes son, en general, consistentes (ver Bradley, 2000). Por una parte, hay un conjunto de medidas que permiten diferenciar las imágenes positivas de las negativas: el reflejo de sobresalto, la frecuencia cardiaca, la electromiografía de los músculos corrugador y cigomático, y la respuesta cardiaca de defensa. Por otra parte, hay otro conjunto de medidas que permiten diferenciar las imágenes en función de su arousal afectivo, esto es, las imágenes altas en arousal (positivas y negativas) frente a las imágenes bajas en arousal (neutras): la actividad eléctrica de la piel y los potenciales corticales evocados (la onda de positividad tardía).

La principal dificultad con estos estudios es que mientras que los patrones de respuesta de los estímulos negativos y positivos se diferencian entre sí, las diferencias en los patrones de respuesta ante estímulos positivos y neutros no siempre alcanzan la significatividad estadística –como en el caso del reflejo de sobresalto- quedando la duda de si se ha conseguido inducir genuinamente una emoción positiva (Ruiz-Padial y Vila, 2007). Los datos son más claros con respecto a la inducción de emociones negativas: miedo, asco, tristeza. Además, cabe la duda de si las imágenes sexuales pueden considerarse imágenes inductoras de emociones positivas en sentido estricto. Por otra parte, en el caso de las mujeres, es evidente que las imágenes sexuales no son evaluadas como las más positivas. Y las que sí lo son –las imágenes de bebés y familias-tienden a ser evaluadas como poco activantes (bajas en arousal), lo que impide realizar comparaciones bien controladas con respecto a imágenes negativas.

1.6 Aproximación al estudio de la emoción asociada a la identidad

Nuestra propuesta de aproximación al estudio de la emoción asociada a la identidad de personas familiares consiste en el registro simultáneo de variables del sistema nervioso periférico y central así como el empleo de evaluaciones subjetivas durante la visualización pasiva de estímulos asociados con la identidad de la personas (en este caso, el rostro). La utilización de este paradigma permite la aproximación al fenómeno de una forma más integradora a la vez que capta el fenómeno emocional de una forma más fiel. El registro de variables periféricas sensibles a la valencia y al arousal afectivo permite delimitar las contribuciones de ambas dimensiones en las emociones relacionadas con el apego, así como en los procesos de reconocimiento de rostros familiares. Poder desentrañar los efectos de la valencia afectiva requiere, además, la utilización de estímulos igualados en arousal y distintos en valencia. Otro rasgo distintivo de nuestros estudios tiene que ver con la utilización de estímulos faciales con diferente valencia emocional, pudiendo controlar el efecto de la valencia positiva relacionada con las caras familiares con el efecto de la valencia negativa evocada por otro tipo de estímulos faciales (caras mutiladas, caras de personas familiares desagradables y caras de persona feas).

Por otro lado, es necesario un exhaustivo control de la familiaridad asociada a los rostros familiares y de los mecanismos asociados a su procesamiento, con el fin de poder diferenciarla del fenómeno emocional. Gran parte de la investigación sobre reconocimiento facial ha tenido como objetivo delimitar los mecanismos asociados con el procesamiento de la familiaridad. El fenómeno de la familiaridad ha sido definido como un componente del reconocimiento explícito, fenómeno principalmente cognitivo asociado con la recuperación de recuerdos fácticos y episódicos (Voss & Paller, 2006, 2007;

Gobbini & Haxby, 2007). La familiaridad con respecto a una cara querida depende por lo tanto de la cantidad de conocimiento fáctico acumulado sobre la persona, que a su vez depende de variables como la duración de la relación, la cantidad de tiempo compartido o la cantidad de información acumulada. Estudios previos sobre el procesamiento de caras queridas han controlado la familiaridad a través de la comparación con caras de famosos, conocidos o caras aprendidas en laboratorio. En nuestros estudios controlamos esta variable, además de con la presentación de caras de personas famosas, a través de la comparación entre la cara del padre y la de la pareja, habiendo controlado que el nivel de familiaridad hacia las caras de los padres era superior a la de la pareja.

Otra novedad de los estudios presentados en esta tesis con respecto a estudios previos, se refiere al tipo de vínculos afectivos estudiados. Las investigaciones previas en la mayoría de los casos se han limitado a investigar un tipo de relación de apego, fundamentalmente el amor romántico o el amor maternal (Bartels y Zeki, 2000, 2004; Aron et al., 2005; Acevedo et al., 2011; Leibenluft et al., 2004; Swain et al., 2008; Strathearn et al., 2008). Algunos estudios más recientes sí que han utilizado una categoría más heterogénea de personas queridas en las que se incluyen a la pareja y a los padres, o familiares y amigos (Gobbini et al., 2004; Bobes et al., 2007; Taylor et al., 2009). Según nos consta, hasta la fecha no se han planteado estudios que se aproximen al fenómeno del apego y al estudio de la emoción asociada a la identidad desde una perspectiva que incluya tanto las relaciones de pareja como las relaciones filiales y de amistad. Partiendo de que los mecanismos básicos que modulan los diferentes tipo de relaciones amorosas son en gran parte compartidos, esta alternativa supondría un acercamiento integrador al fenómeno de las relaciones familiares afectivas. Similitudes y diferencias en el acceso a la información proveniente de caras con las que se mantienen relaciones afectivas de diferente naturaleza (padres frente a pareja, por ejemplo), puede a su vez aportar información valiosa acerca de los mecanismos de acceso a la información emocional y recuerdos autobiográficos asociados con la cara. A continuación, hacemos un breve resumen de los objetivos de esta tesis doctoral y de los capítulos que la conforman realizando una breve exposición de sus contenidos.

1.7 Objetivos

El objetivo general de esta tesis doctoral fue estudiar los mecanismos centrales y periféricos del procesamiento afectivo de caras familiares queridas. Este objetivo general se concretó en los siguientes objetivos específicos:

1. Determinar los efectos psicofisológicos debidos al procesamiento de la valencia afectiva, el arousal y la familiaridad en el procesamiento de caras de personas familiares queridas.

2. Determinar la posible modulación del reflejo de sobresalto durante la visualización de caras queridas.

3. Analizar posibles diferencias de género en el procesamiento de caras familiares queridas.

4. Describir la modulación de los potenciales evocados relacionados con el procesamiento de caras familiares queridas, el patrón temporal de los diferentes procesos y la localización cerebral asociada a ellos.

5. Ilustrar los efectos centrales (IRMf) y periféricos del procesamiento emocional de rostros que diferían en familiaridad (familiares vs. desconocidas) y en valencia (agradables vs. desagradables).

1.8 Resumen de los capítulos de la Tesis

1.8.1 Capítulo 1

En este capítulo se presentan tres estudios cuyo objetivo común fue determinar los mecanismos periféricos y centrales subyacentes al procesamiento de caras familiares queridas con especial énfasis en desentrañar la contribución de la valencia afectiva, el arousal indiferenciado y la familiaridad. Los tres estudios tienen en común: (1) la utilización de un paradigma capaz de diferenciar los efectos de la valencia y del arousal, el paradigma de visualización pasiva (Lang, 1995; Lang et al., 2000, 2006; Codispoti et al., 2001; Bradley & Lang, 2007), (2) el registro simultáneo de la actividad del sistema nervioso central (potenciales evocados) y periférico (electromiografía, electrocardiografía y conductancia eléctrica de la piel), y (3) la utilización de estímulos faciales que difieren en valencia afectiva, arousal y familiaridad.

En el primer estudio publicado por Vico y colaboradores (2010), los participantes visualizaron de forma pasiva caras pertenecientes a cinco categorías diferentes: caras queridas (pareja, padres, hermanos/as, familiares de segundo grado y amigos), caras de famosos, caras de desconocidos (pertenecientes al conjunto de caras familiares de otro participante), caras de bebés del IAPS, y caras neutrales de la base de Ekman y Friesen (1978). Durante la visualización de estas imágenes se registró la conductancia eléctrica de la piel, el electrocardiograma, la actividad del músculo cigomático y el electroencefalograma. Al terminar el registro psicofisiológico los participantes volvieron a visualizar las imágenes mientras evaluaban sus sensaciones subjetivas (valencia, arousal y dominancia) utilizando el Self Assessment Manikin (SAM) (Bradley y Lang, 1994). Los resultados de este primer estudio mostraron una respuesta potenciada en todas las variables registradas durante la visualización de las caras queridas en comparación con el resto de categorías de caras. Con respecto a los potenciales evocados, se pudo observar una onda de mayor positividad ante las caras queridas, que comienza aproximadamente a los 200 ms después de la presentación de la imagen y se mantiene hasta casi la finalización del período de 1000 ms post-imagen. El segundo estudio presentado en este capítulo (Guerra et al., 2011) utilizó un paradigma muy similar en el que un grupo de mujeres visualizaron de forma pasiva caras familiares queridas (pareja y padre), desconocidas y caras de bebés. Este estudio fue especialmente diseñado con el fin de controlar el grado de familiaridad entre las diferentes categorías de caras. La fotografía del bebé se utilizó con el objetivo de controlar los efectos debidos a la sensación de placer provocado por la visualización de una fotografía agradable y para controlar los posibles efectos oddball (frecuencia estimular) y von Restorff (saliencia visual) en los potenciales evocados. Los resultados de este estudio confirmaron los encontrados por Vico y colaboradores (2010), siendo las caras queridas las que provocaron las mayores respuestas en conductancia eléctrica de la piel y actividad del músculo cigomático. En cuanto a la tasa cardíaca, en este estudio las caras queridas se diferenciaron de las desconocidas (mayor aceleración cardíaca) pero no de las de bebés. Con respecto a los potenciales evocados se volvió a encontrar una mayor amplitud en los componentes

P300 y potencial positivo tardío (LPP) durante el visionado de caras familiares en comparación con las caras desconocidas y de bebés.

En el tercer y último estudio incluido en este capítulo (Guerra et al, 2012), se utilizó el paradigma de la modulación del reflejo de sobresalto durante el visionado pasivo de caras familiares queridas (pareja, madre, padre y amigo/-a), desconocidas (imágenes seleccionadas del conjunto de caras queridas de otro participante) y desagradables (caras mutiladas provenientes del IAPS). Los resultados en conductancia eléctrica de la piel, actividad del músculo cigomático y tasa cardíaca replican los resultados obtenidos en los dos estudios anteriores. La conductancia eléctrica de la piel, como medida sensible al arousal, mostró mayor respuesta ante las caras queridas y las desagradables, diferenciándose ambas de las caras neutrales. En cuanto a los potenciales evocados se volvió a encontrar una mayor amplitud del componente P300 ante las caras queridas en comparación con el resto de categorías, y del LPP en comparación con las caras desconocidas. En resumen, los resultados de los tres estudios presentados en este capítulo evidencian que la visualización de caras de personas queridas provocan un patrón de cambios fisiológicos característico de un estado motivacional altamente positivo. Por otra parte, dichos efectos no pueden explicarse por una mayor familiaridad o un mayor nivel de arousal de las imágenes de caras de personas queridas.

1.8.2 Capítulo 2

En este capítulo se presentan de forma detallada y en mayor profundidad los resultados del estudio 3 resumido en el capítulo previo. El objetivo principal de este estudio fue comprobar la posible modulación del reflejo de sobresalto durante la visualización de caras de personas queridas en comparación con caras de desconocidos y caras desagradables. Además, se pretendía replicar los resultados obtenidos en estudios anteriores y ampliarlos a la población masculina. El paradigma de sobresalto es uno de los más utilizados en investigación psicofisológica con el fin de estudiar la implicación de los sistemas defensivo y apetitivo en diferentes emociones. En este capítulo se propone la hipótesis del posible vínculo entre la inhibición del sistema motivación defensivo y los efectos beneficiosos sobre la salud que conlleva el acceso a relaciones afectivas satisfactorias. El resultado más llamativo de este estudio es una clara inhibición del reflejo de sobresalto ante las caras de personas queridas. Este efecto no se ha encontrado ante otro tipo de rostros emocionales positivos (expresiones faciales de felicidad), y sólo se encuentra ante imágenes afectivas altamente activantes (eróticas). Por otro lado, se realizaron análisis para comprobar posibles diferencias de género en la modulación de las respuestas psicofisiológicas. Cabe resaltar las diferencias que se encontraron entre hombres y mujeres en la actividad del músculo cigomático siendo las mujeres más reactivas que los hombres en esta variable. En cuanto al control de la familiaridad que se realizó entre las fotografías de los padres (alta familiaridad) y la de la pareja (baja familiaridad) cabe resaltar que fue la cara de la pareja la que estuvo asociada con las mayores respuestas en conductancia eléctrica de la piel y actividad del músculo cigomático.

En conjunto, estos datos aportan evidencia acerca de la capacidad inhibidora de respuestas defensivas que poseen las caras familiares queridas, a la vez que señalan que tanto hombres como mujeres procesan de forma muy similar este tipo de estímulos.

1.8.3 Capítulo 3

En este capítulo presentamos los resultados de potenciales evocados y localización de fuentes cerebrales obtenidos en el estudio 3 previamente descrito. Los potenciales evocados han mostrado ser un método muy útil a la hora de determinar el patrón temporal de diferentes fenómenos cognitivos y emocionales. La información aportada a través de la latencia y amplitud de determinados componentes de la onda de potenciales ha señalado la existencia de un procesamiento secuencial en el reconocimiento facial que en un primer momento se encarga del análisis estructural del objeto visual y en etapas posteriores de la identificación y clasificación del rostro. Los componentes tardíos de los potenciales evocados (P300 y LPP) presentan una mayor amplitud ante estímulos familiares y ante estímulos pictóricos con contenido emocional. Esta modulación se ha interpretado en la mayoría de los casos como un aumento de la atención asignada a estímulos relevantes. Un estudio dirigido por Bobes y colaboradores encontró modulación del componente P3a (de latencia inferior al P3b y localización frontal) entre caras familiares que diferían en su contenido en información social y emocional. Las caras familiares provocaron un aumento del P3a en comparación con caras familiares aprendidas en laboratorio. Estos resultados llevaron a los investigadores a postular la hipótesis de que el P3a era reflejo del acceso rápido y automático a la información social y emocional presente en los rostros familiares.

Nuestros resultados encajan con la hipótesis planteada por Bobes y colaboradores, siendo las caras de personas queridas las que provocaron la mayor amplitud del P3a. A su vez, los análisis de fuentes sobre este componente mostraron que los generadores neurales de dicho componente se encontraban en áreas asociadas con el procesamiento de estímulos faciales familiares (corteza temporal inferior) y con el procesamiento de estímulos emocionales (cíngulo anterior y corteza orbito-frontal).

Este estudio aporta información muy novedosa referente a la modulación de los potenciales evocados a través de caras familiares queridas y sobre la localización del componente P3a en áreas asociadas con el procesamiento de la familiaridad y de estímulos gratificantes.

1.8.4 Capítulo 4

El estudio presentado en este capítulo utilizó tanto el paradigma de visualización pasiva de imágenes afectivas como el registro de la actividad hemodinámica cerebral durante la visualización de caras que diferían en familiaridad (familiares vs. desconocidas) y en valencia afectiva (caras agradables vs. desagradables). La manipulación de ambas variables dio lugar a cuatro categorías de caras: caras familiares queridas, caras familiares desagradables, caras desconocidas atractivas y caras desconocidas desagradables. El objetivo del estudio fue investigar la posible especificidad de los procesos emocionales asociados a la identidad a nivel periférico y central, y la posible modulación diferencial de la valencia afectiva (positiva y negativa) asociada tanto a la identidad como a características más perceptuales.

Los datos en tasa cardíaca, conductancia eléctrica de la piel y actividad de los músculos cigomático y corrugador vuelven a equipararse con los encontrados en nuestros estudios anteriores. A pesar de que las caras desconocidas utilizadas en este estudio también contenían información emocional (a través de la apariencia física) volvieron a ser las caras familiares las que provocaron mayores niveles de activación subjetiva y mayor respuesta en conductancia eléctrica de la piel. En consonancia también con resultados previos, fueron las caras queridas las únicas en provocar una activación del músculo cigomático. Los resultados de resonancia magnética mostraron cómo las caras familiares en comparación con las desconocidas, activaron una serie de estructuras cerebrales encargadas de procesar la familiaridad visual (giro fusiforme), de recuperar el conocimiento acerca de la persona (precuneus, cingulado posterior, corteza frontal) y de tratar la información emocional (ínsula, operculum). Las caras familiares queridas en comparación con las caras desconocidas atractivas activaron, además de las áreas mencionadas previamente, la corteza orbito-frontal medial. Este área ha sido propuesta como una de las estructuras sensibles al valor hedónico de los estímulos, mostrando activación ante caras consideradas como altamente atractivas en estudios previos. Por lo tanto, la activación de la corteza orbito-frontal medial puede ser un reflejo de las emociones placenteras asociadas con las personas queridas.

Chapter 2

Affective Processing of Loved Familiar Faces: Integrating central and peripheral electrophysiological measures[1]

2.1 Introduction

The face represents a key aspect of social and emotional communication. It conveys information on how you feel (facial expression) and who you are (personal identity). It also provides information on many other aspects relevant for social behavior, such as the gender, age, race, and attractiveness of individuals, as well as their friendly or hostile attitudes, intentions, and thoughts (Dekowska et al., 2008; Adolphs, 2009). Most studies on the psychology of face perception and recognition have focused on emotional facial expressions following the seminal work of Tomkins (1962), Izard (1971, 1977, 1994), and Ekman (1984, 1992), based on the evolutionary perspective outlined by Darwin in his book The expression of emotions in man and animals (1872).

In 1992, Ekman noted 9 relevant contributions of research on facial expressions to our understanding of emotion: (a) the universality of facial expressions; (b) the nature and nurture interaction in the expression of emotions; (c) the search for emotion-specific

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physiology; (d) identification of the specific events that precede emotions; (e) ontogeny of emotional development; (f) relevance of non-verbal communication in social interactions; (g) consideration of emotions (and emotional facial expressions) as families of emotions that share commonalities in their expression and physiology; (g) consideration of emotions as discrete rather than dimensional states; and (h) reduced number of emotions with distinctive universal facial expressions. Although at that time Ekman did mention the contributions made by a new generation of investigators who used facial expressions to the study of autonomic and central nervous system activity (Ekman, 1992, pag. 385), he could not anticipate the extraordinary growth of neurophysiological studies of face perception in the following two decades.

In this period, a large number of studies have used electrophysiological (EEG, ERP, MEG) and metabolic (PET, fMRI) techniques to understand the brain mechanisms of facial perception and recognition (see Adolphs, 2002; Faihall & Ishai, 2006; Dekowska et al., 2008; Li et al., 2010). Event-related potentials (ERP) and functional imaging techniques have proven especially useful in this context. A number of ERP components have been identified as reflecting successive steps in the processing of facial information: P1, N170, N200, P300, and N400. For the most part, these potentials have their source in temporal-parietal areas of the right hemisphere, with early components reflecting the processing of structural face configuration and identity recognition, and later ones indexing the retrieval of biographical and emotional information (Bruce & Young, 1986; Bentin et al., 1996). Imaging techniques, on their part, have helped to identify the specific brain areas involved in face perception and recognition, including recognition of emotional expression and personal identity (Adolph, 2002; Gobbini & Haxby, 2007; Zeki, 2007). These areas represent a distributed neural network with a core system integrated by cortical areas in the visual region (inferior occipital gyrus, lateral fusiform gyrus, and superior temporal sulcus) and an extended network that processes not only knowledge about the person (anterior temporal cortex, anterior paracingulate, and precuneus), but also the emotions associated with that person (amygdala, insula, and reward system).

In the context of this broad neuroscientific literature, a subset of recent studies have specifically examined the emotional processing associated with recognizing the faces of familiar loved ones (relatives, own children, or romantic partner) by using electrophysiological or fMRI indices of brain activity (Bartels & Zeki, 2000, 2004; Herzmann et al., 2004; Aron et al., 2005; Fisher et al., 2005; Bobes et al., 2007; Langeslag et al., 2007; BaÁar et al., 2008; Grasso et al., 2009). All these studies, however, disregarded Ekman's (1992) explicit suggestion and limited their scope to central nervous system activity, thus excluding autonomic and other peripheral physiological measures that could provide unambiguous evidence regarding the genuine positive emotional response evoked by familiar faces. And it is fundamental to note that two confounding factors are always merged in experimental designs that use only central physiological measures: emotional arousal and familiarity.

Functional imaging techniques used to investigate brain mechanisms of familiar and romantic love by viewing or discriminating loved faces (Bartels & Zeki, 2000, 2004; Aron et al., 2005; Fisher et al., 2005; Zeki, 2007) do not obviate the confounding problems we just mentioned. Previous studies did not record peripheral physiological indices that could unambiguously differentiate positive affect from emotional arousal and familiarity. Most of them relied solely on subjective reports, a method not absent of validity problems (see Podsakoff et al., 2003). Notably, some studies recorded skin conductance (Bartels & Zeki, 2000; Bobes et al., 2007), in line with classic studies on the recognition of familiar faces in patients with prosopagnosia (Ellis et al., 1979; Bauer, 1984; Tranel & Damasio, 1985; Hirstein & Ramachandran, 1997).

Research on people with impaired recognition of familiar faces, such as patients with prosopagnosia or Capgrass syndrome, has traditionally employed both central and peripheral physiological measures in order to differentiate the cognitive and emotional components involved in the recognition of face identity. People with prosopagnosia are unable to identify familiar faces, although they do recognize their voices and gestures. Capgrass syndrome is a psychiatric condition in which patients recognize familiar faces but believe that identical-looking impostors have replaced their relatives. In part to explain these deficits, some have proposed that the processing of face identity involves two parallel routes (see Breen et al., 2000): the cognitive route that allows conscious recognition of identity and enables access to semantic and episodic memory about the person, and the emotional route that permits covert recognition of identity by evoking affective responses.

In the context of these studies, the non-cognitive affective route has been investigated by means of peripheral indices of autonomic activity, particularly the skin conductance response, whereas the non-affective cognitive route has been investigated by means of electrophysiological indices of brain activity (Ellis et al., 1979; Bauer, 1984; Tranel & Damasio, 1985; Hirstein & Ramachandran, 1997; Ellis & Lewis, 2001; Brighetti et al., 2007; Dobel et al., 2008). However, there are two difficulties associated with the use of skin conductance as an index of emotional processing and of brain potentials as indices of cognitive processing. First, skin conductance cannot be equated with emotional processing, as it may also reflect cognitive processing, such as that inherent in the orienting response (Dawson, Schell, & Filion, 2007). Secondly, electrophysiological indices of brain activity do not solely reveal cognitive processing; some ERP components also indicate emotional processing, although, as in the case of skin conductance, without separating affective valence from emotional responses (Schupp et al., 2000, 2003, 2004).

Here, we summarize the main results from three studies aimed at unraveling the psychophysiological mechanisms underlying the processing of loved familiar faces while separating the relative contributions of affective valence, undifferentiated emotional arousal, and familiarity. All three studies combine the following elements: a) the use of an experimental paradigm capable of separating valence- and arousal-related effects: the picture viewing paradigm (Lang, 1995; Lang et al., 2000, 2006; Codispoti et al., 2001; Bradley & Lang, 2007), b) simultaneous recording of a broad set of peripheral and central measures, and c) sets of stimuli that differ in their valence, arousal, and familiarity ratings.

2.2 Emotional arousal versus valence effects

Emotional arousal refers to the intensity of an emotion regardless of its affective valence (whether positive or negative). The most consistent finding of ERP modulation during the processing of loved familiar faces is an increase in amplitude of late ERP positive components (P3 and Late Positive Potential or LPP) at posterior locations, which is elicited by loved faces compared to control familiar and unfamiliar faces. Interestingly, the same cortical potentials to loved familiar faces have been recorded in response to highly unpleasant pictures, such as mutilated faces or attacking animals, thus calling into question whether the larger late positivity evoked by loved faces indexes activation of positive emotional mechanisms or simply reflects emotional arousal activated by the faces (Palomba et al., 1997; Cuthbert et al., 2000; Schupp et al., 2000, 2004; Sabatinelli et al., 2007; Bradley, 2009).

The physiological differences between emotional valence and arousal have been extensively investigated in the context of Lang's picture-viewing paradigm and the motivational priming hypothesis (Lang, 1995; Lang et al., 2000, 2006; Codispoti et al., 2001; Bradley & Lang, 2007). In Lang's paradigm, the modulation of peripheral and central physiological measures is simultaneously examined during the passive viewing of pleasant, neutral, and unpleasant pictures selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008), an instrument that provides normative values of subjective valence, arousal, and dominance for each picture. Using this paradigm, valence and arousal can be unambiguously differentiated by distinct sets of physiological responses: one that reliably measures positive versus negative valence (eyeblink startle, heart rate, and zygomatic/corrugator electromyography) and a second one that reliably measures emotional arousal (skin conductance, P3, and Late Positive Potential).

Highly arousing pleasant pictures are associated with: (a) reduced startle responses, (b) a pattern of accelerative changes in heart rate, (c) increases in zygomatic major activity, and (d) decreases in corrugator supercilious activity. The opposite response pattern is associated with highly arousing unpleasant pictures. The different modulation of the startle reflex when people are viewing pleasant and unpleasant pictures is explained by Lang and colleagues as due to the congruence versus incongruence between the motivational system engaged by the pictures and the type of reflex being elicited (motivational priming hypothesis): unpleasant stimuli that engage the aversive motivational system potentiate defensive reflexes, whereas pleasant stimuli that engage the appetitive motivational system inhibit them (Lang & Davis, 2006). In addition, highly arousing pleasant and unpleasant pictures, when compared to low arousing neutral pictures, produce: (a) larger skin conductance responses, and (b) higher amplitudes of the P3 and Late Positive Potential recorded from central and parietal locations (Bradely et al., 2001; Lang & Bradley, 2010). If these ERP components or the skin conductance response were to be taken by themselves, no conclusion could be reached concerning the valence of the elicited emotional response, since both electrophysiological measures exclusively reflect undifferentiated emotional arousal.

Therefore, the central electrophysiological responses reported in studies on loved familiar faces confound valence and arousal, not being able to differentiate positive from negative affect. Such a differentiation requires the use of physiological indices from the two sets of measures indicated above. This was the specific aim of the three studies (Vico et al., 2010; Campagnoli et al., 2009, 2011; Sanchez et al., 2010, 2011) that we summarize here, undertaken by investigators from the Human Psychophysiology Laboratory at the University of Granada.

In the study by Vico et al. (2010), participants passively viewed 5 pictures of loved familiar faces (romantic partner, parents, siblings, second-degree relatives, and friends) interspersed with 5 pictures of four different face categories: famous faces from the media, unknown faces from sets of familiar faces of other participants, babies from de IAPS, and neutral faces from the Ekman and Friesen series (1978). Pictures were presented in black and white and with no emotional expression. Two viewing rates, in two different blocks, were used: a slow presentation rate to facilitate the recording of peripheral measures (4-s picture presentation with an inter-trial interval of 16-20 s) and a fast presentation rate to facilitate the recording of ERP measures (0.5-s picture presentations with an inter-trial interval of 1.1-1.2 s). When the presentation rate was slow, each face was seen twice following a double Latin-square (5x5) procedure (counterbalanced across participants to control for order of picture presentation), making a total of 50 trials. When the presentation rate was fast, each face was seen 8 times in random order, totaling 200 trials. Order of presentation rate blocks was counterbalanced across participants. After the second block, participants again viewed the pictures and reported their subjective feelings (valence, arousal, and dominance) using the Self-Assessment Manikin (Bradley & Lang, 1994).

As shown in Figure 1, peripheral responses to loved faces, compared to famous, unknown, baby, and neutral faces, were obtained both when the slow block was presented first and when it was presented second. Thus, despite the evident habituation effect in skin conductance and zygomatic activity, larger responses to loved faces are maintained. Interestingly, the heart rate response to loved faces did not show habituation when the slow block was presented second. Figure 2 displays central physiological responses. As in the case of heart rate, no habituation was observed. Both P300 and LPP amplitudes revealed significant differences between faces of loved ones and all other face categories, irrespective of presentation rate.

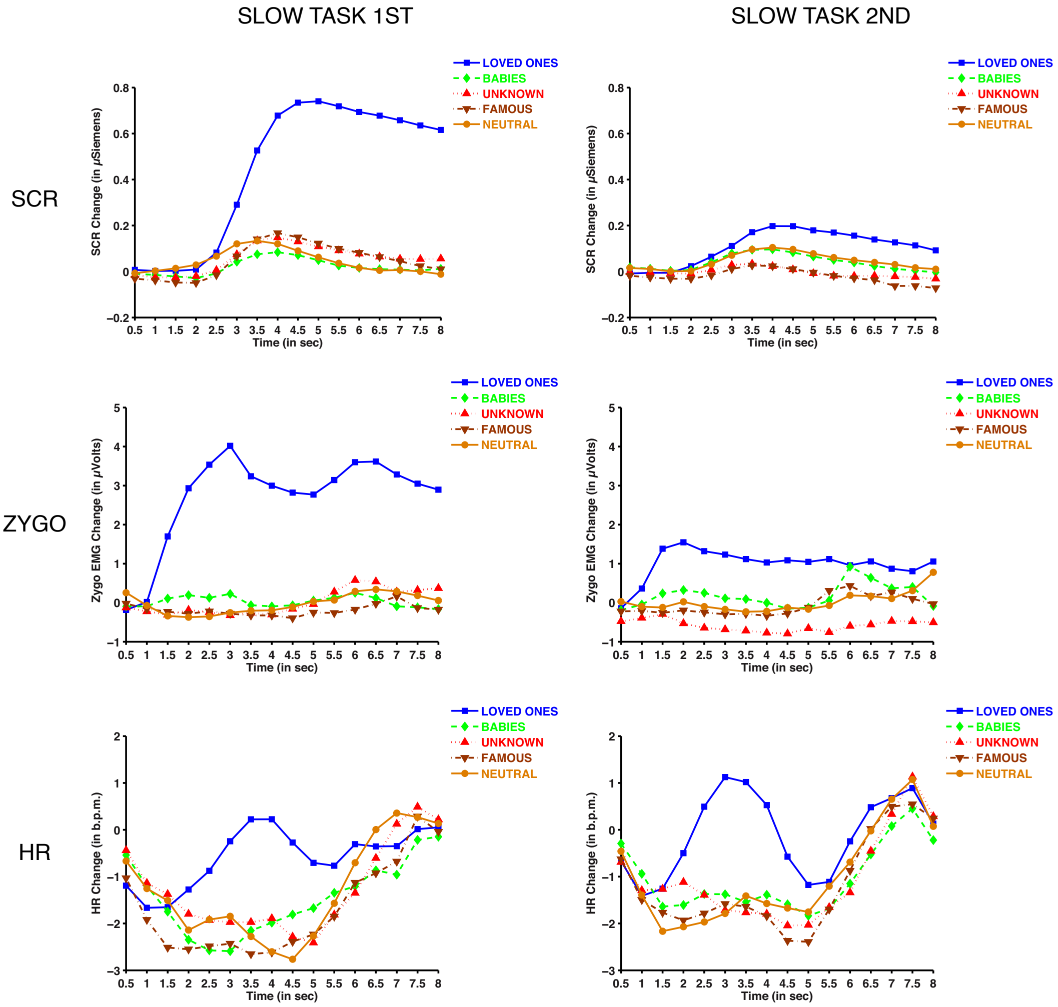

Figure 2.1: Skin conductance (top row), zygomatic activity (middle row), and heart rate (bottom row) as a function of Face Category (loved, babies, neutral, famous, and unknown) in the slow task presented first (left column) and presented second (right column) (from Vico et al., 2010). Skin-conductance waveforms depict the response to all face categories starting around 2.5 s after picture presentation. When the slow task was administered in the first place (left panel, top row), only loved faces prompted a significant increase in skin conductance compared to all other face categories. A clear habituation effect in skin conductance was observed when the slow task was performed in second place (right panel, top row). For zygomatic activity, only the faces of loved ones elicited a clear response, starting almost immediately after picture presentation and continuing until the end of the 8-s period (left panel, middle row). A clear habituation effect was also observed when the slow task was presented in the second place (right panel, middle row), affecting all picture categories. Finally, in terms of heart rate, only the response evoked by the loved faces showed a triphasic change. This effect was independent of whether the slow task was administered in first or second place.

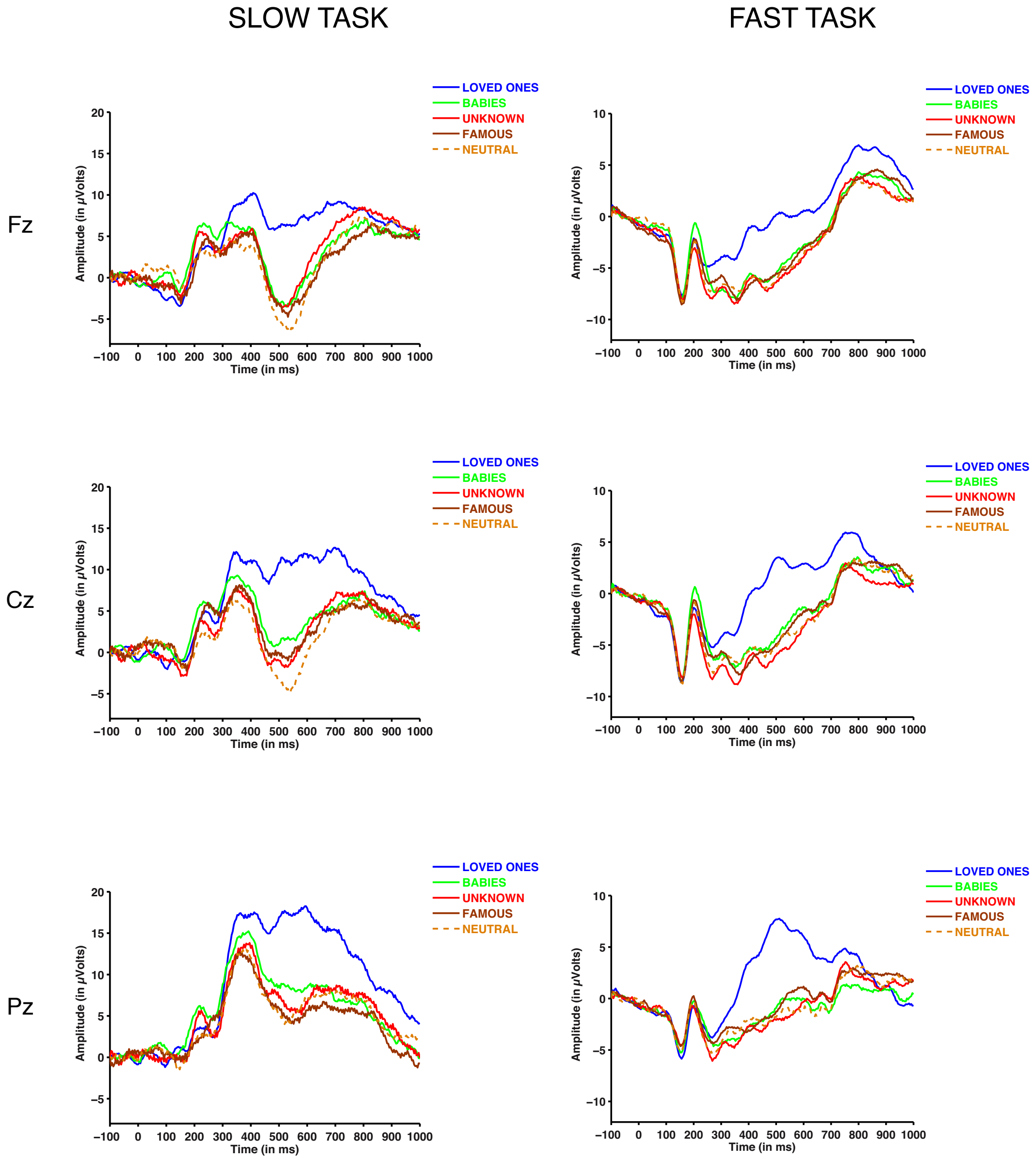

Figure 2.2: Event-related potentials (ERPs) at Fz (top row), Cz (middle row), and Pz (bottom row) as a function of Face Category (loved, babies, neutral, famous, and unknown) in the slow task when it was presented first (left column) and when it was presented second (right column) (from Vico et al., 2010). Both P300 and LPP clearly differentiated loved faces from all other categories, regardless of task type: slow (left panel) or fast (right panel).

Using a similar paradigm, Campagnoli et al. (2009, 2011) explored physiological responses to loved familiar, unknown, and baby faces in a design that controlled appropriately the degree of familiarity among the different pictures. Female participants passively viewed black and white pictures of their boyfriend, father, control-boyfriend (unknown boyfriend of other participant), control-father (unknown father of other participant), and baby. There were two reasons to include the baby picture in this study. First, as in the previous study, to control for pleasantness induced by the picture itself, rather than by recognition of the face, since baby pictures are the type of IAPS picture evaluated by women as the highest in inducing pleasant feelings. And second, to control for potential effects of differences in frequency and salience of the pictures (oddball and von Restorff effects), since the less frequent (oddball effect) and most physically salient (von Restorff effect) stimulus in the present study was the baby picture.

Each picture was presented 20 times, yielding a total of 100 trials with the following structure per trial: 4-s baseline, 4-s picture presentation, and 4-s post-picture period. The picture sets were arranged in five different sequences to control for potential order effects. Peripheral responses to the pictures confirmed the findings obtained by Vico et al. (2010). As it can be observed in Figure 3, loved familiar faces elicited larger responses in skin conductance and zygomatic activity compared to both unknown and baby faces. Regarding heart rate, both loved and baby faces evoked larger responses compared to unknown faces. No significant differences were found between baby and loved categories. Significant effects between picture categories were also found for three components of the ERP waveform (see Figure 4): N200 amplitude was smaller and P300 and LPP amplitudes were larger for loved faces, compared to both unknown and baby faces.

Finally, in a third study by Sánchez et al. (2010, 2011), male and female participants viewed faces belonging to one of three different categories: loved ones (romantic partner, father, mother, and best friend), unknown (pictures of another participant's loved ones), and unpleasant (four mutilated faces from the IAPS), adding the startle probe to the picture viewing paradigm (Lang, 1995). The task started with a 5-minute baseline period, followed by 72 trials with the following structure per trial: 4-s baseline, 6-s picture presentation, and 4-s post-picture interval. Two-thirds of the pictures (48) were presented together with a startle probe (a burst of white noise at 105 dB, 50-ms duration, and nearly instantaneous rise time) at either 4, 4.5, 5 or 5.5 s after picture

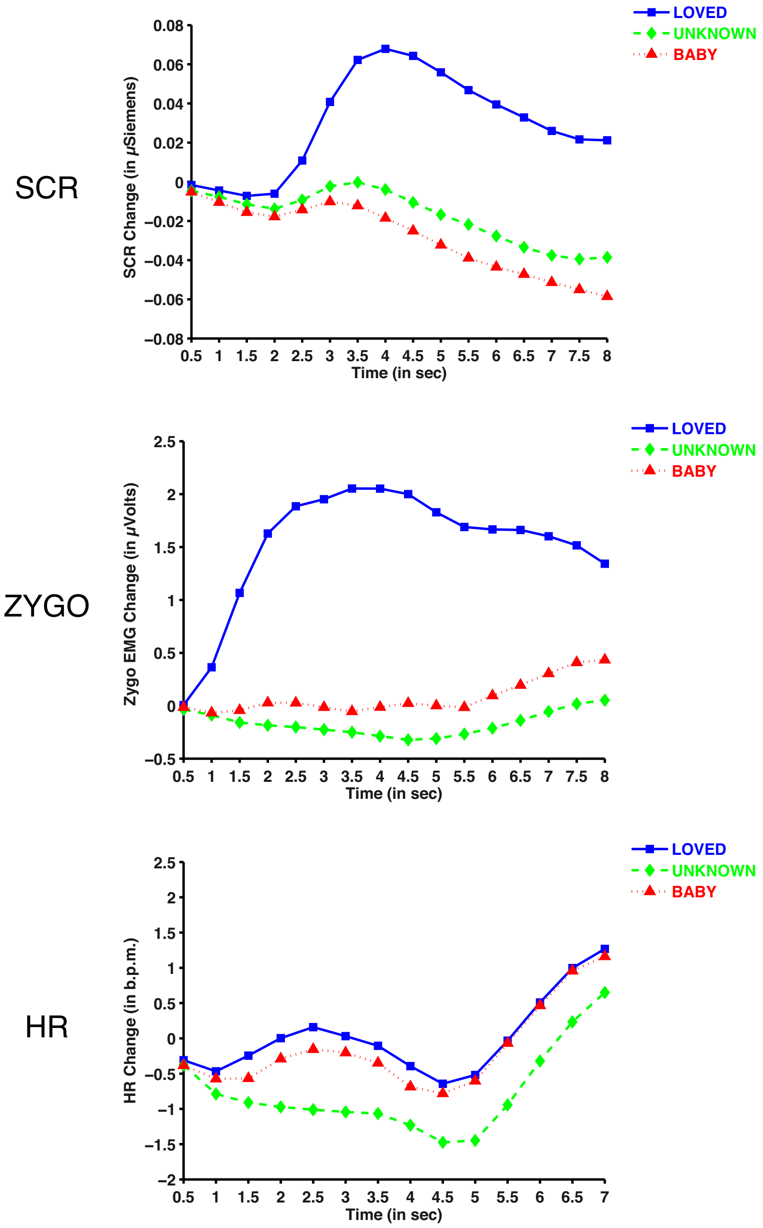

Figure 2.3: Skin conductance (top row), zygomatic activity (middle row), and heart rate (bottom row) as a function of Face Category (loved ones, unknown, and baby faces) (from Campagnoli et al., 2009, Guerra et al., 2011). Confirming the findings by Vico et al. (2010), skin conductance responses were evoked by all face categories starting at about 2.5 s after picture onset, with significantly larger responses to loved faces (top row). The middle row depicts the increased zygomatic activity evoked by loved faces when compared to unknown or baby faces. Finally, heart rate responses showed a triphasic change in response to both loved and baby faces, and a sustained deceleration (until second 5 after picture onset) in response to unknown faces.

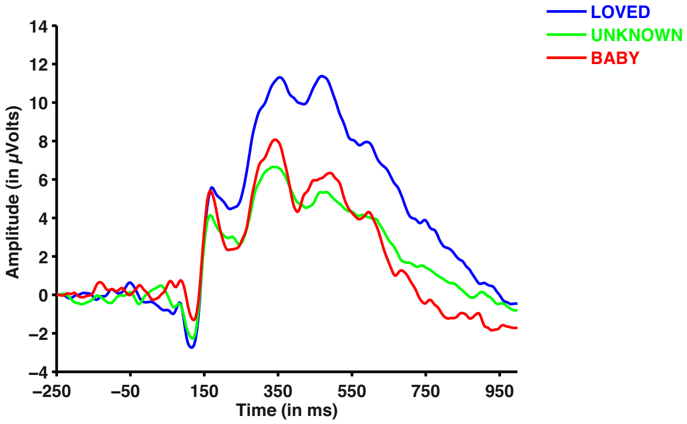

Figure 2.4: Event-related potentials (ERPs) at Pz as a function of Face Category (loved ones, unknown, and baby faces) (from Campagnoli et al., 2009, Guerra et al., 2011). Reduced N200 amplitude and increased P300 and LPP amplitudes clearly differentiated faces of loved ones from all other categories.

onset. Results confirmed the findings of the two first studies: loved familiar faces elicited larger autonomic (heart rate), somatic (zygomatic activity) and central (frontal P3) responses than either neutral or unpleasant faces. No differences were found in skin conductance or the LPP component between loved familiar and unpleasant faces. Importantly, a clear inhibition of the startle reflex was observed for loved familiar faces compared to both neutral and unpleasant faces, the latter exhibiting an augmentation of the startle reflex compared to both neutral and loved faces. These findings, which are in complete agreement with Langs' motivational priming hypothesis, clearly indicate that loved familiar faces elicit an intense positive emotional response (positive valence + arousal) that cannot be accounted for exclusively by undifferentiated arousal.

2.3 The familiarity issue

In the context of research on recognition of familiar faces, familiarity has been defined as a form of explicit or declarative memory (Voss & Paller, 2006, 2007; Gobbini & Haxby, 2007). This type of memory involves the ability to recollect events and factual knowledge (Eichenbaum, 2000). Thus, the familiarity of a familiar face refers to the amount of factual knowledge about the person behind the face, which depends on many factors, including length of time spent with the person, number of previous encounters, duration of the relationship, or information accumulated about the person. This type of familiarity is different from the so-called pure familiarity, understood as recognition that is unsubstantiated by episodic recall (Paller, Voss, & Boehm, 2007). The metric and control of familiarity in studies on the identification or processing of loved familiar faces have been particularly difficult. Attempts to control for familiarity include viewing faces of acquaintances, famous people, friends, or newly learned faces. But familiarity of loved people will always exceed that of control faces because of the greater amount of time spent with them (Grasso et al., 2009).

ERP studies on familiarity of faces have reported enhancement of the late positivities found at posterior locations (Eimer, 2000; Yovel & Paller, 2004; Voss & Paller, 2006). Voss and Paller (2006), for instance, found that explicit memory retrieval for celebrity faces was associated with enhancement of those positive potentials, which have also been reported in studies of loved familiar faces (Herzmann et al., 2004; Bobes et al., 2007; Langeslag et al., 2007; Grasso et al., 2009). And precisely those same potentials have been recorded as well in studies using Lang's picture-viewing paradigm with highly pleasant and unpleasant pictures, as mentioned above.

Though difficult to tease apart, emotional arousal and familiarity are not inevitably confounded. As mentioned above, in studies using the picture-viewing paradigm with pleasant, neutral, and unpleasant pictures from the IAPS, the enhanced late positivity found at posterior locations has been interpreted in terms of undifferentiated emotional arousal, rather than familiarity, since all pictures are new and there is no explicit memory involvement. In studies on loved familiar faces, however, face familiarity is necessarily confounded with emotional arousal, since both explicit memory and emotion are involved in their processing. Thus, the larger ERP responses elicited by loved familiar faces cannot be unambiguously interpreted in terms of emotional processing.

In the study by Vico et al. (2010), familiarity of the faces was indirectly controlled by comparing loved faces with famous faces, and loved faces with different levels of familiarity (parents, siblings, romantic partner, and friends) among themselves. Famous faces produced much smaller responses than loved faces, as shown in Figures 1 and 2. When subcategories of loved faces were examined, differences in terms of level of familiarity also appeared in skin conductance, zygomatic activity, and arousal ratings. In these three measures, the face of the partner produced more prominent responses than the faces of parents, siblings, and friends. Thus, the less familiar face in terms of time of acquaintance (i.e., the romantic partner) elicited a greater skin conductance and zygomatic response than the faces of parents or siblings (which were presumably more familiar than the partner) or friends (which were probably about as familiar or less than the partner). Furthermore, these larger psychophysiological responses were accompanied by higher subjective reports of emotional arousal (see Figure 3).

These findings suggest that familiarity is not the major contributing factor in determining the substantial central and peripheral physiological responses evoked by loved faces in Vico et al. (2010). Rather, the intense positive emotional response (valence + arousal) elicited by loved faces seems to be the key factor. And yet, as mentioned before, the level of familiarity of loved and famous faces are not comparable and, regrettably, Vico et al. did not equate subcategories of familiar faces (parents, siblings, second-degree-relatives, and friends) in number or order of presentation. In fact, of the 30 participants, 15 included both parents among the 5 loved faces; 6 included only the mother; one included only the father; and 8 did not include any parent. Similar uneven numbers were associated with siblings, second-degree relatives, and friends. Similarly, given the reduced number of trials per subcategory (two in the slow presentation block and 8 in the fast presentation block), the familiarity analysis could not be conducted for the ERP measures.

In the study by Campagnoli et al. (2010, 2011), the face of the romantic partner (boyfriend) was compared with the face of the father, as well as with control unknown faces (partner and father of other participants) and baby faces selected from the IAPS. Participants were students who had lived in the family home with their father at least until they were 18 years old. In contrast, their relationship with their romantic partner could not exceed a period of 6 years. Therefore, two categories of loved familiar faces, differing in amount of familiarity, were compared. Their results replicated those of Vico et al. (2010) regarding loved faces versus unknown and baby faces. They also replicated the familiarity effect. Larger peripheral responses (zygomatic activity) were evoked by the less familiar face (i.e., the romantic partner) than to the more familiar face (i.e., the father), and those were accompanied by higher levels of subjective arousal. In contrast, P3 at frontal and central location was larger for the more familiar face (the father) than the less familiar face (the romantic partner). The heart rate and the LPP, however, did not distinguish between the faces of partner and father.

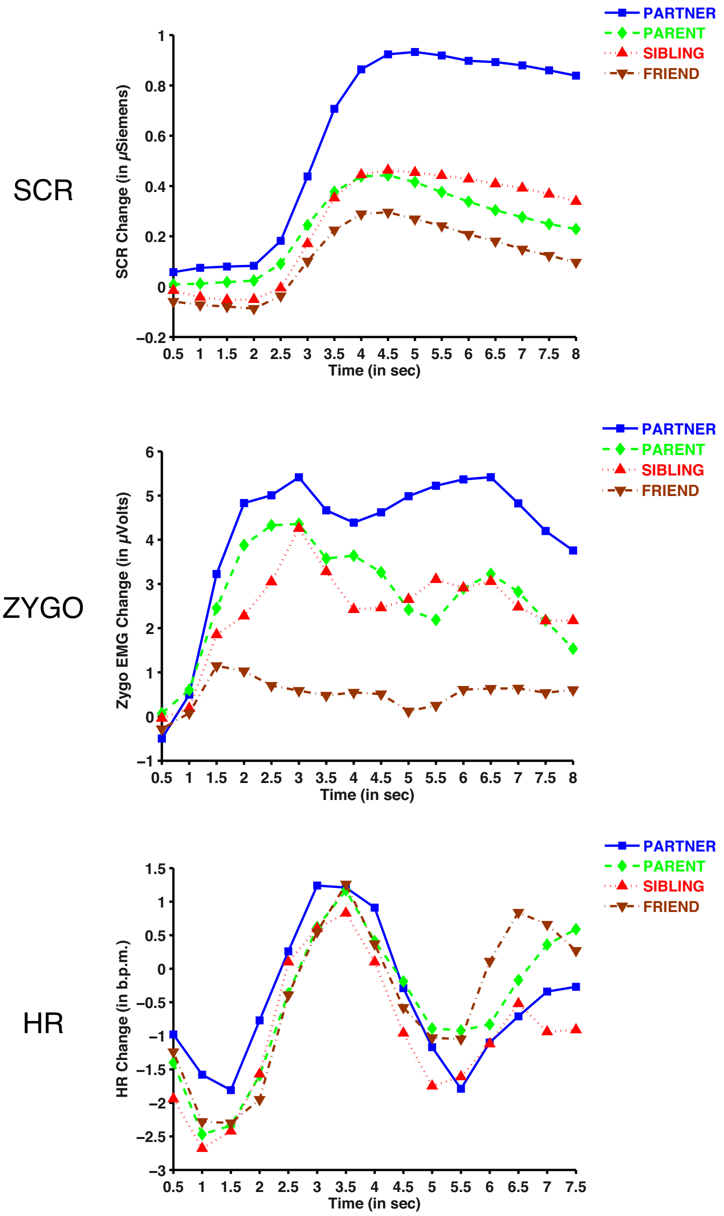

Figure 2.5: Skin conductance (top), zygomatic activity (middle), and heart rate (bottom) as a function of Subcategory of loved faces (partner, parent, sibling, and friend) (from Vico et al., 2010). It can be readily observed in both skin conductance (top row) and zygomatic activity (middle row) that the less familiar face (i.e., the partner's) tends to elicit larger responses when compared to the faces of parents, siblings, and friends. This tendency is not apparent in the heart-rate data (bottom row).

A similar pattern of results was found in the study by Sanchez et al. (2010, 2011) when female participants were viewing loved familiar faces with various levels of familiarity (romantic partner, father, mother, and best friend). Confirming previous findings, larger skin conductance and zygomatic activity responses were associated with the face of the romantic partner when compared to all other loved familiar faces. However, as in the two previous studies, no differences were found in heart rate response among any of the loved faces.

2.4 The dominance scale

In the picture-viewing paradigm, the dominance scale has received less attention than the valence and arousal scales (see Bradley & Lang, 2007). The dominance scale differentiates between feeling dominant, represented in the SAM by a large figure or manikin, and feeling dominated, represented by a much smaller figure. In general, dominance ratings tend to show a positive correlation with valence ratings; that is, the more pleasant a feeling, the more dominant the individual tends to feel. In the study by Vico et al. (2010), however, the ratings of valence and dominance obtained when viewing loved faces were negatively correlated, thus contrasting with the expected positive correlation found between them when viewing baby faces. Negative correlations between valence and dominance have also been reported in the context of research on addictions and eating disorders (RodrÌguez et al., 2005, 2007; MuÒoz et al., 2009). In these latter contexts, the negative correlation between valence and dominance ratings is easily interpreted in terms of loss of control (i.e., the more pleasant your feeling when viewing drug and food-related pictures, the less control you feel over those substances). In the context of viewing loved adult faces and baby faces, the corresponding negative and positive correlations can also be easily interpreted in terms of protection or care (i.e., feeling protective or giving care versus feeling protected or receiving care). If so, viewing baby faces would induce feelings of positive affect and of offering protection, whereas viewing loved adult faces would induce feelings of positive affect and of receiving protection.

However, in our two subsequent studies (Campagnoli et al., 2009; S·nchez et al., 2010) a difference was also detected in the dominance scale concerning the less familiar face (the romantic partner) and the more familiar face (the father or mother). In those studies, female participants rated their feelings as more dominant when viewing the face of the romantic partner than when viewing the face of the father or mother. In this case, the dominance scale might be interpreted in terms of both protection and control: viewing the face of the father or mother would induce a positive feeling accompanied by a feeling of receiving protection or being controlled (feeling small), whereas viewing the loved face of the romantic partner would induce a feeling of giving protection or being in control (feeling big).

2.5 An integrative perspective

The consistency of the above findings highlights the value of simultaneously recording central and peripheral physiological measures, in addition to subjective indices of valence, arousal, and dominance, in order to unravel the complex mechanisms underlying the affective processing of loved familiar faces. Such mechanisms are reflected in a rich pattern of neurophysiological responses that a single type of physiological measure, be it central (ERP, fMRI) or peripheral (skin conductance), would fail to capture accurately. The present approach, based on the picture-viewing paradigm, facilitates a comprehensive look at those complex mechanisms.

From the subjective point of view, the faces of loved people induce strong feelings of positive affect and emotional arousal, together with feelings of being protected (if the faces are of adult familiar loved ones) or giving protection (if the faces are of the romantic partner or babies).

The peripheral physiology presented in this paper demonstrates that loved familiar faces elicit a pattern of autonomic (heart rate) and somatic (zygomatic activity and eye-blink startle) responses specifically associated with positive emotions (increases in heart rate and zygomatic activity, paired with startle reflex inhibition). In addition, loved familiar faces also elicit a strong sympathetic response (skin conductance), indicative of increased emotional arousal.

Central physiology, on the other hand, reveals that various components of the ERP waveform (N200, P3, and LPP) clearly differentiate loved faces from all other face categories (i.e., famous faces, unknown faces, babies, and neutral faces). These components provide new insights on the temporal pattern of cognitive processes underlying the emotional processing of loved familiar faces. N200 was the first ERP component modulated by loved faces, and it was reduced in amplitude when participants were viewing the loved faces, thus confirming previous reports of N200 amplitude reductions when mothers viewed pictures of their own children (Grasso et al., 2009). Although the N200 has been interpreted in many different ways, a widely accepted interpretation is in terms of action inhibition (Folstein & Petten, 2008; Grasso et al., 2009). If so, our data would suggest that, when a face is recognized as that of a loved person, either the action inhibition is suppressed or an opposite action disposition is activated presumably to facilitate approach behaviors. N200 reduction was followed by a P3 increase to loved faces. P3 has been considered as an index of perceptual discrimination leading to top-down attention allocation for memory updating (Polich, 2007). Here, the increase in P3 amplitude could be interpreted as a sign of greater attentional allocation to the more familiar face. The LPP, the subsequent ERP component modulated by loved faces, appears to reflect both motivational engagement (Schupp et al., 2004; Bradley, 2009) and explicit memory (Voss & Paller, 2006, 2007). Therefore, the enhancement of LPP amplitude evoked by loved faces could be interpreted as the combined mobilization of motivational and attentional resources towards the most familiar and emotionally laden faces.

The neural structures underlying this complex set of subjective and physiological responses have been recently investigated using neuroimaging techniques. Lang and colleagues (see Lang and Bradley, 2010, for a review) used ERP dipole source analysis and fMRI to identify the brain structures that underlie the Late Positive Potential of the ERP when subjects view pleasant and unpleasant pictures. They found enhanced activation for both types of emotional pictures, compared to neutral ones, in occipital and parietal regions involved in secondary visual processing, as well as in the amygdala and inferotemporal cortex (Sabatinelli et al., 2005, 2007a, 2007b). Given the large amplitude and sustained duration of this late positivity, Lang and Bradley postulate that the greater activation in these regions is attributable to re-entrant projections to the sensory system from the brain's motivational circuits, namely from the central nucleus of the amygdala. Amygdala activation also prompts activation of the sympathetic nervous system via projections to the lateral hypothalamus, which mediates pupil dilation and skin conductance responses, among others, indexing emotional arousal for both appetitive and aversive stimuli (Lang and Bradley, 2010).

Investigations on the specific brain structures that underlie positive emotions have also been reported using ERP source analysis and fMRI techniques. Bartels and Zeki (2000, 2004) were the first to show BOLD activation in specific brain regions of the reward system (i.e., anterior cingulate, medial insula) when mothers viewed facial pictures of their own children or people viewed pictures of their romantic partner, compared to pictures of familiar children or familiar adults. Similar findings concerning activation in regions of the reward system (ventral tegmental area, dorsal striatum, caudate) have been recently reported in people at the early-stage (Xu et al., 2011) and late-stage (Acevedo et al., 2011) of their romantic relationship when viewing faces of their loved partner. Using the picture viewing paradigm, Lang and colleagues (Sabatinelli et al., 2007a) have also examined BOLD responses when participants were viewing pleasant (erotic, romantic couples), neutral (unexpressive people), and unpleasant (mutilated bodies, dental operation, threatening people) pictures. Only the pleasant pictures activated the medial prefrontal cortex and the nucleus accumbens, consistent with the view that these structures are implicated in the reward system. Finally, Bobes and colleagues investigated ERP generators and BOLD responses to emotionally laden familiar faces, compared to unfamiliar and artificially-learned faces (Bobes et al., 2007, 2010; ValdÈs-Sosa et al., 2009). They found a specific frontal P3 component evoked by emotionally laden familiar faces with generators in medial orbitofrontal cortex, rectus, insula, and anterior cingulate. BOLD responses to the same type of faces confirmed the implication of medial orbitofrontal cortex and anterior cingulate in the processing of emotionally laden familiar faces.

2.6 Conclusions

The present approach to the study of the affective processing of loved familiar faces adds peripheral circuitry to the central neural networks involved in the processing of face identity. The integration of central and peripheral measures seems crucial to disentangle the separate contributions of affective valence, emotional arousal, and familiarity, as well as to provide a comprehensive understanding of the complex mechanisms underlying love. The functional significance of these complex mechanisms, as Bartels and Zeki (2004) indicated, is the maintenance and perpetuation of the species, ensuring the formation of firm bonds between individuals.

Perhaps most noteworthy in the three studies summarized here is the consistency of the results, delineating a coherent pattern of physiological responses that allows us to conclude that viewing pictures of loved familiar faces elicits an intense positive emotional reaction that cannot be explained either by undifferentiated emotional arousal or familiarity. It is evident, however, that emotional arousal and familiarity are also involved in the processing of loved familiar faces. In fact, the positive emotional response occurs when the appetitive motivational/emotional system is activated after the facial cue has been perceptually processed and recognized, giving access to the biographic and episodic memory about the person (Gobbini & Haxby, 2007; Lang & Bradley, 2010). Thus, familiarity is a necessary, although not sufficient, condition for the emotional response to take place. If the face is identified as that of a loved one, then the cortical and subcortical areas involved in emotional processing are also activated eliciting the peripheral autonomic and somatic responses. These responses contribute to both the intensity (arousal) and direction (positive valence) of the emotional response, providing simultaneous feedback to the central circuits to facilitate further cognitive processing and attention to the loved faces.

Several clinical implications can be drawn from the data presented here. First, clinical assessment of people with deficits in recognition of familiar faces, such as patients with prosopagnosia or Capgrass syndrome, might benefit from the picture viewing methodology and the use of joint central and peripheral electrophysiology to objectively confirm their presumed emotional or cognitive deficit in face recognition. Second, the capacity of viewing loved familiar faces to inhibit defensive reactions, such as the startle reflex, provides a potential explanation for the reported benefits of close and supportive relationships in protecting against physical and mental illnesses. And third, given the magnitude of the physiological changes observed in our three studies, viewing photographs of loved familiar faces might be used as an additional intervention to increase the effectiveness of standard treatments for stress management and anxiety disorders.

Chapter 3

Viewing Loved Faces Inhibits Defense Reactions: A Health-promotion Mechanism?[1]

3.1 Introduction

Over the last several decades, evidence has accumulated on the fundamental role that social factors play in brain organization and function (Cacioppo, Berntson, Sheridan and McClintock, 2000; Amodio and Frith, 2006), as well as in preserving physical and mental health (Reblin and Uchino, 2008; Xu and Roberts, 2010). For humans, survival depends on effective social functioning. Care giving and attachment, the two key elements of love (Mikulincer and Goodman, 2006), are essential not only for survival during infancy and childhood, but also for physical and psychological wellbeing across the life span (Taylor, 2010). Social support, defined as receiving information that one is loved, valued, and part of a social network, has been known for decades to be associated with reduced morbidity and mortality rates (Taylor, 2010, Berkman and Syme, 1979). Recent neuroscience research on social support has examined the effects of both positive and negative aspects of social environments on genetic expression, physiological functioning, and brain activity.

Regarding genetic expression, it has been reported, for instance, that a loving and caring family reverses the expected negative effects of the short/short polymorphism in

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the serotonin transporter gene (5-HTTLPR), which is associated with depression and other forms of psychopathology (Way and Taylor, 2010). In terms of physiological functioning, it has been found that the presence of a loved person during the preparation for an acute stress task (the Trier Social Stress Test) reduces activity in the hypothalamic pituitary-adrenal axis (cortisol) during the task (Heinrichs et al., 2003). This effect was enhanced by intranasal oxytocin administration, the neuropeptide implicated in both parent-child bonding and prosocial behaviors (Young and Wang, 2004). With regard to brain activity, the conditions of perceived social isolation (Cacioppo, Norris, Decety, Monteleone and Nusbaum, 2009) and social exclusion (MacDonald and Leary, 2005) characterized by lack of support have been found to be associated with both reduced activation in brain reward areas and increased activation in areas involved in the defense system.

The link between social support and positive health outcomes is likely to depend on the neurophysiological regulatory mechanisms underlying reward and defense reactions. Some researchers have argued (Krantz and McCeney, 2002) that unsupportive social environments, especially those that lead to social exclusion, play the role of threatening cues that activate both the defense motivational system and the broad spectrum of stress responses known to adversely impact an organism's physical and mental health (Krantz and McCeney, 2002). Loving environments may play the opposite role, providing safety cues that simultaneously activate the appetitive reward system and inhibit defense reactions. To support this idea, a recent study (Eisenberger, Master, Inagaki, Taylor, Shirinyan, Lieberman and Naliboff, 2011) has shown that female participants rated painful stimulation as less painful when viewing the picture of a romantic partner, compared to the picture of a stranger. They also displayed reduced neural activation in pain-related regions and increased activation in safety signal-related regions. However, to date no study has directly examined the capacity of loved faces for inhibiting defense reactions. Here, we set out to confirm this hypothesis by means of the startle probe paradigm.

The startle probe paradigm is one of the strongest and most recent paradigms developed to study the neurophysiological mechanisms of appetitive and defense reactions, as well as their reciprocal inhibitory function (Lang, 1995). In this paradigm, the modulation of the eye-blink startle reflex elicited by a noise burst, together with other peripheral (heart rate, skin conductance, zygomatic major muscle activity, and corrugator supercilii muscle activity) and central (event-related potentials) physiological responses, is examined while participants view pleasant, neutral, and unpleasant pictures selected from the International Affective Picture System (IAPS). Using this paradigm, Lang and his colleagues (Lang, 1995) have consistently demonstrated that the magnitude of the eye-blink response to the noise burst is augmented when people are viewing highly unpleasant pictures and diminished when viewing highly pleasant ones. They explain this modulation as due to the congruence versus incongruence between the motivational system engaged by the perceptual stimuli and the type of reflex that is being elicited (motivational priming hypothesis). Thus, unpleasant stimuli that engage the defense motivational system potentiate defense reflexes, while pleasant stimuli that engage the appetitive motivational system inhibit those same defense reflexes.

The startle probe paradigm has never been used to investigate the neurophysiological mechanisms of love. This paradigm has two basic elements: the passive viewing of pictures and the elicitation of the eye-blink startle reflex. Interestingly, a number of recent studies have used a modification of the picture viewing procedure by substituting pleasant pictures with photographs of loved, familiar faces (Bartels and Zeki, 2000, 2004; Herzmann, Schweinberger, Sommer and Jentzsch, 2004; Aron, Fisher, Mashek, Strong, Li and Brown, 2005; Fisher, Aron and Brown, 2005; Bobes, Quiñonez, Perez, Leon, Valdés-Sosa, 2007; Langeslag, Hansma, Franken and Strien, 2007; Grasso, Moser, Dozier and Simons, 2009; Xu, Aron, Brown, Cao, Feng and Weng, 2011) . However, none of these studies recorded eye-blink startle or other peripheral physiological measures that might confirm elicitation of a genuine positive emotional response to the faces. Almost all these studies restricted the physiological measures to central indices of brain activity (ERP and fMRI). A major problem in these studies is the absence of clear evidence concerning elicitation of such a positive emotional response. Two confounding factors are always merged in emotional studies that exclusively use central physiological measures: emotional arousal and familiarity. Emotional arousal refers to the intensity of an emotion, regardless of its affective valence (whether positive or negative). The same electrophysiological brain responses to loved familiar faces (i.e., larger P3 and Late Positivity Potentials) have been found in response to highly unpleasant pictures (Schupp, Cuthbert, Bradley, Cacioppo, Ito andLang, 2000; Bradley and Lang, 2007), thus calling into question whether the larger ERPs evoked by loved faces are indicative of positive emotional mechanisms or simply reflect undifferentiated emotional arousal.

Familiarity refers to a form of explicit or declarative memory (Eimer, 2000). This type of memory involves the ability to recollect events and factual knowledge about a person, which depends on many factors, including length of time spent with the person. Studies on explicit facial memory (Yovel and Paller, 2004, 2006) have consistently reported that larger P3 and Late Positive Potential amplitudes at posterior locations are associated with familiarity. Attempts to control for familiarity in studies on loved familiar faces include viewing faces of acquaintances, famous people, or newly learned faces. But the familiarity of loved familiar people will always exceed that of control faces because of the greater amount of time spent with them (Grasso et al., 2009). Thus, the most consistent finding in terms of cortical brain potentials to loved familiar faces—i. e., larger P3 amplitudes and Late Positive Potentials- cannot be attributed to positive emotional responses because similar enhanced brain responses are consistently associated with both undifferentiated emotional arousal and explicit facial memory.

The startle probe paradigm goes beyond elucidating the inhibitory capacity that viewing loved faces has on the startle reflex by including simultaneous recording of peripheral neurophysiological measures, together with subjective reports, that allow unambiguous differentiation between positive emotion, arousal, and familiarity. In addition to reduced startle responses, highly arousing pleasant pictures are associated with a pattern of accelerative changes in heart rate, increases in zygomatic major activity, and decreases in corrugator supercilious activity. The opposite response pattern is associated with highly arousing unpleasant pictures. On the other hand, both highly arousing pleasant and unpleasant pictures are associated with larger skin conductance responses. Using these measures, our group has shown in two recent studies (Vico et al., 2010; Guerra et al., 2012) that, when female university students view loved, familiar faces, a marked increase in zygomatic activity and a pattern of heart-rate accelerative changes (indicative of positive emotion , together with an increase in skin conductance (indicative of undifferentiated arousal (Bradley and Lang, 2007)), is elicited. Additionally, the second study compared two categories of loved faces: one with higher familiarity but lower emotionality (father) and the other with lower familiarity but higher emotionality (romantic partner). Familiarity was defined in terms of amount of time spent with the father and the romantic partner (Grasso et al., 2009). The results revealed larger responses to the less familiar face, thus suggesting that familiarity is not the key factor in explaining the observed responses.

The aim of the present study was to test the hypothesis that viewing loved familiar faces, compared to neutral (unknown) and unpleasant (mutilated) faces, inhibits the eye blink startle reflex. The study also intended to replicate the previous findings on women and extend them to men. Participants were required to have a romantic partner and a satisfactory relationship with their partner, father, mother, and best friend (opposite sex from partner). As in the second study (Guerra et al., 2011), they were also required to have lived with their parents until they were at least 18 years old, whereas their relationship with the romantic partner could not exceed 6 years. Control faces were neutral faces (four faces selected from the loved-faces category provided by other participants) and unpleasant faces (four mutilated faces taken from the International Affective Picture System (Lang, Bradley, Cuthbert, 2008). To control for familiarity, two loved faces were also compared: the face of the romantic partner (lower familiarity) and the face of the parent of same gender as partner (higher familiarity).

3.2 Methods

3.2.1 Ethics Statement

The research was approved by the Ethical Committee of the University of Granada (Spain) and was conducted according to the Declaration of Helsinki. All subjects signed written informed consent forms and received course credits for their participation.

3.2.2 Participants

Participants were 54 healthy undergraduate students (24 of whom were men). All were right-handed and had normal or corrected-to-normal vision. Before the physiological session, participants completed a set of questionnaires to assess general health (Rocha, Pérez, Rodríguez-Sanz, Borrell and Obiols (2011), social support (Revilla Ahumada, Luna del Castillo, Bailónn Muñoz, Medina Moruno, 2005), empathy (Pérez-Albéniz, de

Paúl J, Etxeberría, Montes and Torres, 2003), attachment (Alonso-Arbiol, Balluerka and Shaver, 2007), and positive-negative affect (Sandín, Chorot, Lostao, Joiner, Santed and Valiente, 1999). They also rated the familiarity and quality of their relationship with the romantic partner and their parents using a rating scale from 0 to 100. As expected, the familiarity was higher for the parents than for the romantic partner, whereas the quality of their relationship was highly positive in both cases. Results concerning the other questionnaires are being reported separately.

3.2.3 Stimuli and task

Four faces of loved people (father, mother, romantic partner, and best friend), four faces of unknown people (selected from the loved faces provided by other participants), and four unpleasant faces (mutilated faces) were used. Pictures of loved faces were provided by the participants following specific instructions (i.e., the pictures should not be taken by the participants themselves, and the photographed people were required to look straight at the camera with a neutral expression). Photographs were edited and matched for size, color (black and white), and background. The pictures were presented on a 19” flat screen monitor located at approximately 60 cm from the subject. Participants were randomly assigned to six different picture presentation sequences that followed a set of eight 3x3 Latin squares (72 trials, 6 trials per picture) to guarantee that all pictures had an equal preference distribution. Each presentation consisted of a 4-sec baseline, 6-sec picture presentation, and 4-sec post-picture interval. Two-thirds of the trials (48), equally distributed across the three face categories, were presented together with a startle probe (a burst of white noise at 105 dBs, 50-ms duration and nearly instantaneous rise time) at 4, 4.5, 5 or 5.5 sec after picture onset. Duration of the physiological test was around 30 minutes.

3.2.4 Physiological measures

Left orbicularis and zygomatic EMG activity were measured using Coulbourn V75-04 bioamplifiers and V76-24 integrators. Time constants and sampling rates for zygomatic and orbicularis muscles were 500 and 20 ms, and 100 and 1000 Hz, respectively. Heart rate was derived from the electrocardiogram recorded with a V75-04 bioamplifier at lead

II and sampled at 1000 Hz. Skin conductance was recorded using a V75-23 bioamplifier with the electrodes placed on the hypothenar eminence of the left hand. The signal was acquired at a sampling rate of 50 Hz.

3.2.5 Self-report measures

The startle probe paradigm uses three pictographic scales entitled the Self-Assessment Manikin Lang et al., 2008) to assess three bipolar emotional dimensions: Valence (pleasant-unpleasant), Arousal (relaxed-activated), and Dominance (dominant-dominated). Each scale depicts five humanoid figures (from a sad to a happy face for valence, from a relaxed to an exited body for arousal, and from a very small to a very large body for dominance) that represent the intensity levels of each dimension providing a score that ranges from 1 to 9.

3.2.6 Procedure

We first contacted participants by phone to invite them to attend two laboratory sessions. The first session ensured that participants complied with the inclusion criteria. They completed the questionnaires mentioned above and were provided with the camera and instructions on how to take the photographs. At the second session, we administered the physiological test to participants. Upon arrival in the laboratory, we invited the participant to sit on a reclining chair in a dimly lit room. After we placed the sensors, participants viewed the pictures as explained above. We instructed them to view each picture for the entire time it was on screen. After this task, we removed the sensors, and the participant evaluated the valence, arousal, and dominance of the 12 pictures using the Self-Assessment Manikin. Finally, we thanked participants for their time and fully explained the purpose of our study.

3.2.7 Data reduction and analysis

The startle reflex amplitude was defined as the difference in microvolts between the peak and the onset of the response, in a time window between 20 and 120 ms after stimulus onset, scored by means of the algorithm described by Balaban et al. (Balaban, Losito, Simons and Graham, 1986). To control for between-subject variability, startle amplitude for each subject was converted to standardized t scores. Responses in heart rate, skin conductance, and zygomatic EMG activity were determined by averaging across each half-second during the 6-sec picture presentation and subtracting that activity from the activity obtained 3 seconds before picture onset. Data analysis for eye-blink startle and subjective measures was performed using ANOVAs, with Gender as a between-subjects factor and Face Category as a repeated-measures factor. For zygomatic activity, heart rate, and skin conductance, a second repeated-measures factor of Time was added (the 12 half-second bins through the duration of the picture display). The Greenhouse-Geisser correction was used to correct any violation of sphericity in the repeated-measures factors. Post-hoc planned comparisons between loved, neutral, and unpleasant faces were conducted using Bonferroni test. The level of significance was set at 0.05 for all analyses.

3.3 Results

3.3.1 Loved versus neutral versus unpleasant faces

Startle reflex. The 2 (Gender) x 3 (Face Category) ANOVA results yielded a significant effect of Face Category (F (2, 104) = 24.11, $p < 0.0001$; $\eta p^2 = 0.317$) and a significant Face Category x Gender interaction (2, 104) = 4.38, $p < 0.02$ $\eta p^2 = 0.078$). No significant main effect of Gender was found. Figure 1 (left panel) shows the magnitude of the average eye-blink startle to the acoustic sound when female (top) and male (bottom) participants were viewing each of the three face categories. For both gender groups, the startle reflex showed reduced amplitude while viewing loved faces and increased amplitude when viewing unpleasant faces, compared to neutral ones. However, the differences were larger for females than for male participants. Analysis of the interaction showed a significant linear trend in both groups (females: $p < 0.0001$; males: $p < 0.012$), but the slope of the trend was significantly larger in the female group ($p < 0.009$). In this group, startle magnitude while viewing loved faces was significantly reduced compared to both neutral ($p < 0.007$) and unpleasant ($p < 0.0001$) faces. In the male group, significant differences were limited to the comparison between loved and unpleasant faces ($p < 0.04$).

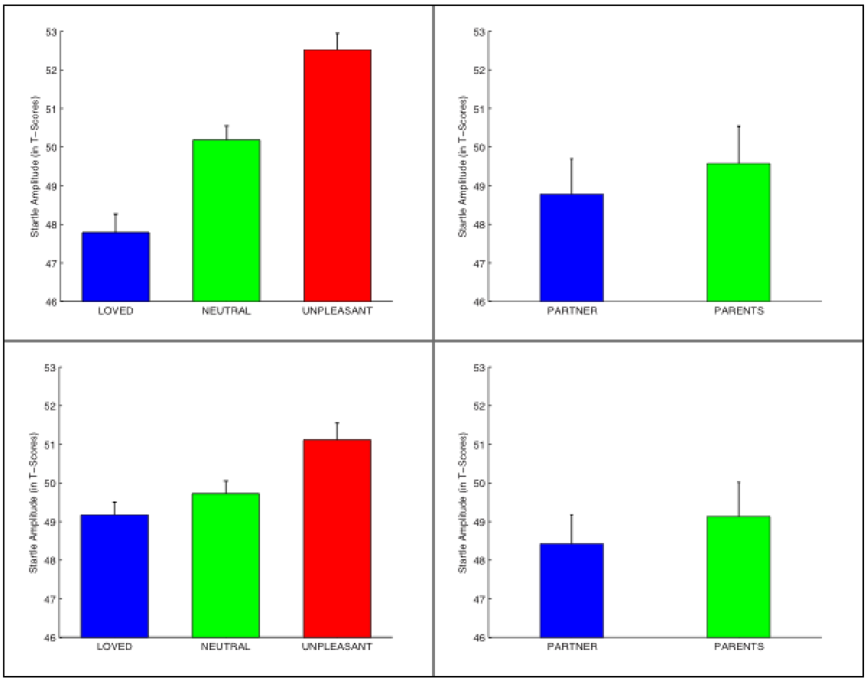

Figure 3.1: Startle reflex response to the faces. Magnitude of the startle reflex to the acoustic noise while participants viewed faces. Left: Loved vs. neutral vs. unpleasant faces (top: females; bottom: males). Right: Romantic partner (boyfriend/girlfriend) vs. same-sex parent (father/mother) faces (top: females; bottom: males). Bars are standard errors.

Zygomatic muscle activity. The 2 (Gender) x 3 (Face Category) x 12 (Time) ANOVA results yielded significant effects for Face Category (F (2, 104) = 19.69, $p < 0.0001$, $\eta p^2 = 0.275$), Time (F (11, 572) = 13.81, $p < 0.0001$, $\eta p^2 = 0.210$), Gender (F (1, 52) = 4.92, $p < 0.03$, $\eta p^2 = 0.087$), Face Category x Time (F (22, 880) = 17.80, $p < 0.0001$, $\eta p^2 = 0.255$), Gender x Time (F (11, 572) = $p < 0.02$, $\eta p^2 = 0.084$), and Gender x Face Category x Time (F (22, 1144) = 5.29, $p < 0.02$, $\eta p^2 = 0.084$). Figure 2 (left panels) shows changes in zygomatic muscle activity during picture presentation for both female (top) and male (bottom) participants. In both groups, loved, familiar faces prompted a clear response starting almost immediately after the picture presentation onset and continuing until the offset of the image. The response was significantly larger in women than in men, and in both groups it was significantly larger to loved faces than to neutral and unpleasant faces from second 1.5 through the offset of picture presentation (all p-values < 0.03 for women, and < 0.05 for men). No significant differences were found between neutral and unpleasant faces ($p > 0.18$ for women, and $p > 0.6$ for men).

Heart-rate. The 2 (Gender) x 3 (Face Category) x 12 (Time) ANOVA results yielded significant effects for Time (F (11, 572) = 4.78, $p < 0.003$; $\eta p^2 = 0.084$) and Face Category x Time (F (22, 1144) = 3.64, $p < 0.004$; $\eta p^2 = 0.065$). No significant effect of Gender was found. Figure 3 (left panel) displays the heart-rate response during picture presentation for all three face categories. Neutral and unpleasant faces induced a decelerative response that was maintained throughout the entire period of picture presentation. In contrast, loved faces, after an initial deceleration, induced a cardiac acceleration between seconds 2,5 and 5, with a peak at 3.5 seconds. Significant differences between loved and neutral faces were found at all time points between seconds 2 and 5.5 (all p-values < 0.04). Significant differences between loved and unpleasant faces were found between seconds 3 and 5 (all p-values < 0.04). No significant differences were found between unpleasant and neutral faces ($p > 0.6$).

Skin conductance. The 2 (Gender) x 3 (Face Category) x 12 (Time) ANOVA results showed significant effects of Face Category (F (2, 104) = 7.11, $p < 0.001$, $\eta p^2 = 0.120$), Time (F (11, 572) = 27.34, $p < 0.0001$, $\eta p^2 = 0.345$), and Face Category x Time (F (22, 1144) = 8.34, $p < 0.0001$, $\eta p^2 = 0.138$). No significant effect of Gender was found. Figure 4 (left panel) shows the skin conductance response. All picture categories

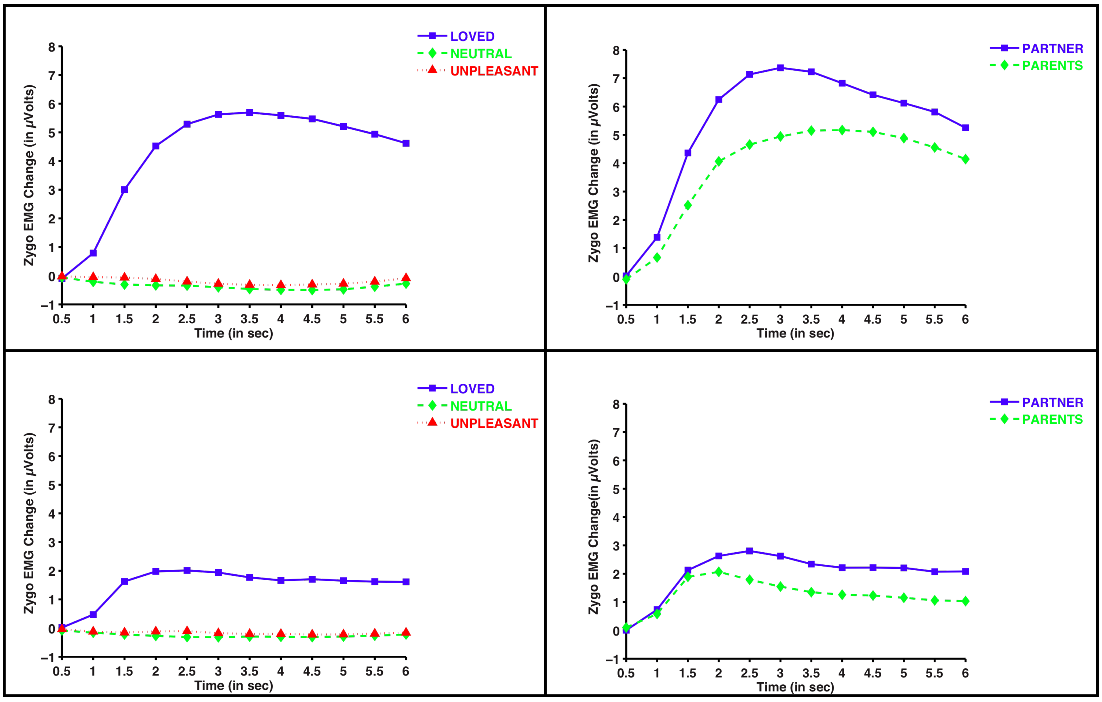

Figure 3.2: Zygomatic muscle response to the faces. Zygomatic muscle activity while participants viewed faces. Left: Loved vs. neutral vs. unpleasant faces (top: females; bottom: males). Right: Romantic partner (boyfriend/girlfriend) vs. same-sex parent (father/mother) faces (top: females; bottom: males)

produced a response starting approximately 2.5 seconds after picture onset. Responses to loved and unpleasant faces were significantly larger than responses to neutral faces at all time points between seconds 4 and 6 (all p-values < 0.04). No significant differences were found between loved and unpleasant faces (all p-values > 0.16).

Subjective ratings. Table 1 shows the mean and standard deviation scores for the participants' self-report ratings of valence, arousal, and dominance. The 2 (Gender) x 3 (Face Category) ANOVAs yielded significant main effects for all three scales, Valence (F (2, 104) = 409. 07, p < 0.0001; $\eta p^2 = .887$), Arousal (F (F (2, 104) = 41.33, p < 0.0001; $\eta p^2 = 0.443$), and Dominance (F (2, 104) = 24.34, p < 0.0001; $\eta p^2 = 0.319$), and significant interactions of Valence x Gender (F (2, 104) = 6.54, p < 0.006; $\eta p^2 = 0.112$) and Arousal x Gender (F (2, 104) = 6.02, p < 0.004; $\eta p^2 = 0.104$). For the valence scale, in both men and women, viewing loved faces elicited higher pleasant feelings than

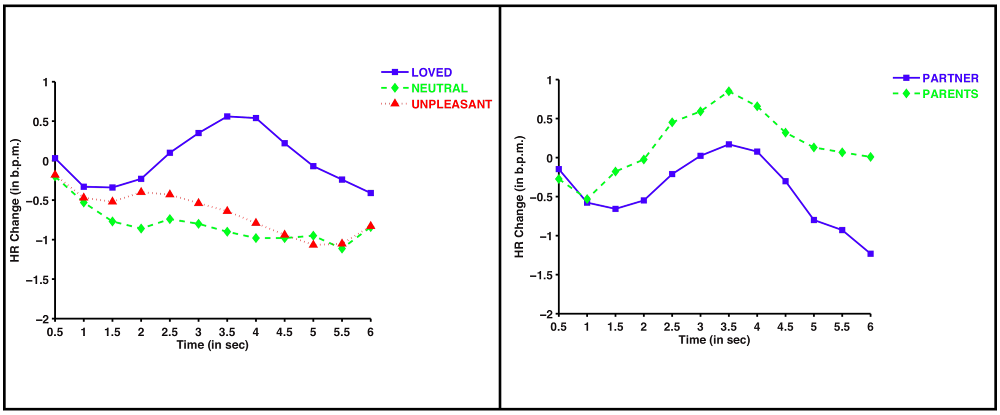

Figure 3.3: Heart rate response to the faces. Heart rate changes while participants viewed faces. Left: Loved vs. neutral vs. unpleasant faces. Right: Romantic partner (boyfriend/girlfriend) vs. same-sex parent (father/mother) faces

viewing neutral and unpleasant faces (all p-values < 0.0001), the pleasant feelings for loved faces being higher in women than men ($p < 0.0001$); for the arousal scale, in both genders, viewing loved faces elicited higher feelings of arousal than neutral faces ($p < 0.02$), but lower feelings of arousal than unpleasant faces, the arousal feelings of unpleasant faces being higher for women than men ($p < 0.05$) and the arousal feelings of pleasant and neutral faces being higher for men than women (both p-values < 0.04) ; and for the dominance scale, viewing loved faces elicited higher feelings of dominance than unpleasant faces ($p < 0.0001$) but no significant differences with respect to neutral faces ($p > 0.5$).

3.3.2 Romantic partner versus father/mother face

Startle reflex. Figure 1 (right panel) shows the magnitude of the average eye-blink startle to the acoustic sound when female (top) and male (bottom) participants were viewing the faces of the romantic partner (boyfriend or girlfriend) and the parent of the same gender as the partner (father or mother). The 2 (Gender) x 2 (Face Category) ANOVA yielded no significant effects (all p-values > 0.43. The startle response was not significantly different across face categories.

Zygomatic muscle activity. Figure 2 (right panel) shows the zygomatic muscle response elicited by the faces of the romantic partner and the face of the parent of same

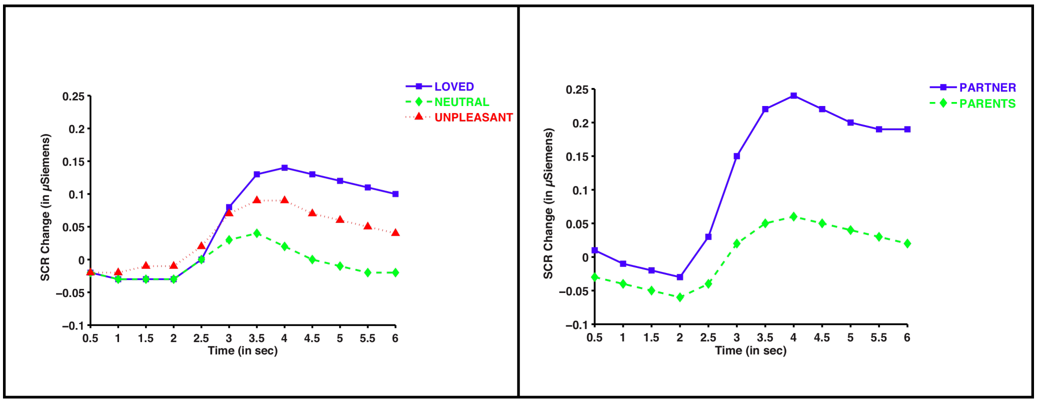

Figure 3.4: Skin conductance response to the faces. Skin conductance changes while participants viewed faces. Left: Loved vs. neutral vs. unpleasant faces. Right: Romantic partner (boyfriend/girlfriend) vs. same-sex parent (father/mother) faces.

gender. The 2 (Gender) x 2 (Face Category) x 12 (Time) ANOVA yielded significant effects of Gender (F (1, 52) = 4.53, $p < 0.003$, $\eta p^2 = 0.162$), Face Category (F (1, 52) = 10.90, $p < 0.002$, $\eta p^2 = 0.173$), Time (F (11, 572) = 15.37, $p < 0.0001$, $\eta p^2 = 0.228$), and Gender x Time (F (11, 572) = 5.14, $p < 0.01$, $\eta p^2 = 0.090$). As illustrated in Figure 2, the face of the romantic partner showed a larger zygomatic response than the father/mother face in both male and female participants ($p < 0.002$), but the two responses of female participants were significantly larger than the two responses of male participants from second 3 to second 6 (all p-values < 0.04).

Heart rate. Figure 3 (right panel) shows the heart rate response when participants were viewing the faces of the romantic partner and the face of the parent of same gender. The ANOVA results yielded only a significant effect of time (F (11, 572) = 3.92, $p < 0.009$, $\eta p^2 = 0.070$). Face Category and Gender showed no significant effects.

Skin conductance. Figure 4 (right panel) shows the skin conductance response when participants were viewing the faces of the romantic partner and the face of the parent of same gender. The ANOVA results yielded significant effects of Time (F (11, 572) = 26.00, $p < 0.0001$, $\eta p^2 = 0.333$), Face Category (F (1, 52) = 9.90, $p < 0.003$, $\eta p^2 = 0.160$), and Face Category x Time (F (11, 572) = 8.61, $p < 0.0001$, $\eta p^2 = 0.142$). No gender effect was found. As illustrated in Figure 4, the face of the romantic partner showed a significantly larger response than the face of the father/mother from second

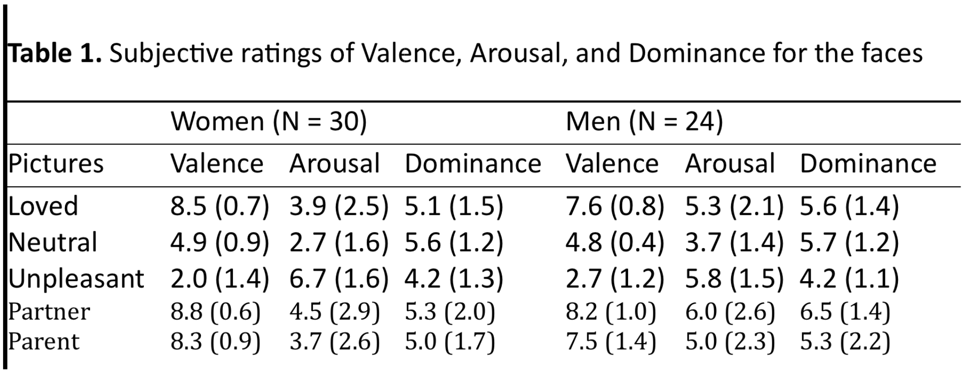

Table 1. Subjective ratings of Valence, Arousal, and Dominance for the faces

	Women (N = 30)			Men (N = 24)		
Pictures	Valence	Arousal	Dominance	Valence	Arousal	Dominance
Loved	8.5 (0.7)	3.9 (2.5)	5.1 (1.5)	7.6 (0.8)	5.3 (2.1)	5.6 (1.4)
Neutral	4.9 (0.9)	2.7 (1.6)	5.6 (1.2)	4.8 (0.4)	3.7 (1.4)	5.7 (1.2)
Unpleasant	2.0 (1.4)	6.7 (1.6)	4.2 (1.3)	2.7 (1.2)	5.8 (1.5)	4.2 (1.1)
Partner	8.8 (0.6)	4.5 (2.9)	5.3 (2.0)	8.2 (1.0)	6.0 (2.6)	6.5 (1.4)
Parent	8.3 (0.9)	3.7 (2.6)	5.0 (1.7)	7.5 (1.4)	5.0 (2.3)	5.3 (2.2)

Mean (standard deviation) of subjective ratings of Valence, Arousal, and Dominance for loved, neutral, unpleasant, partner, and parent faces reported by women and men (score range: 1-9)

3 to second 6 (all p-values < 0.008).

Subjective ratings. Table 1 shows the mean (and standard deviation) scores for the participants' subjective ratings of valence, arousal, and dominance in response to the romantic partner and same-gender parent faces. Participants rated the romantic partner's face as eliciting higher feelings of pleasantness, arousal, and dominance than the same-gender parent's face (valence ($F\ (1, 52) = 11.90$, $p < 0.001$; $\eta p^2 = .186$); arousal ($F\ (1, 52) = 11.\ 02$, $p < 0.002$; $\eta p^2 = .175$); dominance ($F\ (1, 52) = 6.\ 66$, $p < 0.02$; $\eta p^2 = .113$)). Significant main effects of gender were also found for the valence and arousal scales. Women rated their father's and romantic partner's faces as eliciting higher feelings of pleasantness than men ($F\ (1, 52) = 9.76$, $p < 0.003$; $\eta p^2 = .158$), but men rated both faces as eliciting higher feelings of arousal than women ($F\ (1, 52) = 4.29$, $p < 0.04$; $\eta p^2 = .076$).

3.4 Discussion

These results indicate that, for both men and women, viewing loved, familiar faces inhibits paradigmatic defense reactions, such as the eye-blink startle reflex. They also replicate previous findings of peripheral electrophysiological responses shown by women in reaction to loved, familiar faces (Vico et al., 2010; Guerra et al., 2011) and extend the same findings to men. Nevertheless, there were gender differences in terms of the magnitude of some physiological and subjective responses. Women showed a larger startle inhibition and a larger zygomatic response to loved faces than men, accompanied by higher ratings of positive feelings but lower ratings of arousal. In general, our results reinforce the interpretation of the physiological and subjective responses to loved, familiar faces as elicitation of an intense and positive emotional response that is not attributable to undifferentiated arousal or familiarity. Here we discuss the implications of our findings regarding the startle reflex inhibition, the arousal and familiarity issues, and the potential brain mechanisms linking loved faces to health benefits.

To date, the augmentation and inhibition of the startle reflex by viewing emotional pictures has only been consistently demonstrated through use of complex scenes from the International Affective Picture System (IAPS) (Lang et al., 2008) contrasting highly unpleasant (e.g., threatening people or phobic animals) with highly pleasant (e.g., erotic couples or sport images) content. Blink modulation using simple pictures, such as faces showing emotional expressions (e.g., happy, fearful, or angry faces), has remained elusive (Anokhin and Golosheykin, 2010; Alpers, Adolph and Pauli, 2011). Previous studies on adults have reported either no effect of facial expression on startle modification (Sprangler, Emlinger, Meinhardt and Hamm, 2001), blink potentiation only to male actors displaying negative emotions (Hess, Sabourin and Kleck, 2007), or startle potentiation only to fearful and angry facial expressions (Anokhin et al., 2010; Alpers et al., 2011). To date, no study has reported startle inhibition by affective faces. In the context of these null results, our finding of a marked inhibition of the eye-blink startle reflex in response to viewing loved, familiar faces, highlights the capacity of the faces of loved ones to inhibit defense reactions, even when the faces are presented as black-and-white photographs devoid of emotional expression.

This inhibitory capacity is likely to be rooted in biology. The face represents a key aspect of social and emotional communication. It conveys information about the feelings and identity of people, which are two essential cues that help discriminate friendly (i.e., social inclusion) and hostile (i.e., social exclusion) attitudes and intentions. Given such relevance, it is no surprise that the face had been the subject of much research in the past. Although most studies have followed Darwin's seminal work, outlined in The expression of emotions in man and animals, and focused on emotional facial expressions, a number of recent studies have specifically examined the electrophysiological (ERP) and hemodynamic (fMRI) indices of brain activity associated with the recognition of loved, familiar faces (Bartels and Zeki, 2000, 2004; Herzmann et al., 2004; Aron et al., 2005; Fisher et al., 2005; Bobes et al., 2007; Langeslag et al., 2007; Grasso et al., 2009; Xu et al., 2011). As noted in the introduction, one major limitation of these studies is the lack of control for undifferentiated emotional arousal and familiarity. None of these previous studies used peripheral physiological indices to distinguish positive affect from overall arousal and familiarity. Most prior studies relied on subjective reports, a method with obvious validity problems (Hess, Sabourin; Kleck, 2007). On the other hand, previous research attempted to control for familiarity by including the faces of acquaintances, famous people, friends, or newly learned faces. However, the familiarity of loved people will always exceed that of the control faces because of the greater amount of knowledge about and time spent with loved ones (Grasso et al., 2009).

Our physiological results using Lang's startle probe paradigm confirm that viewing loved faces elicits an intense and positive emotional response that is not due to undifferentiated emotional arousal. Zygomatic and heart-rate responses (two specific indices of positive emotion) were larger in response to loved faces than to neutral or unpleasant faces. Skin conductance (a specific index of emotional arousal), as expected, was larger in response to both loved and unpleasant faces than to neutral faces. Thus, physiological measures confirm subjective ratings in indicating the presence of both positive valence and intense arousal in response to loved faces. Although similar responses were found across female and male participants, we observed gender differences in response to loved faces. The magnitude of the zygomatic response and valence ratings were greater in female than male participants, whereas arousal ratings were greater in male than in female participants. These differences are consistent with reports of women's greater zygomatic activity when viewing happy faces and IAPS pictures of families (Bradley, 2001). They are also consistent with our finding of greater startle inhibition in women while viewing loved faces. According to the motivational priming hypothesis, the greater the activation of the appetitive motivational system by the pleasant stimuli, the greater the magnitude of startle inhibition (Bradley and Lang, 2007).

Physiological and subjective results when comparing loved faces with different levels of familiarity (romantic partner and father/mother of same gender as partner) confirm that familiarity is not the key factor in explaining the observed physiological responses. In the context of research on recognition of familiar faces, familiarity refers to factual knowledge about the person being recognized and has been operationalized in terms of amount of time spent with the person (Grasso et al., 2009). In our study, all responses showed similar (heart-rate) or larger (zygomatic activity and skin conductance) responses to the less familiar face (the romantic partner), in conjunction with higher ratings of pleasantness, arousal, and dominance. The larger responses to the romantic partner can be explained by the presumably higher positive emotionality present in romantic love, due to the presence of sexual attraction, a love component absent in filial love (Mikulincer and Goodman, 2006, Guerra et al., 2011). Thus our results, which replicate previous findings in female students comparing filial versus romantic love (Guerra et al., 2011), reinforce the interpretation of the observed physiological responses to loved faces as due to the higher subjective evaluations of the faces (higher valence and arousal) rather than to differences in familiarity. On the other hand, the higher rating of dominance to the romantic partner, compared to the father/mother of same gender, which also replicates previous findings (Vico et al., 2010, Guerra et al., 2011), reinforce the interpretation of the dominance scale in terms of protection or control: participants feel more protected or controlled (feel small) when viewing the face of the father or mother than when viewing the face of the romantic partner.

The relevance of our findings should be evaluated taking into consideration some methodological limitations. Gender differences in our study should be taken cautiously since male and female participants were not balanced in our sample. Moreover, participants were all university students and, consequently, extension of our findings to other populations is not warranted. Keeping these limitations in mind, the finding that viewing loved faces inhibits the startle reflex, together with evidence that such inhibition is accompanied by subjective and physiological responses that indicate the presence of an intense, positive emotional response, supports the hypothesis that loved faces may function as safety cues that activate the appetitive reward system and reciprocally inhibit defense reactions. The neural mechanisms underlying this reciprocal inhibition are still not well understood. However, based on neuroimaging studies of the brain areas activated by loved faces (Eisenberger et al., 2011; Bartels and Zeki, 2000, 2004; Bobes et al., 2007; Xu et al., 2011), together with data on the brain mechanisms that modulate the startle reflex (Anokhin et al., 2010; Alpers et al, 2011) and pain responses (Eisenberger et al., 2011), we may speculate that such mechanisms involve, in addition to activation of the reward system, activation of prefrontal areas known to exert an inhibitory role on subcortical structures, such as the amygdala, which directly modulate the startle reflex and other defense reactions (Lang, Davis and Ohman, 2000; Lang and Davis, 2006). Inhibition of defense reactions, with their broad spectrum of physiological and endocrine stress responses, may contribute in the long term to the positive health outcomes consistently reported in the scientific literature associated with social support.

In summary, the present study shows that viewing loved, familiar faces inhibits the eye-blink startle reflex. Additionally, it replicates previous findings in women regarding greater physiological and subjective responses to loved faces, and extends the same findings to men. This set of data highlights the capacity of loved faces to elicit an intense positive emotional response and simultaneously inhibit defense reactions. We conclude that this inhibitory capacity may contribute to the health benefits associated with social support.

Chapter 4

Event related potentials in response to loved familiar faces: An Erp Source Analysis To Identify Frontal P3 Generators

4.1 Introduction

Previous studies in our laboratory have shown the consistency of the psychophysiological pattern associated with the processing of loved familiar faces. Increases in heart rate, skin conductance response, zygomatic muscle activity and enhanced P3 and Late Positive Potential (LPP) components follow the visualization of relevant familiar faces: partners, friends, parents, etc. (Vico et al., 2010; Guerra et al., 2011). The simultaneous recording of autonomic, somatic, and central physiological measures makes it possible to disentangle the relative contributions of emotional valence (positive vs. negative), undifferentiated arousal (more activation vs. less activation) and the familiarity value of the stimulus (known vs. unknown). Following Lang (Lang and Bradley, 2010), we conceptualize emotions as action dispositions, developed in the context of relevant situations for survival (either to protect ourselves from possible threats or to approach potentially life sustaining situations). In humans, affective induction in the laboratory (via a wide range of experimental procedures including passive viewing, imagery, anticipation, and action -see Bradley, 2007 for a review-), activate a complex pattern of physiological responses that relates to both sensory processes (e.g. increased attention, enhanced perceptual processing) and to mobilizing the organism to perform motor action (Lang & Bradley, 2010). These physiological responses are regulated through the action of two motivational systems in the brain: the appetitive system, related to preservative action dispositions (proximity to nurturance, sex or alimentation) and the aversive system, developed to protect us from danger (fight or flight, freezing, etc.). From this theoretical perspective, it is assumed that affective valence account for which system is engaged and the arousal dimension determines the intensity of its activation. Collected data indicate that the affective state prompted by the visualization of loved familiar faces can be characterized as high in positive valence (indexed by highly pleasant subjective ratings, increases in heart rate and zygomatic muscle activity) and high in arousal (indexed by increases in skin conductance and highly subjective arousal ratings).

In this paper we present Event-Related Potentials (ERPs) and source analysis data obtained during the visualization of loved familiar, neutral/unknown, and unpleasant faces. Peripheral and startle reflex modulation data, also obtained in this study, has been reported in a previous paper (Guerra et al., 2012). The inhibition of the startle reflex described in Guerra's paper constitutes a solid evidence of the implication of the appetitive motivational system in the experience of attachment-related (or love-related) emotions. Despite the great advances in understanding reflex and action systems related to these kind of emotions, less is known about sensory and perceptual processes that precede efferent responses. Differences in the time course regarding the processing of stimuli varying in valence, arousal, and familiarity (loved familiar vs. neutral vs. unpleasant faces) could provide relevant information about sensory and higher order differences in handling pleasant and unpleasant emotional information provided by the face.

ERPs are a fruitful method to describe the temporal course of perceptual, emotional, and cognitive relevant phenomena. Thus, several event-related components such as P1, N170, N250r, P300, N400, and N600 have been used to determine the temporal sequence that goes from pictorial/structural encoding to retrieval of biographical/emotional information (Bentin et al., 1996; Bruce & Young, 1986; Eimer, 2000; Herrmann et al., 2005; Schweinberger, 2011).

Processing of familiar faces with social and emotional relevance involves three fundamental processes: (1) processing of identity (invariant face features), (2) recovery of knowledge about the person (recovery of biographical memories associated to the face) and (3) the emotional response (covered or uncovered) related to identity recognition. Available evidence suggests that these processes depend on different brain structures that work together with each other (Gobbini and Haxby, 2011). In spite of the fact that familiarity and the emotional response are different processes relying on separate neuroanatomical substrates, there has been great confusion in the literature when considering these two processes as independent entities (Shah et al., 2001).

The modulation of the event-related potentials in response to familiar relevant faces (romantic partner, own children, parents and friends) has been recently compared to faces differing in their familiarity level, i.e. famous, newly-learned or unknown faces (Herzmann et al., 2005; Langeslag et al., 2007; Bobes et al., 2007; Langeslag et al., 2008; Grasso et al., 2009; Waisman et al., 2011; Grasso and Simons, 2011; Dai et al., 2013). The most reliable results found in these studies are: (1) enhanced amplitude of the P3 family components (P3a and P3b) and (2) enhanced LPP for loved familiar faces compared to other familiar and unfamiliar faces. The modulation of these two components has also been found in response to highly unpleasant stimuli, putting into question whether this effect reflects an unspecific emotional processes or a positive motivational process (Olofsson et al., 2008). Nevertheless, it has been found that there is an empirical and theoretical relevant distinction between the modulation by familiarity of the earlier and frontally distributed P3a and the later and centro-parietally distributed P3b. Bobes and colleagues (2007) found that during an oddball task, socially and emotionally relevant faces prompted an enhanced frontally distributed positivity when viewing pictures of acquaintances (family and friends) that was absent in the case of newly learned faces (laboratory trained). In addition to differences in the level of familiarity between these two face categories, another important aspect was the lack of social and emotional information provided by the newly learned faces, indicating the sensitivity of the P3a to this kind of information. The P3b, as opposed to the P3a, had a similar amplitude and topographical distribution for both face categories, suggesting that this component show familiarity cognitive processes. Another study by Weisman, Feldman and Goldstein (2011), found an enhanced P3a component when exposed to infant faces in new parents and new lovers, indicating a special sensitivity of this component to attachment-related processes. A recent experiment by Dai and colleagues (2013) reported larger P3a and P3b components when participants viewed pictures of their parents, compared to unknown faces, during an oddball task. Dipole source analysis within the time window of the P3 family has shown significant activation of the medial frontal and anterior cingulated gyruses to the father's and the mother's face, respectively. In this study, precuneus and cerebellar tonsil were also found as brain sources related to these ERPs positive components. To our knowledge, no previous study has tested the modulation by loved familiar faces compared to an unpleasant control face.

In the present experiment we used ERPs and source analysis techniques with the aim of studying the temporal course and relevant brain areas associated with the viewing of loved familiar faces. We compared ERPs of a mixed group (men and women) during the processing of faces belonging to three different categories: loved familiar (partner, parents and friends), unknown neutral (pictures of loved familiar faces of other participants) and unpleasant (mutilated faces from the IAPS). In line with previous studies, we expected enhanced P3a to loved familiar, compared to the other caegories. We also hypothesized that brain sources associated to this early component would be found in areas sensitive to the processing of social and emotional information.

4.2 Method

4.2.1 Participants

54 participants (24 males) took part in this study. None of them reported current physical or psychological problems and none were under pharmacological treatment. All were right-handed and had normal or corrected-to-normal vision. Subjects who were included in the final sample matched the following criteria: (a) to have a current romantic relationship –of, at least, one year duration-, (b) to have a highly positive relationship with both their parents and best friends. All of them signed written informed consent forms and received course credits for their participation. Due to experimental errors, two participants were excluded from analysis.

4.2.2 Design and materials

Participants viewed faces belonging to three categories in a passive picture viewing paradigm: Loved Familiar (partner, father, mother, and best-friend), Neutral (control-boyfriend, control-father, control-mother, and control-best-friend), and Unpleasant faces[1] taken from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008) according to the Spanish normative ratings (Moltó et al., 1999; Vila et al., 2001). Photographs of Loved Familiar people were provided by the participants a few days before the experiment following full detailed instructions about how to take the photographs (i.e., pictures were required not to be taken by the own participant, and photographed people should look straight at the camera with a neutral expression in front of a light background). Neutral pictures were selected among the Loved Familiar pictures provided by other participants after ensuring those pictures didn't depict anyone known to that participant. Photographs of Loved Familiar people were taken using a Nikon D-3000 camera. All pictures were edited using Corel Draw Photopaint (version 7). They were matched in size, color and background. All photographs were cropped to 650 x 650 pixels, transformed to a gray scale (8 bits), and inserted into a circle surrounded by a black background. Pictures were presented using Presentation Software (Neurobehavioral Systems, CA) on a 19" flat monitor located at approximately 60 cm from the participant.

Participants were randomly assigned to six different picture presentation sequences that were created following a set of eight 3x3 Latin Squares. In each of those 3x3 matrices, one out of the four pictures conforming a category was discarded so that, in total, each picture was presented 6 times during the whole task. To control for order effects, each sequence started with a different category.

The task started with a five minutes baseline period, followed by 72 trials with the following structure per trial: 4-sec baseline, 6-sec picture presentation, 4-sec post-picture interval. Two-thirds of the pictures (48) were presented together with a startle probe (a burst of white noise at 105dBs, 50 ms duration and nearly instantaneous rise time) at either 4, 4.5, 5 or 5.5 sec after picture onset. The same number of startle probes was assigned to each picture (n=4). In addition, 8 startle probes were delivered

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[1] International codes for unpleasant pictures were: 3000, 3051, 3060, and 3080)

during the inter-trial interval, in order to minimize the noise predictability. The inter-trial interval varied randomly between 2 and 4 sec (averaging 3). During the whole task a fixation point was presented in the center of the screen to minimize eye movements. Participants were instructed to simply look at the pictures for the entire time they were on the screen.

4.2.3 Electrophysiological measures

EEG recording was accomplished by means of a PC computer running ActiView software (Bisoemi, Amsterdam, The Netherlands). EEG was recorded at 64 locations using an ActiveTwo system (Bisoemi, Amsterdam, The Netherlands) with a sampling rate of 256 Hz. All electrode offsets were kept below 40 Volts. An average reference was used during the whole recording and all signals were band-pass filtered (.016 - 35 Hz) offline. Event-related potentials (ERPs) were averaged for each picture category (loved familiar, neutral and unpleasant). The epoch started 100 ms before and ended 1000 ms after picture onset. The average activity of the 100 ms prior to picture onset was used for baseline correction.

Source estimation for the P3a component was conducted by using the Bayesian Model Averaging (BMA) described by Trujillo-Barreto and colleagues (2004). This method deals with two main limitations of the linear inverse solutions, the ghost sources and the underestimation of deep sources, adding a priori information. The BMA is an application of the Bayesian model inference framework (MacKay, 1992) to the solution of the EEG/MEG inverse problem. BMA provides a method for source reconstruction in which, instead of choosing a single inverse solution (IS) from those under consideration, all ISs (or models) are used, but their influence on the final average solution are weighted according to the support they receive from the data. The different models to be averaged out for a given data set are created by finding a large number of LORETA solutions (Pascual-Marqui et al., 1994) under different anatomical constraints (see Trujillo-Barreto et al., 2004, for a description of the mathematics and properties of the BMA approach).

The intra-cerebral primary current densities (PCDs) were estimated over a source space (grids) of 6000 triangles resulting in 5656 generators, constrained to 76 anatomical compartments of the cortical surface, which were chosen from the "Montreal Average

Brain" (MNI Brain) (Petrides et al., 1993). With this information, the physical term (electric lead field) that relates the intra-cerebral activity to the scalp electric fields was computed. The forward model used in this case consisted of three spheres modeling piecewise homogenous compartments: brain, skull, and scalp. The conductivity values selected in our case were 0.33, 0.022 and 0.013 Ω/m for the brain, scalp, and skull, respectively (Oostendorp et al., 2000; Zhang et al., 2006).

4.2.4 Self-report measures

Self-Assessment Manikin (SAM) (Bradley & Lang, 1994). Valence, arousal, and dominance ratings of each picture were assessed using the Self-Assessment Manikin. The SAM consists of three scales each one depicting five humanoid figures that represent the intensity levels of three emotional dimensions: from a figure with a large smile to a figure with a pronounced frown for valence, from a figure that appears agitated to a figure that looks drowsy for arousal, and from a very small figure to a very large figure for dominance. Each scale provides a score rating from 1 to 9.

4.2.5 Questionnaires

Familiarity and positive affect towards loved familiar faces were assessed by means of a Likert Scale ranging from 0 (very low levels of familiarity or positive affect) to 100 (very high levels of familiarity or positive affect). Familiarity was defined as the amount of time spent with a person. Positive affect was conceptualized as the amount and quality of positive emotions associated to a specific individual.

Attachment styles were evaluated using the Spanish version of the Experiences in Close Relationships Scale (ECR, Brennan, Clark, & Shaver, 1998; Alonso-Arbiol et al., 2007), that provides scores on two dimensions: attachment anxiety and attachment avoidance.

The MOS Social Support Survey (Shebourne & Stewart, 1991) provided information on emotional/informational and instrumental support, as well as on positive social interaction and affection (see Revilla Ahumada et al., 2005, for the spanish validation).

Two other relevant factors, namely, empathy and positive-negative affect, were assessed by means of the Interpersonal Reactivity Index (IRI, Davis et al, 1980; Mestre

Escriv· et al., 2004) and the Positive And Negative Affect Schedule (PANAS, Watson, Clark and Tellegen, 1988; SandÌn et al., 1999), respectively.

4.2.6 Procedure

Participants were contacted by phone and kindly invited to attend a first session in the lab. After ensuring they met inclusion criteria, participants fulfilled all the questionnaires. In this first session they were also provided with the camera and full detailed instructions on how to take the photographs. At the second session, participants were sat in a reclining chair in a dimly lit room. After we placed the sensors, participants were presented with the pictures as described above. Once the task was completed, they evaluated each picture by means of the Self Assessment Manikin (SAM, Bradley & Lang, 1994).

4.2.7 Data reduction and analysis

A two-way procedure was used to identify the different ERP components, followed by a traditional ERP analysis based on mean amplitude scores. Firstly, visual inspection and single sensor waveform analysis served to determine the relevant ERP components. Secondly, mean activity across sensor groups and time bins was calculated to score ERP components. The P1 and N170 components were assessed in a parieto-occipital cluster for time windows ranging from 110 to 130 ms and from 160 to 200 ms, respectively. The P3 component was scored over frontal sites in a time window from 360 to 400 ms. As regards the LPP, it was scored over centro-parietal regions in the time window from 400 to 600 ms. Permutation analysis was performed in order to determine the latency window for the statistical analysis between these two face categories.

ERP data were analyzed by means of a 2 (Gender) x 3 (Face Category) x 2 (Hemisphere) mixed ANOVA. The non-parametric False Discovery Rate analysis was used to determine the threshold for statistical significance of the estimated P3a sources.

A 2 (Gender) x 3 (Face Category) mixed ANOVA was used to analyze the SAM ratings. A One-way ANOVAS, with Subcategory of Loved Familiar Faces as a single factor was performed to analyze familiarity and positive affect scores. Finally, means and standard deviations obtained in the questionnaires were compared to the Spanish normative values.

Where applicable, the Greenhouse-Geisser epsilon correction was used to correct for violation of sphericity. Significance was set at 0.05 for all analyses.

4.3 Results

4.3.1 Self Assessment Maniking

As previously reported (Guerra et al., 2012), the 2 (Gender) x 3 (Face Category) ANOVA yielded significant effects for all three scales, Valence (F(2,104) = 409.07, p < 0.0001, ηp2 = .887), Arousal (F(2,104) = 41.33, p<0.0001, ηp2=.443), Dominance (F(2,104) = 24.34, p < 0.0001, ηp2=.319), and significant interactions of Valence x Gender (F(2,104) = 6.54, p < 0.006, ηp2= 0.112) and Arousal x Gender (F(2,104) = 6.02, p < 0.004, ηp2= 0.104).

Results indicate that the visualization of loved familiar faces prompt higher feelings of positive valence than viewing neutral and unpleasant faces, the pleasant feelings for loved faces being higher for females, compared to males. For both women and men, loved faces elicited higher feelings of arousal than neutral faces, but lower feelings of arousal than unpleasant faces, the arousal feeling of unpleasant faces being higher in women than in men, and the arousal feeling of pleasant and neutral faces being higher for men than for women. Viewing loved faces prompted higher levels of feeling dominant than viewing unpleasant faces, but no significant differences with respect to neutral faces were obtained.

4.3.2 Questionnaires and Scales

Table 1 shows the descriptive statistics for familiarity and positive affect towards partner, father, mother and best friend. The one-way ANOVA for familiarity –with Subcategory of Loved Familiar Faces as single factor- revealed a significant main effect (F(3,162) = 78.11, p $<$ 0.0001, ηp2= 0.591). Planned comparisons confirmed that the face of the partner was considered less familiar, compared to the other faces (all ps $< .004$). Positive affect, on its part, also showed a significant effect for Subcategory

($F(3,162) = 11.038$, $p < 0.0001$, ηp2= 0.170). Pair-wise comparisons revealed significant differences between the face of the best friend (which obtained the lowest score) and the rest of the faces (all ps < .011).

Means and standard deviations for all questionnaires are shown in Table 2.

As regards the subscales of the ECR, participants didn't show high levels of neither attachment anxiety nor avoidance (3.74 and 3.98, respectively, over a total score of 7).

With respect to the IRI, the highest score was obtained for the Perspective taking subscale (3.019 over 5). This subscale indexes the ability to take the other's point of view. The lowest score, on the other hand, was obtained for the Personal distress subscale (1.738 over 5), which informs on anxiety fellings and distress to others' adverse situations. When comparing those subscales that measure cognitive vs. emotional empathy, the results show that the cognitive component is higher in the current sample.

Positive and Negative Affect scores show a stronger trend to experience positive feelings (29.15 for positive affect vs. 22.32 for negative affect scale)

Finally, the high scores obtained for the MOS questionnaire revealed a high level of perceived social support in our participants.

4.3.3 ERPS

4.3.3.1 Early components: P1 and N170

Figure 1 depicts the waveforms for P1 and N170 across categories. No significant differences were found between faces as regards the P1. Analysis of the N170 yielded significant effects of Face Category ($F(2,100) = 165.829$, $p < 0.000$, ηp2= 0.768) and Face Category x Hemisphere ($F(2,100) = 8.972$, $p < 0.000$, ηp2= 0.152). As it can be seen in the figure, unpleasant faces elicited a different pattern, compared to loved familiar and neutral faces. Post-hoc comparisons revealed significant differences between unpleasant faces and the other categories (all ps < .0001).

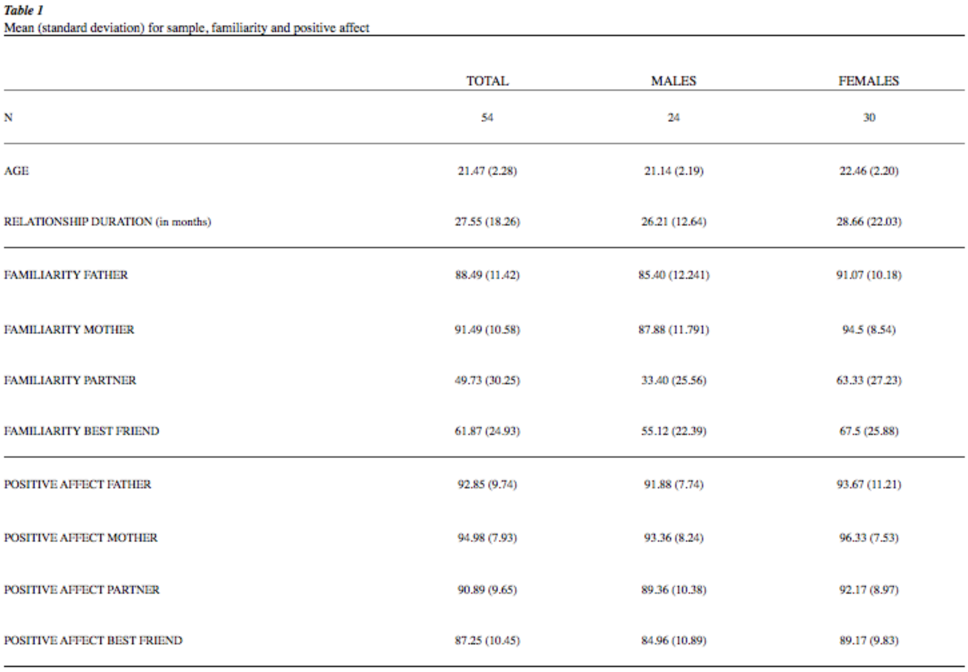

Table 1
Mean (standard deviation) for sample, familiarity and positive affect

	TOTAL	MALES	FEMALES
N	54	24	30
AGE	21.47 (2.28)	21.14 (2.19)	22.46 (2.20)
RELATIONSHIP DURATION (in months)	27.55 (18.26)	26.21 (12.64)	28.66 (22.03)
FAMILIARITY FATHER	88.49 (11.42)	85.40 (12.241)	91.07 (10.18)
FAMILIARITY MOTHER	91.49 (10.58)	87.88 (11.791)	94.5 (8.54)
FAMILIARITY PARTNER	49.73 (30.25)	33.40 (25.56)	63.33 (27.23)
FAMILIARITY BEST FRIEND	61.87 (24.93)	55.12 (22.39)	67.5 (25.88)
POSITIVE AFFECT FATHER	92.85 (9.74)	91.88 (7.74)	93.67 (11.21)
POSITIVE AFFECT MOTHER	94.98 (7.93)	93.36 (8.24)	96.33 (7.53)
POSITIVE AFFECT PARTNER	90.89 (9.65)	89.36 (10.38)	92.17 (8.97)
POSITIVE AFFECT BEST FRIEND	87.25 (10.45)	84.96 (10.89)	89.17 (9.83)

4.3.3.2 P300a

Figure 3 shows a potentiated positivity in frontal locations to loved familiar faces, compared to neutral and unpleasant ones. Due to the differences found in the N170 to unpleasant faces, here we only included the comparison between loved familiar and neutral faces.

The 2 (Gender) x 3 (Face Category) x 2 (Hemisphere) ANOVA revealed significant effects for Face Category (F(2,50) = 32,941, $p < 0.001$, ηp2 = 0.397). Planned comparisons showed significant differences between loved familiar faces and both neutral and unpleasant (all $ps < .0001$), and between neutral and unpleasant faces ($p < .030$).

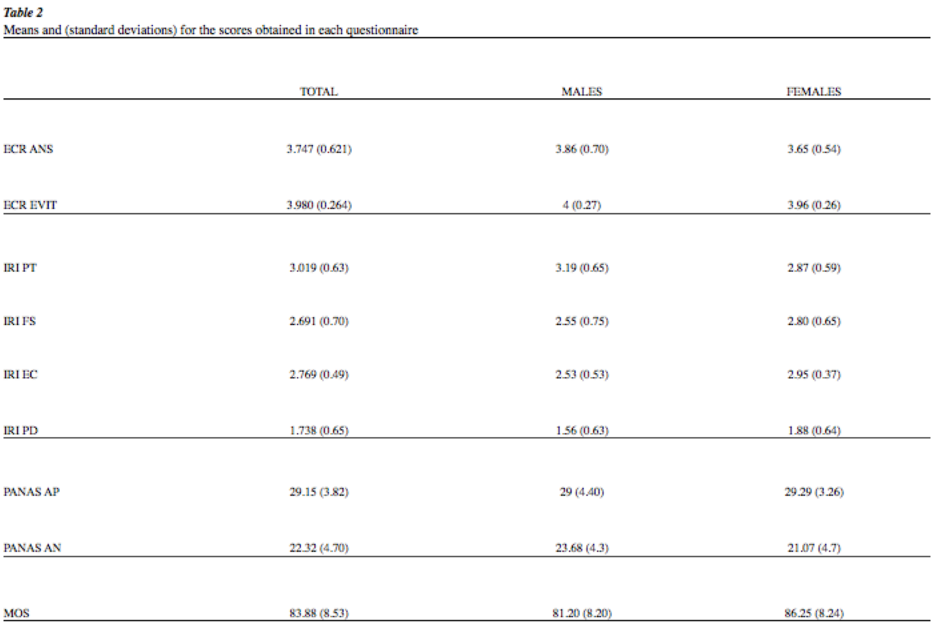

Table 2
Means and (standard deviations) for the scores obtained in each questionnaire

	TOTAL	MALES	FEMALES
ECR ANS	3.747 (0.621)	3.86 (0.70)	3.65 (0.54)
ECR EVIT	3.980 (0.264)	4 (0.27)	3.96 (0.26)
IRI PT	3.019 (0.63)	3.19 (0.65)	2.87 (0.59)
IRI FS	2.691 (0.70)	2.55 (0.75)	2.80 (0.65)
IRI EC	2.769 (0.49)	2.53 (0.53)	2.95 (0.37)
IRI PD	1.738 (0.65)	1.56 (0.63)	1.88 (0.64)
PANAS AP	29.15 (3.82)	29 (4.40)	29.29 (3.26)
PANAS AN	22.32 (4.70)	23.68 (4.3)	21.07 (4.7)
MOS	83.88 (8.53)	81.20 (8.20)	86.25 (8.24)

4.3.3.3 LPP

Figure 3 depicts the ERP waveforms for all face categories, including the LPP. Significant effects were found for Face Category (F(2,100) = 38.062, p = 0.000, ηp2= 0.432) and Hemisphere (F(1,50) = 21.184, p = 0.000, ηp2= 0.298). Pair-wise comparisons showed that emotional faces prompted larger LLPs, compared to neutral ones (all ps $< .0001$). No other differences were found.

4.3.4 Loved familiar vs. Unknown (neutral) faces

Permutation analysis showed that differences between Loved Familiar and Neutral faces were significant in a time window rangin from 180 ms after stimulus onset ($p < .0005$) to 215 ms ($p < 0.0005$).

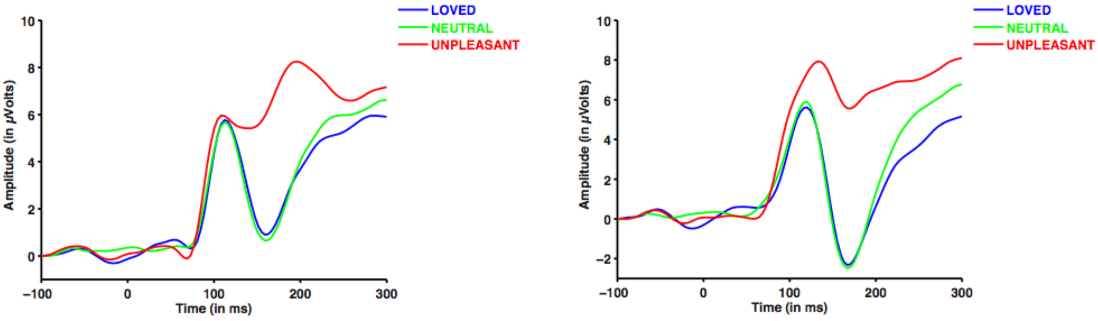

Figure 4.1: ERP waveforms across categories for P1 (left) and N170 (right) components.

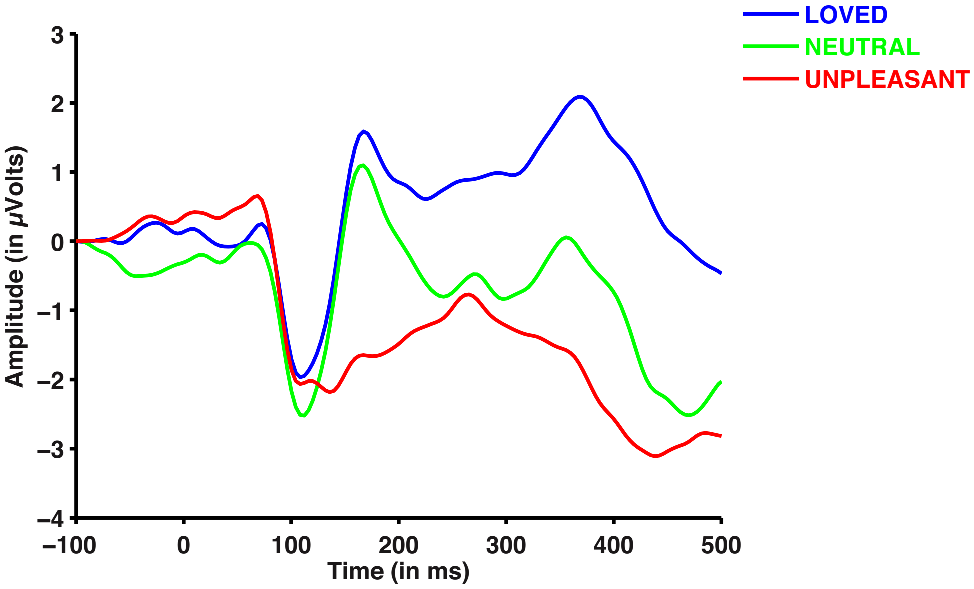

Figure 4.2: ERP waveforms in a centro-frontal location for the three categories of faces. As it can be observed, P3 amplitude was larger for loved familar faces compared to both neutral and unpleasant.

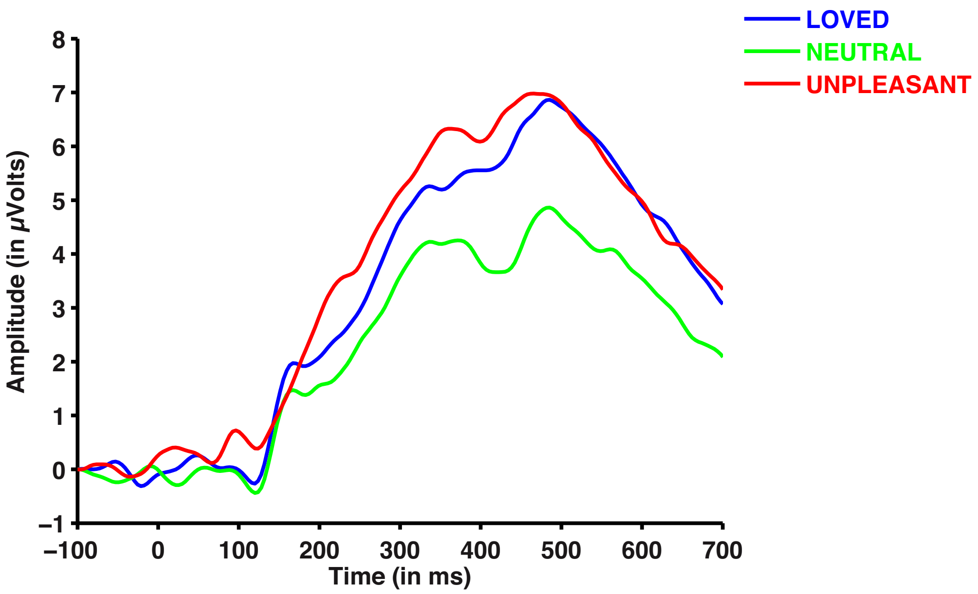

Figure 4.3: ERP waveforms in a parietal location during the visualization of loved familiar, neutral, and unpleasant faces. Pictures with emotinal content elicited an increase in the LPP component, as compared to neutral ones.

Figure 4 depicts sagital and axial planes showing the ·reas involved in the generation of the P3a for the difference between Loved Familiar and Neutral faces. Results yielded significant activations in orbitofrontal cortex, anterior cigulate, and temporal inferior cortex.

4.4 Discussion

The current study was aimed at studying the temporal course and relevant brain areas associated with the passive viewing of loved familiar faces, compared to neutral and unpleasant faces, all of them devoid of emotional expression.

Consistent with previous findings, we found no differences in the early components due to face social and emotional relevance or to face familiarity (Eimer, 2000). The exogenous P100 component displayed a similar latency and amplitude for the three face categories, suggesting this component might index the occurrence of a unspecific

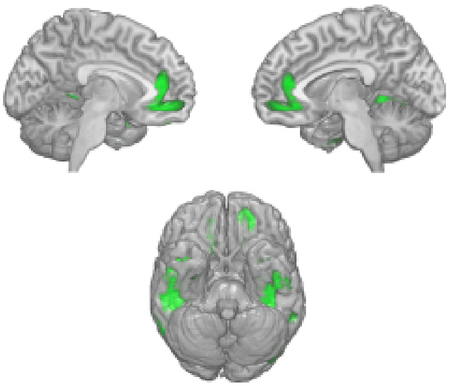

Figure 4.4: Statistical parametric mapping obtained for the P3a generators (Loved Familiar vs. Neutral) by Bayesian Averaging. Upper panel depicts sagittal planes with activations in the orbitofrontal cortex and bilateral anterior cingulate. Lower panel shows the activation of infero-temporal areas.

perceptual analysis. At the facial structural encoding stage, indexed by the N170, unpleasant faces prompted a differential temporal and topographical response pattern. The N170 belongs to the N1 family, that is, exogenous visual components that are observed in certain areas of the extrastriate cortex when participants are presented with any kind of visual stimuli (Eimer, 2010). In addition to being sensitive to physical features of the stimuli, the N170 has been shown to be especially responsive to faces (Allison, 1994; Bentin, 1996; Eimer, 2000). The fact that this component is not modulated by familiarity but by changes in structural features –for instance, head orientation- indicates that it is related to structural encoding, which, in turn, is also associated with recognition of a face as such. Thus, the physical alteration observed in the case of the unpleasant faces might render the recognition of unpleasant pictures as faces more difficult, accounting for the reduced amplitude of the N170 to this category.

The most interesting finding of this study is the enhanced frontal P3 to loved familiar faces. This component also shows a linear decrease in its amplitude to neutral and unpleasant faces. The P3a belongs to the P3 family, a set of components that have been previously related to task relevance, motivational significance of the stimulus, arousal level, and the influence of these factors on mental resource allocation (Olofsson et al., 2007). Previous studies have reported an increase in the P3 amplitude during the visualization of faces with different emotional expressions (Eimer & Holmes, 2007) as well as during the viewing of familiar faces that carry social and emotional significance (Vico et al, 2010; Guerra et al, 2011; Langeslang et al., 2007; Grasso et al., 2009). Current evidence suggests that the P3a is not sensitive to affective valence, whereas the P3b shows a larger amplitude to pleasant stimuli, compared to unpleasant ones (CarretiÈ et al., 2006; Delplanque et al., 2004). Nevertheless, recent studies using the oddball paradigm, have proposed the existence of a differentiated path associated with the processing of social and emotionally relevant information extracted from faces (Bobes et al., 2007; Dai et al., 2013), in contrast to the cognitive route. According to these authors, emotional processing would be indexed by the presence of the P3a, whereas cognitive processing would be reflexed by the P3b.The potentiated P3a to loved familiar faces shown here is congruent with this hypothesis.

Permutation analysis showed that the processing of loved familiar faces, compared to neutral faces, starts as early as 180 ms, suggesting a temporal advantage for emotional information carried by the faces, compared to cognitive. Finally, the location of the P3a generators both in areas related to emotion and reward (orbito-frontal cortex, and cingulate), as well as those related to identity processing (inferior temporal) provides additional support to the proposed hypothesis.

On the other hand, the LPP has consistently been related to the motivational significance of the stimuli (Cuthbert et al., 2000). In line with previous studies, the LPP was similar for both loved familiar and unpleasant faces, compared to neutral.

Taken together, these results show that loved familiar faces modulate central electrophysiological responses as a fucntion of their emotional and social meaning. Retrieval of relevant information associated with loved familiar faces starts rather early, and involves brain areas related to emotion, reward, and identity recognition.

Chapter 5

Pleasantness and Unpleasantness from Identity Recognition: Peripheral and fMRI Insights

5.1 Introduction

The face conveys emotional information that is very relevant for interpersonal communication. This information can be transmitted through different channels, of which facial expressions have been studied in most detail (Darwin, 1872; Ekman, 1992; Eimer and Holmes, 2002; Engell and Haxby, 2007). Face's physical appearance, in the absence of a specific facial expression, also transmit very relevant affective information, as it can be seen in the inferences on personality and psychological traits derived from structural features of the face (for a revision, see Said, Haxby y Todorov, 2011). The stereotype "what is beautiful is good" constitutes a good example of emotional influence of the attractiveness of faces on the perception of moral and personality traits (Dion, Berscheid and Walster, 1972; Tsukiura and Cabeza, 2011). Moreover, fMRI studies have shown how attractive faces act as highly gratifying emotional stimuli activating certain structures related to the reward system, specifically the medial orbito-frontal cortex (Aharon et al., 2001; Kampe et al., 2001; O'Doherty et al., 2003; Senior, 2003; Ishai, 2007). Faces can also act as emotional stimuli in absence of an emotional expression through the recovery of social and emotional memories associated with the identity of the person. This type of emotional response, previously referred to as "emotion from identity" (Bobes et al., 2007), constitutes the focus of this study.

Recent neuro-anatomical models on face perception emphasize the processes associated with the recognition of familiar faces (Gobbini y Haxby, 2007). According to these authors, processing of the physical appearance of the face, recovering knowledge on the individual and the emotional response experienced when seeing a familiar face ("emotion from identity") are components that play a fundamental role in the recognition of a familiar face. Following this model, facial recognition depends both on a central system -responsible for the structural analysis of the face- and on an extended system related to the former in a bidirectional fashion. The extended system serves different functions, such as recovering information on the person observed, simulating the observed facial expression and processing the emotional response of the viewer when seeing the face. Different brain areas have been identified as part of the central system (superior temporal sulcus, fusiform gyrus and occipital gyrus) and as part of the extended system (medial prefrontal cortex, anterior temporal cortex, precuneus, frontal operculum and insula) (Haxby and Gobbini, 2011).

Part of the data used in the development of these models on facial recognition come from neuroimaging studies that have compared familiar faces of varying nature with unknown faces. For instance, these studies used faces of celebrities (Gorno-Tempini, 1998; Leveroni, 2000; Sergent, 1992), laboratory trained faces (Dubois, 1999; Rossion, 2001), familiar faces (Nakamura, 2000), and more recently, familiar faces with social and emotional relevance (Gobbini et al., 2004; Leibenluft et al., 2004; Taylor et al., 2009). The aim of the last three studies was to test the effect of knowledge about the viewed person, as well as the effect of the emotional responses associated to this person in the recognition of familiar faces. Other studies have used loved familiar faces with the aim of determining the neural networks associated with the processing of stimuli related to attachment and love (Bartels and Zeki, 2000, 2004; Aron et al., 2005; Strathearn et al, 2008). These studies revealed a set of brain areas that where engaged both in the processing of the face of the romantic partner and the face of the own child (e.g. medial insula, dorsal anterior cingulated gyrus and striatum), as well as brain structures that were specifically related to romantic or maternal love (e.g. orbitofrontal cortex, periaqueductal gray matter, and hippocampus). A study conducted by Zeki and Romaya (2008) investigated the brain areas that are activated when seeing faces of unpleasant individuals, showing activation of the medial frontal gyrus, putamen, pre-motor cortex, frontal poles and medial insula. Some of these activations, more specifically those located in the medial insula and the putamen, were very similar to those obtained in a previous study when viewing loved faces (Bartels and Zeki, 2004).

All studies mentioned above provide neuroimaging data that are consistent with the model of Gobbini and Haxby, showing the implication of brain areas associated with the recognition of identity and analysis of invariant features of the face (fusiform gyrus, superior temporal sulcus, inferior occipital cortex) as well as with the processing of emotion from identity (insula, amygdala, reward system) when recognizing familiar faces.

Another line of research has focused on the study of the neural correlates of the processing of different facial expressions such as fear, anger, disgust or joy (for a revision see Phan et al., 2002). The meta-analysis carried out by Phan and colleagues shows the existence of a certain specialization of some brain areas when processing specific emotions. For instance, the amygdala seems to be more engaged in the processing of fear expressions while the basal ganglia intervene mainly in the processing of expressions of happiness. Neuroimaging studies on processing of emotional expressions and neuropsychological studies on patients with brain damage have shown that the insula plays a role when recognising and feeling disgust (Phillips et al., 1997, 1998; Calder, Keane, Manes, Antoun, & Young, 2000; Adolphs, 2002). Nevertheless, more recent studies have shown that the insula is also activated when experiencing positive emotions (for a revision see Wager et al., 2003).

The responses of the autonomic and somatic nervous systems are sensitive to differential processing of the affective valence. Passive viewing of unpleasant pictorial stimuli has been related to a deceleration of the heart rate, an increase of corrugator muscle activity and a potentiated startle reflex. The processing of visual stimuli with a positive emotional content is accompanied by a biphasic heart rate pattern, made up of a first deceleration followed by an acceleration, an increase in zygomatic muscle activity and an inhibition of the startle reflex. On the other hand, some measures of the autonomous nervous system such as skin conductance or pupil dilation, react in a similar way when participants are exposed to intense emotional stimuli regardless of their valence (Lang and Bradley, 2010). These findings show that, whereas one part of our nervous system is engaged in a similar way when facing highly emotional cues, there are also circuits which are sensitive to the hedonic value of stimuli. At a central level, the amygdala and the insula seem to be two structures which are engaged in a similar way when processing and modulating emotional responses of positive as well as negative emotions (Davis and Whalen, 2001; Phan et al., 2004; Phillips et al., 1997; Bartels and Zeki, 2000, 2004; Aron et al., 2005). Basal ganglia, medial prefrontal cortex and medial orbitofrontal cortex seem to respond more intensely when facing gratifying stimuli as opposed to stimuli that imply punishment (Kringelbach and Rolls, 2004; Kringelbach, 2005; Ishikawa et al., 2008).

In spite of the contributions of the studies on facial perception and processing of familiar faces previously mentioned, none of them informed on changes caused in the peripheral nervous system during visualization of loved faces. The study of emotional phenomena requires the recording of physiological changes, since these are, partly, what defines the emotional reaction (Adolphs, 2002). In addition, to our knowledge, there have been no attempts to compare emotional responses prompted by familiar faces with social and emotional relevance (emotion from identity) with the responses to other types of emotional faces (emotion from attractiveness). The absence of studies comparing familiar stimuli with other emotional ones makes it difficult to identify those processes that are specifically related to emotion from identity recognition. Lastly, we are unaware about the existence of any fMRI study that has inquired into the comparison between pleasant and aversive responses prompted by the visualization of familiar and unfamiliar faces without any facial expression.

In the present study, our aim was to study the responses of the autonomous, somatic and central nervous system specifically related to processing of emotion from identity. To that end, we compared familiar faces (loved and unpleasant faces) with unknown faces (attractive and physically unpleasant faces). We were also interested in the possible differential modulation of both peripheral and central responses when viewing facial stimuli with varying emotional valence (pleasant faces versus unpleasant faces), regardless of their familiarity value.

Taking into account previous results, we expected to find a modulation of autonomic and somatic variables depending on the motivational significance as well as the affective valence of the faces. We also hypothesized that familiar faces would activate those brain areas sensitive to the processing of visual familiarity, recovery of knowledge about the person and the emotional response to the face, as stated in the model by Gobbini y Haxby. Finally, we expected that the processing of stimuli with positive affective valence and high familiarity value (loved faces), would be reflected in the activation of some of the brain areas that constitute the reward system (e.g. the striatum or medial orbito-frontal cortex).

5.2 Method

5.2.1 Participants

20 students, 10 male and 10 female, with an average age of 22.80 years (Standard Deviation = 2.91) took part in this study. All of them were right-handed, had normal or corrected-to-normal vision and none reported being under pharmacological or psychological treatment. They all gave their written informed consent to participate in this research and the study was approved by the Ethics Committee of the University of Granada. The participation in the study was compensated with academic credits plus 50€ in cash.

We selected those subjects that: (1) were in a highly satisfactory romantic relationship for at least one year, (2) had at least three more people in their lives for whom they felt high levels of positive affect and (3) knew four people in their close environment for whom they experienced high levels of negative affect

5.2.2 Stimuli and tasks

Participants saw faces belonging to four categories: loved familiar, unpleasant familiar, attractive unknown and unpleasant unknown. Each category was made up of four photographs of four different people. The category of loved familiar faces could include, besides the face of the partner, faces of parents, siblings, friends and family members of second-degree relatives. The category of unpleasant familiar faces was made up of exfriends, classmates, expartners and relatives. The images of familiar people were provided by the participants a few days before the first experimental session. All pictures were chosen so that they had, as much as possible, a similar facial expression, orientation of the face and gaze direction.

The attractive and unpleasant unknown faces were chosen by the participants from a database of very attractive faces (models) and 20 very unpleasant faces (jail interns, drug-addicts, boxers) found on the Internet. All faces had a neutral expression, looked straight towards the camera and were matched, as far as possible, in luminosity and contrast.

In the scanner task, a picture of a baby from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2008) was included. This image was used as a “catch-stimulus” and the hemodynamic responses associated to its processing were not analysed.

All images were matched in terms of colour, size and background using the Corel Draw PhotoPaint software (Version 7).

During the psychophysiological recording session images were presented on a 19” screen placed at a distance of 60 cm from the participant. The experiment started with a 5 minutes base-line followed by 64 picture presentation trials with the following structure: 4 seconds base-line, 4 seconds image presentation and 4 seconds post-image. Participants were randomly assigned to one of four stimuli presentation sequences, created following a set of four 4x4 Latin Square, and each sequence started with a different face category. Participants were asked to look at the images as long as they remained visible on the screen. This recording session lasted around 30 minutes.

In the scanner, subjects carried out two different tasks, an event-related one and one with block-presentation. In this article we focus on the results obtained in the event-related task, which consisted of a pseudo-random sequence made up of 180 trials: 160 trials were emotional faces (10 in each image) and 20 catch-type trials were the face of a baby Stimuli were presented through magnetic resonance-compatible liquid crystal display goggles (Resonance Technology Inc., Northridge, California, USA). Each picture was presented for 1 second with a random interval between images of 4 to 5 seconds. Subjects had to respond every time a baby face appeared and their responses were recorded through the Evoke Response Pad System (Resonance Technology Inc., Northridge, California, USA). The total duration of the task was 20 minutes.

5.2.3 Physiological measures

Corrugator and zygomatic muscle activity, skin conductance and ECG were recorded. Raw corrugator and zygomatic muscle activity was amplified by 5000 and filtered between 28 and 500 Hz using a Coulbourn V75-04 bioamplifier. Subsequently, the EMG signals were rectified and integrated with a Coulbourn V76-24 integrator. Sampling rate was 100 Hz and integration constant 500ms. Heart rate was derived from the

ECG registered with a Coulbourn V75-04 in derivation II and sampled at 1000 Hz. Frequencies below 2.5 and above 30 Hz were filtered using a band-pass filter Coulbourn V75-48. Skin conductance was registered with a Coulbourn V75-23 amplifier placing electrodes on the hypothenar eminence of the left hand with a sampling rate of 50Hz.

5.2.4 Subjective evaluations

Each image was evaluated using the SAM (Self Assessment Manikin, Bradley & Lang, 1994) for the dimensions of valence (pleasantness-unpleasantness), activation (relaxation-activation) and dominance (dominant-dominated). Each dimension was evaluated on a pictorial scale with a ranking from 1 to 9. On the valence scale, one extreme was defined as being "happy, pleased, satisfied and optimistic" and the other extreme as being "unhappy, sad, uncomfortable, unsatisfied or morose". On the arousal scale, one extreme is defined by the labels "stimulated, excited, agitated and activated" and its opposite by "relaxed, calm, deactivated or inactive". Finally, the dominance scale uses on one extreme the adjectives "important, dominant or autonomous", and on the other "dominated, influenced, taken care of, submissive or guided".

We also evaluated feelings of positive affect (love) and negative affect (hate) towards familiar people on two scales designed to that end. Both scales included 6 items that could be assessed with a likert scale from 0 ("do not agree at all") to 3 ("very much in agreement"). These scales were developed based on the Passionate Hate Scale (PHS) proposed by Zeki and Romaya to assess feelings of hate (Zeki, Romaya, 2008; Hatfield and Sprecher, 1986). These authors based their work on Sternberg's triangular theory of hate to developed 12 items that assessed the emotion of hatred according to three factors: (1) negation of intimacy, (2) passion or intensity of the fear or anger and (3) devaluation (Sternberg, 2004). For the positive affect scale, we developed mirroring statements to assess feeling of love according to these factors: (1) intimacy, (2) intensity of emotion (passion) and (3) positive evaluation. Assessments were carried out at two moments in time, i.e, in the first session of peripheral recording and in the MRI session.

5.2.5 fMRI scanning

The hemodynamic brain response was recorded with a 3T Philips scanner. An echo-planar sequence was used to allow acquisition, at each volume level, of 30 transversal slices. Repetition time was established at 3 sec, with an acquisition time of 2.9 sec.

After the functional scanner, we performed a T1 sagital plane anatomical scan to obtain a high resolution structural image.

5.2.6 Procedure

In a first telephone conversation or e-mail, participants were asked to fill in a questionnaire to find out if they fulfilled the requirements we had established (see section on Participants). Selected subjects were then informed of the characteristics of the study and invited to a first experimental session. When they arrived at the lab, they were invited to sit in a comfortable armchair in a dimly-lit room. They were asked to fill in the informed consent form and the scales of positive and negative affective valence for each of the loved and the unpleasant familiar people they had chosen for the study. In the next step, they had to choose the four most pleasant and the four most unpleasant faces from a database of 20 highly attractive unknown faces and another database of 20 unpleasant unknown faces. Then, electrodes were placed and the passive viewing task was conducted. After the physiological recording, participants assessed the faces viewed during the task according to three affective dimensions (valence, arousal and dominance), using the Self Assessment Manikin (Bradley and Lang, 1994). Upon task completion, we thanked them for their participation, handed them the participation certificate and gave them their next appointment.

In the second session, participants were welcomed, then asked to fill out some security questions on the use of the scanner, plus an experimental interview and (for the second time) the positive and negative affect scales. Once we had explained the instructions of the task, the subject was placed in the scanner. After completing the scan, subjects received a 50€ compensation for their participation.

5.2.7 Data and analysis reduction

SAM results for each scale were analyzed with a two-factor ANOVA (Scale and Gender). Furthermore, for the Arousal scale we added an ANOVA for the Familiarity factor with two levels: familiar faces (loved and unpleasant) and unknown faces (attractive and unpleasant). Zygomatic and corrugator EMG responses and skin conductance were established by averaging by half seconds the 8 seconds following image presentation and subtracting the activity obtained 4 seconds preceding stimulus presentation. Heart rate was obtained averaging by half-seconds the 8 seconds following stimulus presentation and subtracting the last second of the baseline. Heart rate, conductance and EMG data of the corrugator and zygomatic muscles were analyzed with an ANOVA with two factors of repeated measures, face category (4) and time (16) plus an intergroup factor, which was gender.

fMRI data analysis Functional data were analyzed using SPM8 and related toolboxes (Wellcome Department of Imaging Neuroscience[1]). Outlier functional scans and slices were repaired with the Artifact Repair Toolbox, (Gabrieli Cognitive NeuroScience Lab[2]), after which the images were slice-time corrected taking the middle slice as reference (using SPM5's phase shift interpolation with the unwrap option) and then realigned to the first image in the session. The anatomical T1 image was coregistered (Collignon et al., 1995) with the whole brain EPI, which in turn was coregistered with the mean of these limited field-of-view EPIs. Each participant's T1 scan was bias corrected, then spatially normalized to MNI-space and segmented into gray matter (GM), white matter (WM), and cerebrospinal fluid using the unified procedure in SPM5 (Ashburner and Friston, 2005). The parameters for normalization of the anatomical image were used to transform the functional scans to MNI space. Normalized images were spatially smoothed using an 8 mm Gaussian kernel. Data were high-pass filtered (64 s cut-off period).

A massive univariate general linear model (GLM) was applied, using for each stimulus category a set of design covariates that was obtained by convolving the canonical hemodynamic response function (Friston et al., 1998). Also the six motion-correction parameters were included in the design matrix. Parameters of the GLM were estimated with a robust regression using weighted-least-squares, which was corrected for temporal autocorrelation in the data (Diedrichsen&Shadmehr[3]). A t-statistic was then obtained for each voxel for the contrast of interest in each subject.

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[1] http://www.fil.ion.ucl.ac.uk/spm

[2] http://cibsr.stanford.edu/tools/ArtRepair/ArtRepair.htm

[3] http://www.bangor.ac.uk/~pss412/imaging/robustWLS.html

5.3 Results

5.3.1 Subjective measures

Table 1 shows the mean and standard deviation of subjective ratings in valence and arousal for each of the four face categories: loved familiar, unpleasant familiar, attractive unknown, and unpleasant unknown.

Valence. The two-way ANOVA of Face Category (4) x Gender (2) showed a significant effect of Face Category (F(3,54) = 116.95, $p < 0.000$, ηp2= 0.867), Gender (F(1,18) = 9.128, p< 0.007, ηp2= 0.336), and Face Category x Gender (F(1,18) = 4.837, p<0.041, ηp2= 0.212). All pleasant faces, both familiar and unknown, were rated significantly higher in valence compared to unpleasant faces (p< 0.000 in all comparisons). Loved familiar faces were significantly different from the rest of face categories (p< 0.000 in all comparisons). There was no difference in valence ratings between familiar and unknown unpleasant faces (p< 1.00). The one-way ANOVA (Gender) for each face category revealed differences in the rating of unpleasant unknown faces. Compared to males, females perceived unpleasant unknown faces as more negative.

Arousal. The two-way ANOVA of Face Category (4) x Gender (2) revealed a significant effect of Face Category (F(3,54) = 6.571, p<0.003, ηp2= 0.267). No significant Gender effect was observed. Unpleasant familiar faces were rated as significantly more arousing than unknown faces, both attractive and unpleasant (p< 0.006 in all comparisons). Nevertheless, arousal ratings of unpleasant familiar faces were not significantly different from loved familiar faces (p<0.063). No differences in arousal ratings for the rest of face categories were observed.

The one-way ANOVA for familiarity with two levels (Familiar and Unknown) showed a significant effect of Familiarity (F(1,19) = 7.454, p<0.013, ηp2= 0.282): familiar faces were rated as more arousing than unknown faces.

Dominance. Statistical results did not reveal any significant effect.

Positive and negative Affective scale: positive and negative affect towards familiar faces was rated using two likert scales ranging from 0 to 3. Two-way ANOVA results for

Affect (Positive vs. Negative) and Time (Session 1 vs. Session 2) showed a significant effect of Affect (F(1, 18) = 129.56, $p<0.000$, ηp2= 0.878). Positive ratings for loved familiar faces were significantly different from negative ratings for unpleasant familiar (2.7 vs. 1.2). These results indicate that positive affect intensity towards loved people is superior to negative affect intensity towards unpleasant familiar people.

Table 1. Subjective ratings of Valence and Arousal for the faces

	Women (N=10)		Men (N=10)	
Pictures	**Valence**	**Arousal**	**Valence**	**Arousal**
Loved Familiar	8.2 (0.7)	4.8 (1.6)	8 (0.7)	4.1 (2.3)
Unpleasant Familiar	2.7 (0.8)	5.3 (1.6)	3.3 (0.8)	6.3 (1.1)
Unknown Pleasant	5.6 (0.9)	3.4 (1.7)	6 (0.7)	4.4 (1.2)
Unknwon Unplesant	2.6 (1.3)	4.1 (1.6)	3.8 (1)	4.9 (1.1)

Mean (standard deviation) of subjective ratings of Valence and Arousal for Loved Familiar, Unpleasant Familiar, Unknown Pleasant and Unknown Unpleasant reported by women and men (score range: 1-9)

5.3.2 Psychophysiological measures

Figure 1 presents responses in heart rate, electric skin conductance, zygomatic muscle and corrugator muscle activity for the 8 seconds following picture presentation.

Zygomatic muscle activity. The zygomatic muscle was significantly activated only by loved familiar faces. ANOVA results showed a significant effect of Face Category (F(3,54) = 19.769, $p< 0.000$, ηp2= 0.523), Time (F(15,270) = 10.585, $p< 0.000$, ηp2= 0.370), and Face Category x Time interaction (F(45,810) = 8.455, $p< 0.000$, ηp2= 0.320). Gender did not yield any significant effect. Paired comparisons revealed a significant difference between loved familiar faces and the rest of face categories ranging from second 1 to second 8 following picture presentation ($p< 0.027$ in all comparisons). No significant differences were observed for the rest of the face categories.

Corrugator muscle activity. As observed in Figure 1, the corrugator muscle was activated by unpleasant faces (familiar and unknown) and inhibited by pleasant faces. Unpleasant unknown faces prompted the larger activation, while loved familiar faces resulted in the larger inhibition. ANOVA results showed a significant effect of Face Category (F(3,54) = 11.453, $p < 0.000$, ηp2= 0.389), Time (F(15,270) = 4.674, $p < 0.000$, ηp2= 0.206), Gender (F(1,18) = 5.239, $p < 0.034$, ηp2= 0.225), Time x Gender (F(15,270) = 2.914, $p < 0.000$, ηp2= 0.139), and Face Category x Time (F(45,810) = 7.370, $p < 0.000$, ηp2= 0.291). Paired comparisons showed significant differences between unknown unpleasant and loved familiar faces ranging from second 1 to second 8 following picture presentation ($p < 0.045$ in all comparisons). Differences between unpleasant familiar and loved familiar faces were found at seconds 1.5 through 8 ($p < 0.032$ in all comparisons). Differences between attractive unknown and loved familiar faces were found at seconds 1.5 through 6.5 ($p < 0.05$ in all comparisons). More narrowly localized differences between unknown unpleasant and attractive unknown faces were found at seconds 2 through 3 and 4.5 through 5 ($p < 0.045$ in all comparisons). The same was true for unpleasant familiar and attractive unknown faces at second 4 ($p < 0.048$). The significant Time x Gender interaction can be explained as a tendency of male subjects to demonstrate a larger corrugator inhibition when presented with pleasant faces.

Electric skin conductance. Figure 1 presents skin conductance responses for all four face categories during the 8 seconds following picture presentation. We observe that familiar faces, both loved and unpleasant, prompted a larger response compared to unknown faces. The ANOVA results showed a significant effect of Face Category (F(3,54) = 3.699, $p < 0.038$, ηp2= 0.170), Time (F(15,270) = 6.057, $p < 0.000$, ηp2= 0.252), and Face Category x Time interaction (F(45,810) = 4.646, $p < 0.000$, ηp2= 0.205). Differences between categories were significant at seconds 4 through 8 following picture presentation. Paired comparisons revealed significant differences between unpleasant familiar and attractive unknown faces at seconds 4.5 through 8 ($p < 0.049$ in all comparisons).

As can be seen in the ANOVA results for Familiarity (F(1,18) = 5.407, $p < 0.032$, ηp2= 0.231), there were significative differences in skin conductance levels between familiar and unfamiliar faces, explained by a higher response of this variable to familiar faces.

Heart rate. Figure 1 shows heart rate response to all four face categories. As can be seen, loved familiar faces prompted a biphasic pattern with an initial deceleration followed by an acceleration. Unpleasant familiar faces elicited a similar pattern, but with a markedly reduced acceleration. Unknown faces, both pleasant and unpleasant, prompted a decelerative pattern, which started after presentation of the image. Although these patterns replicate results obtained in previous studies, the ANOVA Category of faces (4) x Gender (2) did not show any significant effect in this case.

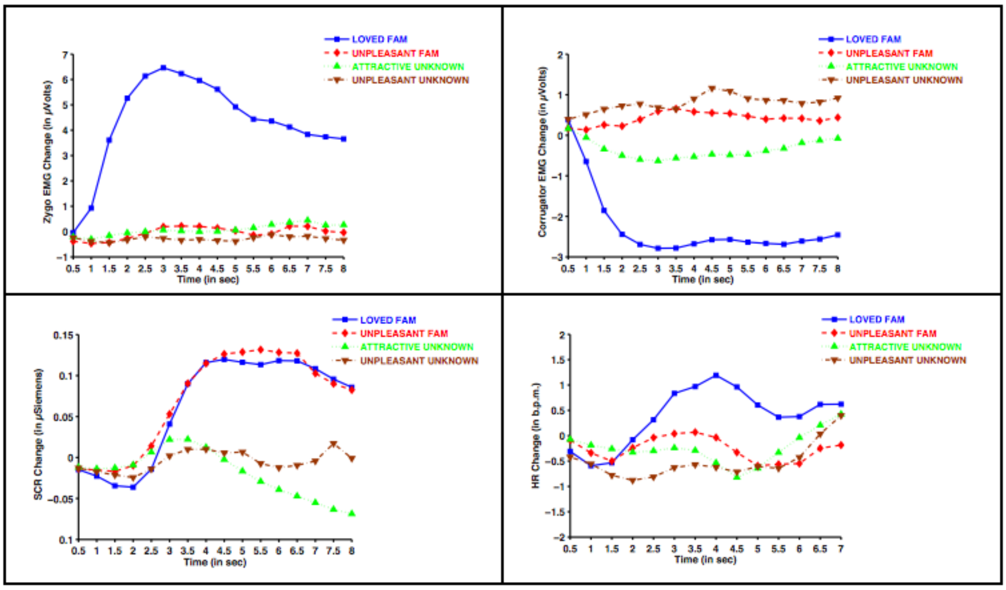

Figure 5.1: Responses in zygomatic (upper left hand corner), corrugator muscle activity (upper right), electric skin conductance (lower left) and heart rate (lower right) during the 8 seconds following the presentation of loved familiar, unpleasant familiar, attractive unknown and unpleasant unknown faces.

5.3.3 Functional Magnetic Resonance Imaging

Familiar vs. Unknown Faces

With the aim of distinguishing those areas related to the processing of familiarity and emotion from identity, we contrasted familiar with unknown faces. Figure 2 shows the areas activated when participants viewed familiar emotional faces in comparison to emotional unknown faces.

Activation for all contrasts between familiar and unknown faces, together with their MNI coordinates and their statistical significance are specified in Table 2. Activations in these contrasts have been determined applying an uncorrected $p < 0.01$. In the general contrast between familiar and unknown faces, the areas activated were: insula, inferior frontal operculum, inferior, medial and superior frontal gyrus, inferior and medial temporal cortex, medial and superior temporal poles, fusiform gyrus, supplementary motor area and cerebellum.

Loved familiar vs. attractive unknown

Figure 3 shows relevant brain areas that were activated while viewing loved familiar faces as opposed to attractive unknown faces: insula, inferior frontal operculum and medial orbitofrontal cortex. There was also an activation peak in the fusiform gyrus, precuneus, angular gyrus and parahipocampal gyrus. Finally, some structures related to motor control, such as the supplementary motor cortex, medial frontal gyrus and cerebellum, were also activated.

Unpleasant familiar vs. unpleasant unknown

Figure 4 shows activation peaks that are significant for this contrast in the insula, operculum, medial frontal gyrus, posterior cingulate, medial temporal gyrus and supplementary motor cortex.

Pleasant vs. Unpleasant Faces

Figure 5 shows those activation areas that are significant for the contrast between pleasant faces (loved and unknown) and unpleasant ones (familiar and unknown). Table 3 shows the MNI coordinates and t values for those areas activated in all contrasts that include the comparison between pleasant and unpleasant faces. Activation peaks for the contrast between pleasant and unpleasant faces were found in the inferior frontal operculum, precentral gyrus, angular gyrus and medial and superior occipital cortex.

Loved familiar vs unpleasant familiar

With this contrast we obtained the activation due to the positive valence effect elicited by loved familiar faces. The activation map can be seen in Figure 6 and the specification of areas and their levels of significance as well as MNI coordinates are to

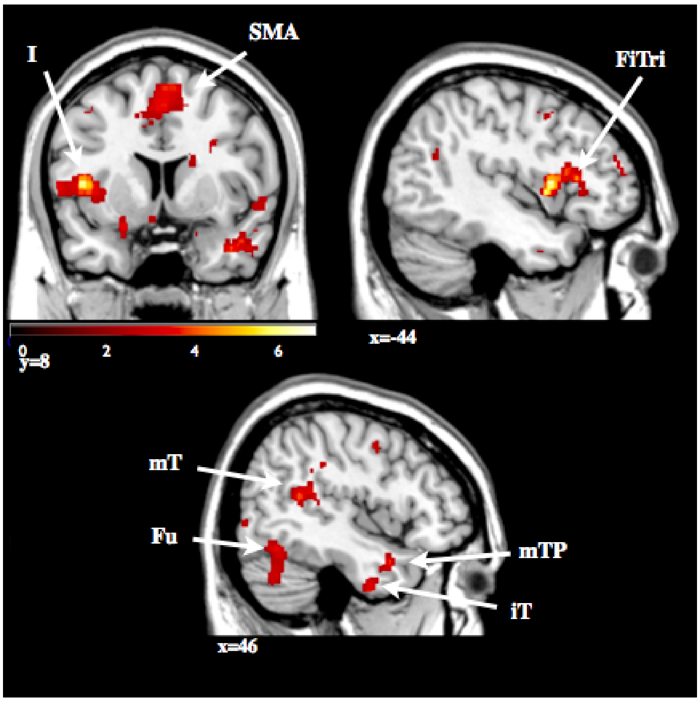

Figure 5.2: Activations for the contrast Familiar Faces > Unknown Faces. Activations revealed when participants saw pictures of their own loved and unpleasant familiar people versus unknown attractive and ugly people, superimposed on a template structural brain. Abbreviations: I = insula; SMA = supplementary motor area; FiTri = frontal inferior triangularis; mT = medial temporal; Fu = fusiform gyrus; mTP = medial temporal pole; iT = inferior temporal.

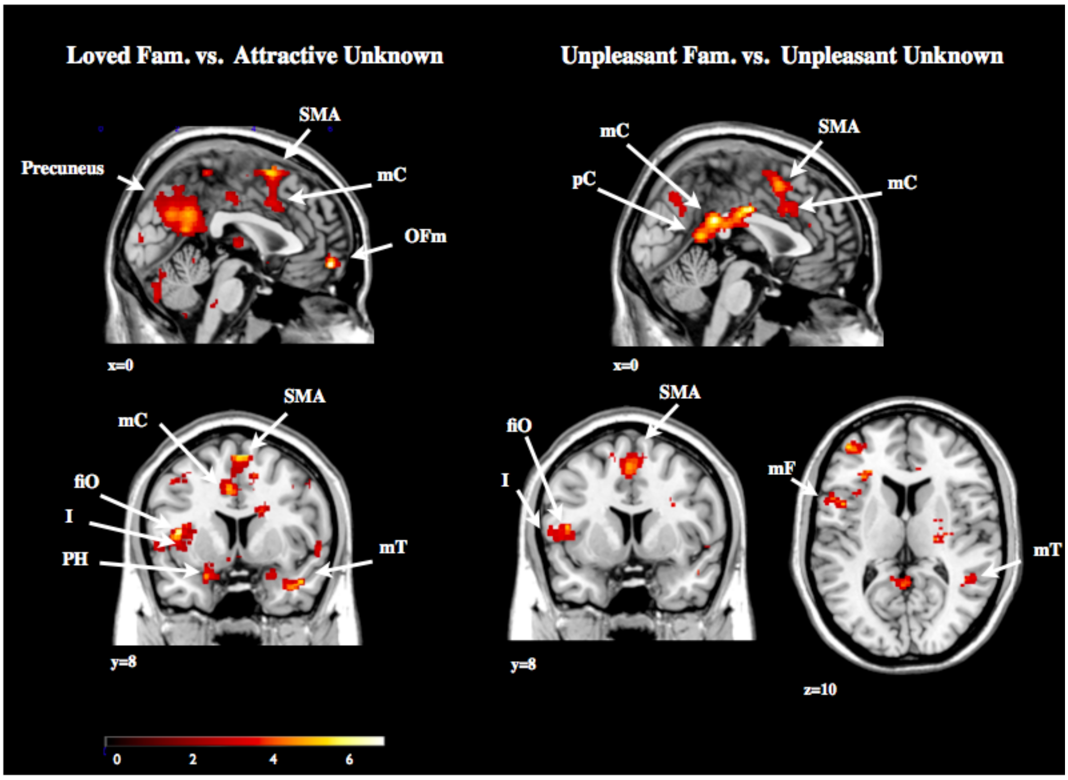

Figure 5.3: On the left side, sagital and coronal brain templates with the activations for the contrast Loved Familiar faces > Attractive Unknown faces. On the right side sagital, coronal and axial brain templates with the activations for the contrast Unpleasant Familiar > Unpleasant Unknown. Abbreviations: OFm = orbitofrontal medial; pC = posterior cingulated; mC = medial cingulate; fiO = frontal inferior operculum; PH = parahippocampal gyrus; C = nucleus caudate; sTP = superior temporal pole; mT= medial temporal; mF = medial frontal.

Table 2. Activations for the three different contrasts included in the Familiar minus Unknown Faces contrast.

	Familiar > Unknown Faces								***Loved Familiar > Attractive Unknown***								***Unpleasant Familiar > Unpleasant Unknown***							
	Left				**Right**				**Left**				**Right**				**Left**				**Right**			
Activations	**x**	**y**	**z**	**T**	**x**	**y**	**z**	**T**	**x**	**y**	**z**	**T**	**x**	**y**	**z**	**T**	**x**	**y**	**z**	**T**	**x**	**y**	**z**	**T**
Insula	-44	8	8	7					-36	24	8	4.26					-28	30	8	5.57	34	-12	18	3.90
Front. Inf. Operculum	-38	16	14	4.94					-40	8	10	6.56					-46	8	10	4.24				
Medial Orbitofrontal									0	56	-10	6.71												
Frontal Inferior Tri.	-44	22	10	4.75	56	22	0	3.49																
Medial Frontal Gyrus	-40	48	24	5.25					-34	48	30	4.28					-40	50	14	5.64				
Sup. Frontal Gyrus					32	-4	58	3.68									-14	44	22	4.68				
Inferior Temporal					50	0	-38	4.89																
Medial Temporal	-44	-58	22	2.89	52	-32	0	3.51					46	8	-26	5.39					46	-46	14	4.19
Medial Temp. Pole					40	6	-30	4.78																
Sup. Temp. Pole					56	14	-6	4.08																
Medial Cingulate									-4	10	40	5.27					0	-12	34	5.44				
Posterior Cingulate																	0	-40	26	5.79				
Fusiform					46	-62	-18	3.83	-44	-50	-24	4.92												
Parahipocampal									-22	6	-22	4.88												
Parietal Superior									-28	-58	52	3.96												
Precuneus									-4	-54	26	5.41												
Precentral Gyrus													38	4	36	5.57								
Suppl. Motor Area	-10	-6	62	4.24	8	10	62	4.34					4	10	64	7	0	10	54	4.21				
Supramarginal																					54	-38	32	4.53
Angular Gyrus									-40	-58	32	4.19												
Medial Occipital									-24	-56	40	3.99												
Cerebellum	-24	-66	-48	4.2	46	-62	-34	3.29	-22	-64	-46	5.47	40	-46	-28	5.58								

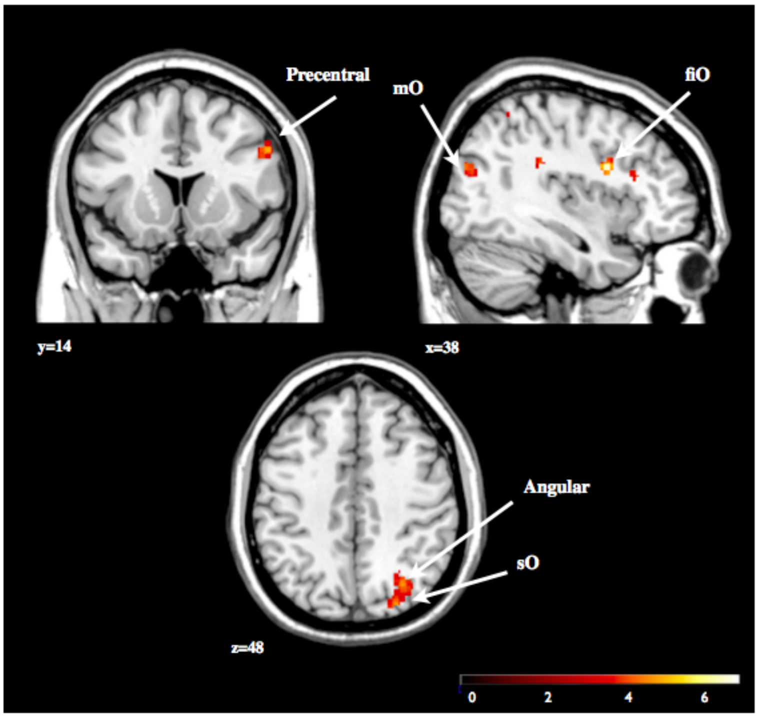

Figure 5.4: Activations for the contrast Pleasant Faces > Unpleasant Faces. As can be seen, this contrast compared with the contrast between Familiar and Unknown Faces resulted in the activation of a smaller set of brain areas. Abbreviations: mO = medial occipital; sO = superior occipital.

be found in Table 3. Activations were found in: inferior frontal operculum, precentral gyrus, postcentral gyrus, medial orbitofrontal cortex, medial cingulated, calcarine fissure, precuneus and cerebellum.

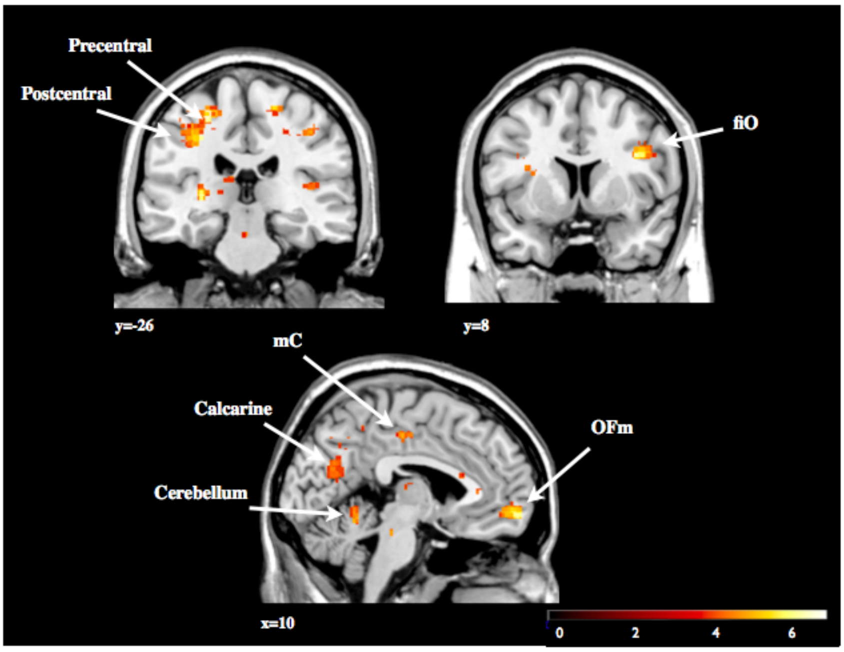

Figure 5.5: Activations for the contrast Loved Familiar > Unpleasant Familiar Faces. Again the medial orbitofrontal was activated during the processing of loved familiar faces.

Attractive unknown vs. unpleasant unknown

The contrast between attractive unknown and unpleasant faces resulted in an activation of the superior occipital gyrus and superior parietal gyrus.

5.4 Discussion

In this study on the emotional processing of faces, we were interested in investigating the peripheral and central modulation of emotion from identity as well as the effects of affective valence (positive vs. negative) when viewing known and unknown faces.

Processing of familiarity and of emotion from identity

By comparing the reactions to familiar faces (loved and unpleasant) vs. unknown faces (attractive and unpleasant), we were able to compare responses related to emotions elicited by recognition with emotions elicited by physical traits of the face, as well as identifying those areas related to the recovery of knowledge about the person. Motivational relevance of familiar stimuli can be seen in the subjective feelings as well as in the autonomic and central responses. Familiar faces, compared to unknown ones, were evaluated as more activating, prompting higher responses of skin conductance and mobilizing a network of structures associated with processing of emotional stimuli: insula, operculum, frontal cortex (Kurth et al., 2010; Haxby and Gobbini, 2011; Shamay-Tsoory et al., 2009). Furthermore, we observed an increase in activation of brain areas associated to facial identity recognition inferior and medial temporal cortex, fusiform gyrus and temporal poles (Adolphs, 2002; Bartels and Zeki, 2004; Leibenluft et al., 2004; Gobbini et al., 2004; Gobbini and Haxby, 2007). The temporal poles, apart form playing a role in the recognition of identity through visual and auditory stimuli, they are also related to socio-emotional processing, and more specifically, the right temporal pole seems to be related to the formation, recovery and modulation of emotionally and socially relevant memories (Olson et al., 2007). The engagement of areas associated with motor control, such as the supplementary motor area and the cerebellum, may be related to the motor mobilization that prepares the body for interaction and communication with someone familiar. Different studies using passive viewing of loved familiar faces (children and partners) have also informed about activation of the cerebellum and areas of the motor cortex (Bartels and Zeki, 2000; Strathearn, 2008)

Processing of familiarity and positive emotion from identity

Loved faces and attractive faces alike are highly gratifying stimuli that activate the central reward systems (Grammer and Thornhill, 1994; Kampe et al., 2001; Aharon et al., 2001; Aron et al., 2005; Bartels and Zeki, 2000, 2004). In the case of loved faces, positive emotional experience is related to the access to pleasant memories associated to the person displayed and therefore depends on conscious or unconscious recognition of the face identity. Nevertheless, positive emotions related to the visualization of attractive faces are related with physical and personality traits that can be inferred from them (Dion, Bersheid and Walster, 1972; Said et al., 2011). Therefore, comparing activation when viewing loved faces with activation when seeing attractive faces, serves to identify those areas specifically related to the access to episodic and autobiographic memories connected to the displayed person and the evocation of emotional responses elicited by these memories.

Both the subjective measures and those of the autonomic and somatic nervous system showed differences in emotional perception of stimuli. The subjective perception of happiness, well-being and satisfaction during the visualization of loved familiar faces was higher than when viewing pleasant unknown faces. The peripheral nervous system, in its autonomic and somatic branches, responded in a differentiated way to these two types of stimuli. Loved familiar faces elicited a higher response in skin conductance, stronger zygomatic activation and higher corrugator inhibition. The contrast between loved familiar and pleasant unfamiliar faces resulted in activation of the insula and operculum, brain areas engaged in sensorial integration, emotional modulation and social cognition (Mesulam et al., 1982; Flynn, 1999; Schienle et al., 2002; Kurth et al., 2010; Haxby and Gobbini, 2011). We also found activation of the medial orbitofrontal cortex, an area specifically related with processing of the hedonic value of stimuli (Kringelbach, 2005). There was also a significant activation of the precuneus, the angular gyrus and the hyppocampal gyrus, structures associated with recovery and processing of episodic memories (Squire and Zola–Morgan, 1991; Gobbini and Haxby, 2007; Seghier, 2013). Finally, there was also activation of different areas related to planning and motor control, such as the medial frontal gyrus, supplementary motor area, precentral gyrus and cerebellum (Rushworth et al., 2004; Lang y Bradley, 2010). Zeki and Romaya (2008) interpret the activation of the medial frontal gyrus when viewing an unpleasant familiar face as a mobilization of the motor system for a possible fight or flight reaction to a threatening person. Our hypothesis is that the activation of these areas may be related to motor planning for social interaction and communication, and, among other things, to production of emotional expressions.

Processing of familiarity and negative emotion from identity

Unpleasant familiar faces elicited subjective responses of dissatisfaction, unpleasantness and sadness that were similar to those elicited by unpleasant unknown faces. Nevertheless, in arousal sensitive measures (subjective arousal and skin conductance) unpleasant familiar faces elicited higher responses than unpleasant unknown faces. Similarly to loved familiar faces, unpleasant familiar faces prompted activation of areas related to the processing of episodic memories (posterior cingulate and medial temporal gyrus), to emotional modulation (insula, operculum) and to motor planning and control (supplementary motor area and medial frontal gyrus).

Processing of affective valence: positive vs negative emotion

The comparison of responses related to the processing of pleasant vs. unpleasant faces resulted in higher scores of subjective positive valence, higher zygomatic activation and corrugator inhibition, and higher peaks of activation in operculum, precentral gyrus, angular gyrus and medial and occipital cortex for pleasant ones. Activation of the precentral gyrus and frontal operculum may be related to higher activation of the zygomatic muscle, which is activated when smiling (Haxby y Gobbini, 2011). No significant differences were found in measures sensitive to arousal, such as skin conductance and subjective arousal.

Processing of positive valence associated to identity: loved familiar vs unpleasant familiar faces

The results on positive and negative affect scales showed that the intensity of positive affect towards loved people was higher than the intensity of negative affect towards unpleasant familiar people. Nevertheless, the SAM arousal score did not show significant differences between both categories of familiar faces. The same was true for skin conductance. Facial muscle activity showed a differential response to loved familiar faces vs. unpleasant familiar ones: there was activation of the zygomatic and inhibition of the corrugator muscle while viewing loved familiar faces. Another statistically significant activation was observed in the medial orbitofrontal cortex, the operculum, precentral gyrus, postcentral gyrus, precuneus and cerebellum for loved familiar faces. This group of activated areas reflects the different processes activated while viewing loved familiar faces that, following Gobbini and Haxby's model (2011), are related to recovery of memories about the person (precuneus), the processing of hedonic value of the face (medial orbitofrontal cortex), emotional response (operculum, precentral gyrus and postcentral gyrus and also to motor planning (cerebellum) (Lang and Bradley, 2010; Kringelbrach, 2005; Haxby and Gobbini, 2011).

Processing of positive valence associated to physical appearance: pleasant unknown vs. unpleasant unknown

Valence scores for these two types of faces were statistically different: while pleasant unknown faces provoked a feeling of pleasure and well-being, unpleasant faces prompted feelings of displeasure. There was no difference registered neither in subjective arousal nor in skin conductance.

In seconds 3.5 and 4.5, the corrugator activation when seeing unpleasant unknown faces was significantly higher than the inhibition prompted by pleasant unknown faces. At a cortical level, this contrast resulted in a significant activation of the superior occipital cortex and superior parietal cortex.

Altogether, the results of this study show the existence of a widely distributed network of brain areas all in charge of processing familiarity and emotion from identity. This network, which seems to be modulated independently from affective valence, includes the insula, operculum, inferior temporal cortex, fusiform gyrus and areas of motor control such as the supplementary motor area, cerebellum and medial frontal gyrus. Moreover, our results show the specialization of the orbito-frontal cortex in processing of positive stimuli with social and emotional relevance (loved familiar faces). The motivational relevance of these stimuli can be detected even when compared to other types of highly gratifying stimuli (attractive faces).

Chapter 6

Discusión general y conclusiones

El objetivo general de este trabajo fue investigar las bases fisiológicas de un fenómeno altamente relevante en nuestra vida cotidiana, el reconocimiento de caras familiares. Uno de los componentes que ha mostrado ser de mayor importancia a la hora de conseguir el reconocimiento exitoso de un rostro familiar se refiere a la respuesta emocional que experimentamos cuando vemos una cara cuya identidad conocemos (Haxby y Gobbini, 2011). Con respuesta emocional nos referimos a los cambios fisiológicos experimentados durante la exposición a un estímulo con contenido emocional y que ocurren de forma inmediata, tienen una breve duración y en la mayoría de los casos no llegan a la consciencia (Adolphs, 2002). Estos cambios corporales ocurren en los sistemas endocrino, visceral, autonómico y musculoesquelético y son procesados en áreas cerebrales encargadas de la integración sensorial y de generar la sensación subjetiva emocional o feeling (ínsula y amígdala). El fenómeno emocional por lo tanto está constituido por la respuesta fisiológica y por la sensación subjetiva. Para vincular ambos fenómenos hace falta que se preste suficiente atención al estímulo causante y que se asocie temporalmente su aparición con la respuesta emocional. El contenido emocional evocador de respuestas emocionales puede formar parte del repertorio compartido por la gran mayoría de los seres humanos y animales (por ejemplo, señales de peligro o amenaza) o puede formar parte del repertorio individual que cada ser humano ha desarrollado a lo largo de su experiencia vital (Damasio, 2010). La emoción asociada a la identidad es evocada por un tipo de contenido totalmente individualizado, ya que depende de la historia y los recuerdos particulares de cada individuo. La ausencia o alteración de una respuesta emocional adecuada ante un rostro familiar podría suponer un fracaso en el reconocimiento consciente de la persona, como se postula que ocurre en el Síndrome de Capgras (Ellis et al., 1997; Hirstein y Ramachandran, 1997).

A pesar de la importancia de la respuesta emocional "per se" en el reconocimiento facial, pocos estudios hasta la fecha han centrado su interés en capturar su esencia y en la mayoría de los casos no han utilizado la metodología necesaria para hacerlo. Partiendo de que el fenómeno emocional está completamente ligado a los cambios experimentados a nivel corporal, el registro de las variables fisiológicas intervinientes en los procesos emocionales se convierte en requisito a la hora de captar el fenómeno emocional. Los estudios incluidos en esta tesis doctoral fueron desarrollados con el objetivo de ofrecer a la comunidad científica una visión integradora sobre los cambios periféricos y centrales asociados a la emoción a través de la identidad.

El estudio psicofisiológico de los cambios corporales asociados a la emoción ha estado en muchos casos guiado por un modelo teórico que se ha desarrollado con el objetivo de poder investigar en el laboratorio el complejo fenómeno emocional. Según este modelo, existen dos dimensiones que conforman el espacio emocional en el que pueden ubicarse todas las emociones individuales (Russell, 1980; Lang, 1995). La principal dimensión que definiría este espacio emocional es la valencia afectiva y se refiere al nivel de agrado-desagrado experimentado en una emoción determinada. La segunda dimensión, el arousal emocional, se refiere a la activación (estado de alerta, atención, excitación) que define cada emoción. Así por ejemplo, la tristeza se encontraría en un extremo de la dimensión de valencia (altamente desagradable) y en un punto intermedio o bajo de la dimensión de arousal (poco o nada activante), mientras que la euforia se encontraría en el extremo opuesto de la escala de valencia (altamente agradable) y en el extremo de alta activación en la dimensión de arousal. Una gran acumulación de investigación psicofisiológica ha mostrado la existencia de un patrón fisiológico que permite diferenciar las emociones negativas de las positivas (valencia) y las activantes de las poco activantes (arousal) (Bradley y Lang, 2001; Lang y Bradley, 2010). De este modo, la conductancia eléctrica de la piel responde ante una estimulación emocional intensa y la amplitud de su respuesta es reflejo de los niveles de activación autonómica. La tasa cardíaca ha mostrado ser sensible a la dimensión de valencia durante el visionado pasivo de imágenes afectivas, al igual que la electromiografía de los músculos faciales (corrugador y cigomático). El registro de los potenciales evocados bajo este paradigma emocional ha mostrado consistentemente una mayor amplitud de los potenciales positivos tardíos ante imágenes emocionales frente a imágenes neutras.

Otro fenómeno que resaltan los modelos actuales de percepción facial como necesario para la consecución del reconocimiento del rostro tiene que ver con la recuperación del conocimiento, los recuerdos episódicos y semánticos, asociados a la persona visualizada (Haxby y Gobbini, 2011). Este tipo de acceso a la memoria declarativa asociada con el rostro ha sido denominada por algunos autores como familiaridad (Voss & Paller, 2006, 2007; Gobbini & Haxby, 2007). Según detallan los modelos más recientes de percepción facial, la familiaridad y la reacción emocional ante un rostro conocido serían fenómenos dependientes de estructuras diferenciadas aunque relacionadas entre si. Así se explicarían déficits como el que presentan algunos pacientes prosopagnósicos que preservan parte de la respuesta emocional ante las caras familiares (respuestas en conductancia eléctrica de la piel) a pesar de sufrir una pérdida de la capacidad de acceder al conocimiento de la persona a través de la información aportada por el rostro (Bauer, 1984; Tranel, Damasio y Damasio, 1995). Por lo tanto, en el estudio del procesamiento de rostros familiares es importante tener en cuenta la diferenciación de ambos fenómenos y saber qué mecanismos responden a qué tipo de procesamiento.

Los estudios presentados en el capítulo 1 de esta tesis doctoral tuvieron como objetivo principal descifrar la contribución específica de los fenómenos de valencia afectiva, arousal y familiaridad durante la visualización de caras familiares queridas. La metodología utilizada en los tres estudios que conforman este primer capítulo consistió en: (a) la utilización de un paradigma sensible a la hora de determinar los efectos debidos a la valencia y al arousal: el paradigma de visualización pasiva de imágenes de P. J. Lang, (b) el registro simultáneo de la actividad del sistema nervioso autónomo, somático y central, y (c) el uso de estímulos faciales que diferían en valencia afectiva, arousal y familiaridad. Los resultados de los tres estudios, con respecto a la modulación observada ante las caras familiares queridas en comparación con diferentes caras controles, muestran una elevada consistencia entre si. Estos resultados se pueden resumir en: (1) las caras queridas provocaron una mayor amplitud en aquellas variables sensibles al arousal, es decir, la conductancia eléctrica de la piel y el potencial positivo tardío de la onda de potenciales, (2) las caras queridas desencadenaron la activación del músculo cigomático, un patrón bifásico en tasa cardíaca y la inhibición del reflejo de sobresalto junto con altas puntuaciones en valencia afectiva subjetiva, y (3) la comparación entre caras muy familiares (padres) y caras menos familiares (pareja) resultó en mayores respuestas en conductancia eléctrica de la piel, activación del músculo cigomático y evaluaciones subjetivas de placer y activación en respuesta a la cara de la pareja. Estos resultados indican que las caras de personas queridas provocan una serie de cambios fisiológicos y subjetivos reflejo de una intensa respuesta emocional positiva. Estos cambios no pueden ser atribuibles únicamente a un efecto indiferenciado del arousal o de la familiaridad.

El segundo estudio tuvo como objetivo analizar el posible vínculo entre la inhibición de respuestas defensivas y los efectos beneficiosos que el apoyo social, y en concreto las relaciones afectivas satisfactorias, tienen sobre la salud. Para ello utilizamos el paradigma de la modulación del reflejo de sobresalto, reflejo que ha mostrado ser sensible al procesamiento de la valencia afectiva (Bradley, Cuthbert y Lang, 1990; Angrilli, Mauri, Palomba, Flor, Birbaumer, Sartori y di Paola, 1996). Cuando el organismo se encuentra en un estado motivacional positivo el reflejo de sobresalto ha mostrado inhibirse, mientras que estados emocionales aversivos tienen el efecto opuesto (potenciación del reflejo) (Lang, 1995). En este estudio incluimos por primera vez participantes masculinos, además de femeninos, con el objetivo de poder generalizar los resultados a la población masculina a la vez que analizar posibles diferencias de género en cuanto al procesamiento de caras familiares queridas. El resultado más novedoso de este estudio consistió en la inhibición del reflejo de sobresalto durante la visualización de caras familiares queridas en comparación tanto con las caras desconocidas como con las desagradables. Así mismo fue interesante encontrar diferencias de género en cuanto a las evaluaciones subjetivas de los estímulos y a la actividad del músculo cigomático. Las mujeres presentaron una modulación de la actividad del músculo cigomático en respuesta a las tres categorías de caras muy similar a los hombres, pero la amplitud de su respuesta ante las caras queridas fue mucho mayor. Estos resultados concuerdan con las diferencias de género encontradas en las evaluaciones subjetivas de valencia, ya que las mujeres informaron de sensaciones más placenteras ante las caras queridas que los hombres. Por otro lado, también se encontraron diferencias de género en cuanto a la evaluación de las imágenes en la escala de arousal. Las mujeres evaluaron como más activantes que los hombres las imágenes de caras mutiladas, mientras que los hombres evaluaron como más activantes que las mujeres las caras familiares queridas y las neutrales.

En conjunto estos datos llevan a plantear la hipótesis de que las caras queridas actúen como señales de seguridad activando el sistema motivacional apetitivo e inhibiendo el defensivo. Este mecanismo de inhibición recíproca podría ser el que se encontrase en la base del efecto beneficioso que las relaciones satisfactorias tienen sobre la salud (Reblin y Uchino, 2008). A pesar de la novedad e interés de la hipótesis propuesta, sería necesaria más investigación para poder establecer un nexo claro entre estos dos fenómenos.

Con respecto a las diferencias de género encontradas en este estudio cabe resaltar que nuestros datos son consistentes con la literatura previa. Un estudio dirigido a analizar posibles diferencias de género en la activación motivacional (Bradley et al., 2001b) informó de que mientras que las mujeres reaccionaban con mayores respuestas en el músculo cigomático ante imágenes agradables y evaluaban las imágenes desagradables como más activantes que los hombres, los hombres tendían a evaluar las imágenes apetitivas como más activantes que las mujeres. Estos datos pueden ser interpretados desde la creencia popular de que las mujeres tienden a ser más expresivas y a exteriorizar más sus emociones que los hombres. Al igual que en el caso de la hipótesis anterior, sería necesaria más investigación para poder confirmar nuestra hipótesis.

En el capítulo 3 se presentan los datos de potenciales evocados y localización de fuentes durante el visionado pasivo de caras familiares queridas, desconocidas y desagradables. El objetivo principal de este capítulo es aportar información relevante sobre el curso temporal y localización de los diferentes componentes que aparecen incrementados durante el procesamiento de caras familiares con relevancia social y emocional. La técnica de registro de los potenciales evocados posee una alta resolución temporal por lo que resulta óptima a la hora de aportar información sobre el curso temporal de procesos cognitivos y emocionales (Pizzagalli, 2007). La investigación sobre percepción facial ha señalado la existencia de determinados componentes de la onda de potenciales sensibles a las diferentes etapas que conforman el análisis de rostros familiares. El componente más estudiado en relación al procesamiento facial es el face-sensitive N170, sobre el que existe un amplio consenso en considerarlo un índice del procesamiento estructural de las caras. En etapas posteriores de procesamiento se ha detectado la modulación de los componentes N250r, P300 y LPP ante caras familiares (Herzman et al., 2005; Langeslag et al., 2007, Bobes et al., 2007; Langeslag et al., 2008; Grasso et al, 2009; Waisman et al. 2011; Grasso et al., 2011; Lu et al., 2012; Doi et al., 2013). Por lo tanto, los datos acumulados hasta el momento sobre el curso temporal del análisis facial apuntan a una primera etapa de análisis estructural seguida de fases en las que se accede a información acerca de la identidad del rostro. El estudio electrofisiológico de caras de personas familiares ha mostrado la mayor amplitud de determinados potenciales tardíos, P300 y LPP, durante la visualización de rostros familiares. Dependiendo en parte de la manipulación experimental utilizada en cada estudio, la modulación observada en los componentes positivos tardíos ha sido interpretada de diferente forma. Algunos de los estudios apuntan a una significación motivacional resultante en un aumento de la atención hacia las caras de personas queridas (Langeslag et al., 2007, 2008), otros señalan la sensibilidad de estos componentes a procesos de tipo relacional como el apoyo percibido, la satisfacción o el tipo de apego (Grasso et al., 2009; Grasso y Simons, 2011; Doi et al., 2013) y otros ponen énfasis en los procesos de memoria relacionados con el acceso rápido y automático a los recuerdos de tipo social y emocional asociados con las caras familiares (Bobes et al., 2007). En consonancia con este último estudio, nuestros resultados muestran una mayor amplitud del P3a durante la visualización de caras familiares queridas en comparación con caras desconocidas y desagradables. La menor amplitud de este componente ante las caras desagradables descartaría una significación puramente motivacional, ya que se ha demostrado que el contenido aversivo es incluso más potente que el positivo a la hora de implicar al sistema motivacional y aumentar los recursos atencionales prestados al estímulo (Blanchard y Blanchard, 1989; Fanselow, 1994; Lang, Davis y Öhman, 2000; Öhman y Mineka, 2001). Por lo tanto, interpretamos nuestros datos en la línea de Bobes y colaboradores como un reflejo del acceso rápido y automático a la información emocional y social contenida en los rostros familiares. Esta interpretación se ve reforzada tanto por los análisis de permutaciones como por los análisis de localización de fuentes realizados para la comparación entre las caras familiares queridas y las caras desconocidas. Según los análisis de permutaciones, las caras queridas empiezan a diferenciarse de la desconocidas en una latencia inferior a los 200 ms, lo que indica que se trata de un proceso enormemente rápido. Las áreas que aparecen asociadas a la generación del componente P3a fueron la corteza orbito-frontal, el cíngulo anterior y la corteza temporal. Las dos primeras estructuras mencionadas han sido asociadas con el procesamiento de estímulos emocionales, especialmente positivos (Kringelbach, 2005; Devinsky, Morrell and Vogt, 1995; Douville et al., 2005; Haist, Bowden Gore, & Mao, 2001; Leveroni et al., 2000), y la última es una estructura clave en el reconocimiento de caras familiares a través de la recuperación de conocimiento acerca de la persona. Por lo tanto, los datos de este estudio aportan información novedosa sobre el momento y la localización del acceso a la información social y emocional asociada con los rostros familiares queridos.

En el capítulo 4 se presenta un estudio de resonancia magnética funcional en conjunto con medidas del sistema nervioso periférico cuyo objetivo fue desentrañar la implicación tanto de los sistemas neurales como de los sistemas autónomo y somático en el procesamiento de la emoción asociada a la identidad. Además de la introducción de la técnica de neuroimagen de mayor resolución espacial que se conoce hasta el momento (Wager, Hernandez, Jonides y Lindquist, 2007), este estudio añade la novedad de un control adecuado de la valencia afectiva asociada a la identidad: las caras de personas familiares desagradables. A su vez, aporta la inclusión de caras emocionales asociadas a la apariencia física, lo que permite un control meticuloso de los procesos de valencia afectiva específicamente asociados con la emoción asociada a la identidad. Los resultados de este estudio, en línea con los estudios previos, mostraron cómo las caras familiares queridas implicaron de forma masiva los sistemas de respuesta musculoesquelético, (electromiograma del músculo cigomático) y autonómico (conductancia eléctrica de la piel y electrocardiograma). De la misma forma, las caras familiares desagradables provocaron aumentos en la conductancia eléctrica de la piel, tasa cardíaca y actividad del músculo corrugador. A nivel central se pudo observar que mientras que algunas áreas respondieron de forma incrementada ante las caras familiares, otras se activaron de forma específica sólo ante las caras familiares queridas. La ínsula al igual que el operculum frontal inferior, el giro frontal medial y el área motora suplementaria mostraron activarse significativamente en los tres contrastes realizados para la comparación entre caras familiares y desconocidas (familiares ¿ desconocidas, familiares queridas ¿ desconocidas atractivas y familiares desagradables ¿ desconocidas desagradables). La corteza orbito-frontal medial apareció activada de forma significativa únicamente ante las caras familiares queridas. La comparación a nivel de valencia entre las caras agradables y las desagradables resultó en la activación de una red menos extensa que la obtenida para la comparación entre estímulos familiares y desconocidos. El contraste que resultó en la activación de más áreas cerebrales fue el que comparó las caras familiares queridas con las caras familiares desagradables. La corteza orbitofrontal medial volvió a activarse significativamente ante las caras familiares queridas junto con una red extensa que incluía entre otras estructuras al operculum frontal inferior, cíngulo medial y precuneus. Debido a que la ínsula es una región cerebral encargada de la integración sensorial a la vez que ha sido definida como generadora de la sensación emocional (Damasio, 2010), interpretamos su activación ante las caras familiares como un reflejo de la mayor intensidad de la sensación emocional causada por las caras familiares en contraste con las desconocidas. Esta interpretación se vería reforzada por la mayor activación a nivel autonómico y somático que acompaña a la visualización de caras familiares. El operculum frontal inferior ha sido identificado como parte del sistema de neuronas espejo humano, aquel que se encarga tanto de realizar una determinarla acción como de simular una acción observada (Haxby y Gobbini, 2011; Rizollatti et al, 2001). Por lo tanto, su activación también se ha relacionado con la capacidad empática que consiste en experimentar en el propio cuerpo aquello que atañe a otra persona (Montgomery et al., 2009). Por otro lado, el operculum frontal es una de las áreas que aparecen activadas durante la visualización o ejecución de expresiones faciales (Carr et al., 2004; Montgomery and Haxby, 2008; Montgomery et al., 2009). En nuestro estudio por lo tanto, su implicación durante el procesamiento de caras familiares puede estar relacionado tanto con la mayor capacidad de simular las acciones, emociones o estados mentales experimentados por personas familiares, como con la mayor producción de expresiones faciales ante este tipo de caras. Debido a que fue registrada la actividad de parte de los músculos faciales implicados en las expresiones faciales (músculos corrugador y cigomático), una forma de comprobar la validez de esta última hipótesis es remitirse a los resultados electromiográficos. En el caso de la comparación entre las caras familiares queridas y las atractivas desconocidas esta hipótesis encuentra apoyo ya que las caras familiares queridas provocaron mayor activación del músculo cigomático. Sin embargo, no ocurre lo mismo en el caso de las caras familiares desagradables que activaron menos el músculo corrugador que las caras desconocidas desagradables. La activación de áreas asociadas con la planificación y el control motor como son el giro frontal medial y el área motora suplementaria ante las caras familiares es interpretado en este contexto como la planificación de conductas motoras encaminadas a establecer algún tipo de interacción, o como el recuerdo de episodios de interacción en los que la actividad motora estuvo implicada. Esta hipótesis encuentra apoyo en algunos estudios que han encontrado la activación de éstas u otras áreas motoras tanto durante la visualización pasiva de caras familiares con contenido emocional (Bartels y Zeki, 2000, 2004; Zeki y Romaya, 2008) como durante la imaginación de escenas emocionales que implicaban relación (Costa et al., 2010). Por último, la activación de la corteza orbito-frontal medial ante las caras familiares queridas puede interpretarse, en la línea con las investigaciones más recientes, como la recuperación del valor hedónico asociado al vínculo positivo existente con las personas familiares queridas (Kringelbach, 2005).

En conjunto, los resultados de todos los estudios incluidos en esta tesis presentan una alta consistencia, replicándose los resultados obtenidos en los diferentes estudios a la vez que cada uno de ellos añade información novedosa. Así, por ejemplo, el patrón de activación somática y autonómica ante las caras familiares queridas se replica a lo largo de los cuatro estudios expuestos. La visualización de caras queridas está acompañada por un aumento de la conductancia eléctrica de la piel, tasa cardíaca, y actividad del músculo cigomático, a la vez que provoca la inhibición del reflejo de sobresalto. Así mismo, la modulación de los potenciales positivos tardíos ante las caras queridas se replica a lo largo de los tres estudios que realizaron un registro del electroencefalograma. Las caras queridas estuvieron asociadas a una mayor amplitud del componente P3 con localización frontal y del LPP. Estos resultados en conjunto indican la movilización del cuerpo ante estímulos con una alta relevancia social y emocional, las caras de personas familiares queridas, provocando una emoción intensamente positiva. Así mismo es interesante comparar los resultados obtenidos a través de la localización de fuentes del componente P3a con los resultados obtenidos en resonancia magnética funcional en el contraste entre caras queridas y desconocidas. En ambos casos, la corteza orbito-frontal aparece como una de las estructuras significativamente activadas señalando su posible implicación en el procesamiento y recuperación de los recuerdos con valor hedónico asociados a las personas familiares. La combinación de la información con alta resolución temporal aportada por los potenciales evocados con la alta resolución espacial que aporta la resonancia magnética funcional hace posible conjeturar que la activación del significado recompensante de las caras familiares queridas, posiblemente mediado por la corteza orbito-frontal medial, es procesado de forma rápida y automática.

La relevancia del presente trabajo se corresponde con la implicación empírica y teórica que sus resultados pueden tener en diferentes ámbitos de estudio. Por un lado, contribuye al estudio psicofisiológico de la emoción aportando evidencia sobre la existencia de estímulos positivos, las caras familiares queridas, que implican el sistema motivacional apetitivo de forma intensa. La implicación más directa de estos resultados es la aportación de una alternativa al uso de imágenes eróticas en aquellos estudios que estén interesados en investigar una gama más amplia de estímulos motivacionales positivos. Estudios recientes, han utilizado imágenes de parejas románticas o la imaginación de escenas románticas como alternativa a las imágenes eróticas, mostrando que estos estímulos también implican las áreas cerebrales relacionas con la recompensa como el núcleo acumbens y la corteza prefrontal medial (Costa et al., 2010). Sin embargo, no tenemos constancia de que estos mismos estímulos sean lo suficientemente activantes como para implicar al sistema autónomo y somático de la forma en que lo hacen tanto las imágenes eróticas como las caras familiares queridas.

Por otro lado, nuestros datos pueden servir al estudio sobre el reconocimiento facial y las disfunciones asociadas con el mismo. En gran parte de la investigación sobre los procesos subyacentes a la percepción y reconocimiento de rostros, siguiendo una tradición más puramente cognitiva, no ha sido frecuente el uso de una metodología adecuada a la captación de las respuestas emocionales. Por ejemplo, sería interesante comprobar si el reconocimiento encubierto que presentan algunos pacientes prosopagnósicos frente a sus personas familiares es dependiente de procesos que analizan la valencia afectiva o es independiente de la misma. La mayor amplitud en conductancia eléctrica de la piel que presentan algunos de estos pacientes es indicativa de la existencia de un reconocimiento encubierto del valor motivacional de los rostros familiares pero se desconoce si este reconocimiento capta a su vez la valencia afectiva. El registro de variables periféricas sensibles al procesamiento de la valencia, como es el electromiograma de los músculos faciales, podría aportar información muy relevante al respecto. En el caso de encontrarse una implicación del procesamiento de la valencia afectiva en el procesamiento encubierto que presentan los prosopagnósicos, sería necesaria la inclusión en los modelos neuroanatómicos sobre percepción facial, de aquellas áreas encargadas del procesamiento de la valencia afectiva, por ejemplo la corteza orbito-frontal medial.

En conclusión, los resultados informados en esta tesis aportan información sobre el alto valor motivacional que poseen los rostros de personas familiares queridas y sobre la implicación tanto de los sistemas centrales encargados del procesamiento emocional como de los sistemas de respuesta periféricos en su procesamiento. La intensa respuesta emocional positiva que experimentamos al visualizar la cara de un ser querido parece ser incluso más reforzante que aquella experimentada ante otro tipo de caras altamente gratificantes. Otra conclusión que puede inferirse de nuestros resultados es la importancia de los vínculos afectivos positivos en el funcionamiento fisiológico y la salud. La inhibición de respuestas defensivas y la activación del sistema apetitivo durante la visualización de rostros queridos puede ser uno de los mecanismos que subyacen a la relación entre apoyo social y salud.

Aunque quedan todavía muchas preguntas por contestar en el ámbito de las relaciones personales y de las emociones asociadas con el amor y el apego, es de vital importancia que la investigación actual y futura tome en serio el papel fundamental que juegan las relaciones personales en el desarrollo de nuestras vidas y por tanto en el devenir de nuestra sociedad.

6.1 Conclusiones

Las principales conclusiones de nuestra tesis doctoral son las siguientes:

1. La visualización de caras de personas queridas provoca una reacción emocional intensa de signo positivo que no puede ser explicada por un simple efecto del arousal indiferenciado o de la familiaridad.

2. El patrón de respuesta periféricas, centrales y subjetivas reflejo de la emoción intensa experimentada durante la visualización de caras queridas consiste en:

   - evaluaciones altas en valencia afectiva positiva.
   - aumento de la respuesta en conductancia eléctrica de la piel y de la actividad del músculo cigomático.
   - inhibición del músculo corrugador.
   - un patrón cardíaco bifásico consistente en una primera deceleración seguida de una aceleración.

   - mayor positividad de los potenciales evocados corticales P3 y LPP.

3. Las caras queridas son estímulos capaces de inhibir respuestas defensivas tal y como muestra la inhibición del reflejo de sobresalto informado en el capítulo 2.

4. El patrón de respuestas psicofisiológicas encontrado en hombres y en mujeres fue muy similar, aunque se encontraron algunas diferencias significativas en:

   - la actividad del músculo cigomático: el patrón de modulación ante las diferentes categorías de caras fue muy similar en ambos sexos pero las mujeres mostraron respuestas mucho mayores ante las caras queridas que los hombres.
   - las evaluaciones subjetivas: las mujeres evaluaron como más activantes las caras desagradables que los hombres, mientras que los hombres en comparación con las mujeres consideraron más activantes las caras queridas y desconocidas .

5. La visualización de caras queridas provoca una mayor amplitud del componente de la onda de potenciales P3a, cuya latencia es inferior a los 200 ms. y cuyas fuentes cerebrales se encuentran en áreas asociadas tanto al procesamiento del valor recompensante de los estímulos (corteza orbito-frontal y cíngulo anterior) como con la recuperación de la identidad de la persona (corteza inferior temporal).

6. Las caras familiares, tanto queridas como desagradables, suponen estímulos emocionales altamente relevantes que activan de forma masiva tanto al sistema nervioso central como al sistema nervioso periférico. Las caras familiares en comparación con caras desconocidas emocionales:

   - Fueron evaluadas como más activantes, provocaron mayores respuestas en conductancia eléctrica de la piel e involucraron una serie de áreas cerebrales relacionadas con el procesamiento de estímulos emocionales (ínsula, operculum y corteza frontal).
   - Activaron una red de áreas cerebrales encargadas por un lado del procesamiento de la identidad del rostro (giro fusiforme, corteza temporal inferior y medial y polos temporales) y por otro, del control motor (cerebelo y área motora suplementaria).

7. La corteza orbitofrontal medial aparece específicamente relacionada con el procesamiento de las caras familiares queridas, señalando su posible función en el procesamiento del valor hedónico de estos estímulos.

Chapter 7

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