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GABRIEL FERREIRA DIAS GOMIDE

# NEURAL CORRELATES OF EMOTIONAL MEMORY FOR FACES

BELO HORIZONTE/MG
2025

GABRIEL FERREIRA DIAS GOMIDE

# NEURAL CORRELATES OF EMOTIONAL MEMORY FOR FACES

Tese apresentada ao Programa de Pós-Graduação em Neurociências do Instituto de Ciências Biológicas da Universidade Federal de Minas Gerais, como requisito parcial à obtenção do título de Doutor em Neurociências.

Área de Concentração: Neurociência Básica

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Orientador: Prof. Dr. Antônio Jaeger

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# ATA DE DEFESA DE DISSERTAÇÃO/TESE

## GABRIEL FERREIRA DIAS GOMIDE

Realizou-se, no dia 01 de dezembro de 2025, às 13:00 horas, na sala J2-222, do Instituto de Ciências Biológicas da Universidade Federal de Minas Gerais, a 135ª defesa de tese, intitulada *Neural correlates of emotional memory for faces*, apresentada por GABRIEL FERREIRA DIAS GOMIDE, número de registro 2021696000, graduado no curso de PSICOLOGIA, como requisito parcial para a obtenção do grau de Doutor em NEUROCIÊNCIAS, à seguinte Comissão Examinadora: Prof. Antonio Jaeger - Orientador (Universidade Federal de Minas Gerais), Profa. Grace Schennato Pereira Moraes (Universidade Federal de Minas Gerais), Prof. Maicon Rodrigues Albuquerque (Universidade Federal de Minas Gerais), Prof. Weslley Santos Sousa (Instituto de Educação Superior Latino Americano), Prof. André Mascioli Cravo (Universidade Federal do ABC).

A Comissão considerou a tese:
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Belo Horizonte, 01 de dezembro de 2025.

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# Resumo

Esta dissertação investiga os efeitos da emoção nos processos de memória e mecanismos neurais de codificação e recuperação de faces. Três experimentos foram conduzidos utilizando eletroencefalograma para registrar potenciais relacionados a eventos (PREs). No Experimento 1, os participantes codificaram faces com expressões de medo e felicidade. No teste, as faces codificadas foram mostradas novamente com expressões neutras entre faces novas. Os participantes realizaram um teste de reconhecimento e recordaram a expressão emocional com a qual cada face-alvo foi codificada. Descobrimos que faces de medo mostram melhor acurácia de reconhecimento do que faces felizes. Durante a codificação, as amplitudes dos PREs de memória subsequente foram maiores nas latências iniciais/médias para faces de medo, indicando que a excitação influencia a percepção e atenção, modificando a codificação e priorizando estímulos emocionais. Durante a recuperação, faces de medo seletivamente aumentaram a atividade velho/novo de latência inicial a média sobre eletrodos laterais-frontais esquerdos, indicando que os aprimoramentos da memória teriam vindo de processos iniciais de reconhecimento ao invés dos processos típicos de familiaridade e recordação. O Experimento 2 envolveu apresentar faces neutras sobrepostas em diferentes cenas contextuais para codificação, incluindo contextos emocionais negativos, positivos e neutros. No teste, os participantes foram apresentados com faces estudadas e novas e realizaram um teste de reconhecimento. A análise não mostrou diferenças comportamentais entre as condições emocionais, mas uma negatividade precoce nos PREs relacionada à emoção, possivelmente refletindo uma positividade velho/novo atenuada para faces codificadas emocionalmente. Esses resultados sugerem que contextos negativos engajaram uma reativação implícita do sinal de excitação contextual que modulou, mas não fortaleceu, a recuperação explícita. No Experimento 3, os participantes codificaram faces e objetos em cenas contextuais negativas e neutras, e no teste realizaram uma tarefa Lembrar/Saber. A análise mostrou que objetos foram melhor lembrados do que faces. Faces produziram amplitudes de PREs maiores e mais precoces na codificação. Houve um efeito neutro > negativo mais precoce sobre sítios frontais para faces e mais tardio sobre sítios centro-parietais para objetos. Isso sugere que contextos negativos com componentes maiores relacionados à percepção emocional sobrepuseram a codificação relacionada ao alvo, diminuindo as amplitudes dos PREs relacionadas à codificação. Na recuperação, apenas faces exibiram diferenças emocionais fronto-centrais tardias. Isso indica que processos de monitoramento para objetos atenuaram positividades tardias dos PREs, mascarando diferenças emocionais. No geral, esta tese mostrou que a emoção modula a memória tanto na codificação quanto na recuperação de maneiras diferentes. Essa modulação varia por classe de estímulo. A emoção modula a memória para itens neutros tanto através de expressões faciais quanto de contextos de fundo. Faces de medo e faces codificadas em contextos negativos mostraram vantagem de reconhecimento e um efeito emocional frontal esquerdo topograficamente similar durante a recuperação. Embora diferentes no tempo, postulamos que a emoção intensificou sinais perceptuais nesses casos. Criticamente, os efeitos encontrados frequentemente apareceram como modulações, atenuações ou inversões de polaridade dos marcadores de memória dos PREs, revelando impactos neurais latentes não necessariamente evidentes na acurácia.

Palavras-chave: Potenciais relacionados a eventos, Emoção, Faces, Contexto, Efeito velho/novo, Memória de reconhecimento, Efeito de memória subsequente.

# Abstract

This dissertation investigates the effects of emotion on the memory processes and neural mechanisms of encoding and retrieval of faces. Three experiments were conducted using electroencephalogram to record event-related potentials (ERPs). In Experiment 1, participants encoded faces with fearful and happy expressions. At test, the encoded faces were shown again with neutral expressions among new faces. Participants performed a recognition memory test and then were asked to recall the emotional expression each target face was encoded with. We found that fearful faces show better recognition accuracy than happy faces. During encoding, subsequent memory ERP amplitudes were greater in the early/mid latencies for fearful faces, indicating that arousal influence perception and attention, modifying memory encoding and prioritizing emotional stimuli. During retrieval, fearful faces selectively enhanced early to mid-latency old/new activity over left lateral-frontal electrodes indicating that the memory enhancements would have come from early recognition memory processes rather than typical familiarity and recollection processes. Experiment 2 involved presenting neutral faces superimposed on different contextual scenes for encoding, including negative, positive, and neutral emotional contexts. At test, participants were presented with studied and new faces and performed a recognition memory test. The analysis showed no behavioural differences across emotional conditions, but an emotion-related early ERP negativity possibly reflecting an attenuated old/new positivity for emotionally encode faces. These results suggest that negative contexts engaged an implicit, reactivation of contextual arousal signal that modulated, but did not strengthen, explicit retrieval. In Experiment 3, participants encoded both faces and objects in negative and neutral contextual scenes, and at test performed a Remember/Know task. The analysis showed that objects were better remembered than faces. Also, faces produced larger and earlier ERP amplitudes at encoding. There was a neutral > negative effect which was earlier over frontal sites for faces and later over centro-parietal sites for objects. This suggests that negative contexts larger emotion perception-related components (EPN/LPP) overlapped target-related encoding, diminishing encoding related ERP amplitudes. At retrieval, only faces exhibited a late fronto-central emotional differences. This indicates that monitoring processes for objects attenuated late ERP positivities, consequently masking emotional differences. Overall, this doctoral dissertation showed that emotion modulates memory at both encoding and retrieval differently. Also, this modulation varies by stimulus class. Emotion modulates memory for neutral related items through both facial expressions and contextual backgrounds. Fearful faces and faces encoded in negative contexts showed both a recognition memory advantage and a topographically similar left frontal emotional effect during retrieval. Although, different in timing, we pose that emotion enhanced perceptual signals in these cases. Critically, the effects we found in this research often appeared as modulations, attenuations or even polarity shifts, of ERP memory markers, revealing latent neural impacts not necessarily evident in accuracy.

Keywords: Event-related potentials, Emotion, Faces, Context, Old/New effect, Recognition memory, Subsequent memory effect.

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## List of Abbreviations and Acronyms

ERPs – Event-Related Potential

EEG – Electroencephalogram

SME – Subsequent memory effect

Dm – Difference due to memory

MEG – Magnetoencephalography

EPN – Early posterior negativity

LPP – Late positive potential

LPC – Late positive complex

fMRI – Functional magnetic resonance imaging

SD – Standard Deviation

RT – Reaction Time

ANOVA – Analysis of variance

Ag – Silver

AgCl – Silver chloride

VEOG – Vertical electrooculogram

HEOG – Horizontal electrooculogram

IRR – Infinite impulse response

ICA – Independent Component Analysis

IAPS – International Affective Picture System

GAPED – Geneva Affective Picture Database

NAPS – Nencki Affective Picture System

SOA – Stimulus onset asynchrony

ACC – Anterior cingulate cortex

VTA – Ventral tegmental area

DA – Dopamine

NE – Norepinephrine

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## 1. Introduction

While we typically forget mundane or neutral events relatively rapidly, events associated with strong emotions, such as being approved for an important scholarship or being attacked by a jaguar, are remembered for much longer. Truly, emotional stimuli are better remembered than neutral stimuli (e.g., Bradley et al., 1992; Canli et al., 2000; Dolcos & Cabeza, 2002; Dolcos et al., 2004; Dolcos et al., 2005; Kensinger & Schacter, 2006; Kensinger & Schacter, 2007; Kensinger et al., 2007; Kensinger, 2009; Wirkner et al., 2015). Events linked to rewarding or aversive outcomes are preferably encoded (Yick et al., 2015), consolidated (McGaugh, 2000) and recalled (LaBar, 2007), adaptively enabling predictions and selection of appropriate behaviours for similar events in the future. Some extreme examples of this phenomenon of emotional modulation on memory are flashbulb memories and the weapon focus effect.

Flashbulb memories (Hirst et al., 2015; Hirst & Phelps, 2016) are memories for circumstances in which one first learned of a very surprising and consequential (or better yet, highly emotionally arousing) event. Watching the news as the planes crash into the World Trade Center on September 11th is the prototypical case. Almost everyone can remember, with an almost perceptual clarity, where they were, when they heard the news, what they were doing at the time, who told them, how they felt about it, and also one or more totally idiosyncratic and often trivial concomitant events.

The weapon focus effect (Fawcett et al., 2016) is a phenomenon whereby the presence of an unexpected weapon (e.g., a gun or knife) impairs memory for the perpetrator as well as other details of a criminal event, excluding the weapon itself. As an anecdotal example, we can use the case of February 11th, 2007, when a woman stopped for gas in Montgomery County, Texas. While she stood beside her car, an unfamiliar man pulled out a firearm and demanded her purse. During the intense 20-second incident, the woman expressed immense fear due to the presence of the weapon and later provided a highly detailed description of the firearm. Her portrayal of the wrongdoer lacked precision, particularly her reference to "light eyes," yet it led to the direct indictment of a young man for the robbery. Despite the court accepting expert testimony on other aspects of eyewitness behaviour, such as cross-racial identifications, the defence was not allowed to present expert evidence examining whether the firearm had negatively impacted the woman's recollection. Consequently, the suspect's conviction hinged solely on the woman's uncorroborated testimony, as illustrated in the legal cases of Blasdell v. State in 2010 and 2015. This underscores the importance of investigating how arousing emotional stimuli, like the presence of a weapon, can affect the reliability of eyewitness accounts within the criminal justice system.

These phenomena underscore how the effects of emotion on memory are not always straightforward, often causing opposing outcomes depending on the situation. Emotional modulations on memory occur regularly in our day-to-day lives and in many different contexts. One class of stimuli that is of particular interest is faces. Indeed, facial emotional expressions are powerful stimuli that play a critical role in social interactions (Vuilleumier & Schwartz, 2001; Frith, 2008; Kraft-Feil et al., 2023). The ability to quickly and accurately decode emotional expressions in other people is essential for successfully navigating social environments. Also, in the course of a lifetime, individuals encounter several thousands of different faces, in person and through media. Behind each face there is a unique individual with distinctive physical and biographical characteristics. Yet, given the frequency, ease, and efficiency with which we carry out facial recognition, there is little to remind us of the complexity of the task and of the burdens it must pose for the brain.

The most obvious demand on the brain is the sheer volume of the task. We are required to recognize a huge number of faces, and the problem is compounded because those many different faces must be recognized at the level of unique, individual identity. Most stimuli that humans are called upon to identify need only be recognized as members of a conceptual (semantic) class, and do not require recognition nor distinction as unique individuals (Tanaka & Taylor, 1991; Rosch et al., 1976). These demands put even more weight on the importance of understanding the processes involved in emotional memory for faces.

Considering this, we developed three experiments to investigate the effects of emotion on memory for human faces. We use event-related potentials (ERPs) to examine electrophysiological differences during encoding and retrieval processes for different emotional conditions. The first experiment involved a source recognition memory task in which the studied stimuli were faces with happy or fearful facial expressions. The second experiment involved another recognition memory task, although this time, the studied stimuli were neutral faces presented over background contextual scenes that could be either emotionally neutral, positive, or negative. The third experiment involved a Remember/Know recognition memory task in which faces and objects were presented over background contextual scenes that could be either emotionally neutral or negative.

## 1.1. Emotion and Memory: Recognition Tasks with ERPs

Substantial evidence suggests that emotions significantly influence the modulation of episodic memory (LaBar & Cabeza, 2006; Dolcos et al., 2012). One notable aspect concerning the interaction between emotion and memory is that information with more intense emotional content, whether negative or positive, is generally memorized more easily (Cahill & McGaugh, 1998; Tyng et al., 2017;  Mather, 2009). This effect has also been demonstrated in various laboratory studies, which show that emotionally positive or negative stimuli are more easily retrieved compared to words with neutral emotional content (Kensinger & Corkin, 2003).

When investigating aspects of episodic memory, recognition memory tasks are often used (Meier et al., 2013). Recognition memory tasks include two phases. The first phase involves presenting a series of stimuli to the subject and is called the study or encoding phase.

The second phase, known as the test phase, involves the re-presentation of the stimuli presented during the study phase along with new stimuli (i.e., not presented previously) (Yonelinas, 2002). The subject's task is to identify which stimuli were encountered during the study phase and which are being presented for the first time during the test phase (Rodrigues & Jaeger, 2018).

The most accepted explanation for the phenomena resulting from the experimental paradigm described above is the dual-process model of recognition (Jaeger, 2016). The dual-process model (Yonelinas, 1994) proposes that, in addition to the intensity of a single mnemonic source (i.e., familiarity signal), the retrieval of qualitative and contextual aspects of the studied stimuli also plays a crucial role in the recognition process. In other words, besides familiarity, a functionally distinct process that involves the recollection of qualitative and contextual information would have an important role in recognition, a process referred to as recollection.

The dual-process theory receives support from various approaches in cognitive neuroscience. One of them is the use of event-related potentials (ERPs). ERPs involve capturing the electrical signals generated by networks of neurons related to a specific behavioural event. These signals mainly reflect the macroscopic activity of the cerebral cortex, revealing the cooperative global activity of neurons on a large scale. Thus, ERPs provide a window through which the dynamics of neuronal network activity can be investigated. This neuronal activity is related to a variety of cognitive processes, which are assessed using many different experimental tasks (Bressler, 2022). The instrument used to investigate ERPs is basically the same as the traditional electroencephalogram (EEG) used in neurological examinations. However, in the case of ERPs, the electrical signals generated in different cortical regions are discriminated, relating activation to specific events (Luck, 2014).

The physiological basis of cortical ERPs lies in the electric potential fields generated by interacting neurons. These potential fields are predominantly dendritic in origin and result from a summation of extracellular currents generated by the electromotive forces of dendrites, simultaneously activated in cortical neurons (mainly pyramidal cells) (Nunez & Srinivasan, 2006).

The electromotive forces, generated by synaptic activation of postsynaptic ionic channels, are currents that flow through the cell membrane and intracellular and extracellular spaces. The summation of current flow from a group of neighbouring neurons circulates through the external resistance to form the potential field relative to that specific region (Bressler, 2022; Portillo-Lara et al., 2021). Thus, the ERP technique allows the identification of cortical regions with higher electrical activity at a given moment.

## 1.2. Old/new effect

Investigations of memory retrieval processes using ERPs are typically carried out by comparing the brainwaves elicited during the test phase of the recognition memory task. The investigation of the neural correlates of this phenomenon is usually done by contrasting the brain activity generated by items that successfully retrieve memorized information with the brain activity generated by items that are not associated with a memory trace (i.e., new information). Therefore, the success of retrieval is studied by contrasting the electrical activity generated during the retrieval of encoded information with the activation elicited by non-encoded information. Thus, the ERP correlates of memory retrieval processes are investigated by comparing the potentials elicited by items correctly classified as "old" and those of items correctly classified as "new." The difference between these potentials is referred to as the "old/new" effect (Rugg & Curran, 2007; Kwon et al., 2024; Jaeger & Parente, 2008, for reviews).

In the context of the current study, a significant phenomenon worth considering is the pronounced left parietal positivity observed when participants correctly identify "old" items in contrast to “new” items. This phenomenon is commonly referred to as the "left parietal old/new" effect and typically initiates around 500 milliseconds (ms) after the presentation of the test stimulus. This effect is closely linked to the process of recollection, as highlighted by previous research (Wilding & Rugg, 1996). Another relevant effect is the "frontal old/new" effect, which typically occurs between 300 and 500 ms, and also consists of greater positivity for items correctly classified as "old" compared to "new" items, but in this case over frontal electrodes, predominantly at the right hemisphere. This effect is associated with the subjective experience of familiarity as proposed by dual processes of recognition (Yu & Rugg, 2010).

Previous studies investigating the ERP correlates in emotional memory tasks demonstrate that emotional stimuli, when compared to neutral stimuli, are associated with greater parietal "old/new" effects (Jaworek et al., 2014; Kwon et al., 2024). This suggests an important role for the process of recollection in the retrieval of emotional stimuli (Dolcos et al., 2005).

### 1.3. Subsequent memory effect

Another important approach for investigating memory effects using ERPs is the subsequent memory effect (SME), also known as the “difference due to memory” (Dm) effect. As the name implies, SMEs are measured by comparing the neural activity elicited during the learning phase of a memory task for items that were later retrieved and later forgotten in a subsequent memory test. Typically, SMEs in ERPs show a positive deflection starting at around 400 ms after stimulus onset for remembered items, but the exact nature of the effects depends on stimulus characteristics and mental operations during encoding (Friedman & Johnson, 2000).

Using SMEs enables us to understand the processes involved during encoding of later remembered or forgotten information. SMEs focus on the neural signatures associated with successful memory formation (Wiemer et al., 2021) and can be used as tool to understand the processes that occur during encoding, when they happen, and how the designed paradigm differentially influences the encoding of the studied stimuli.

Studies investigating emotional modulation of SMEs indicate that affective salience strengthens the very encoding operations that forecast later remembering. This indicates that the SME is amplified, and can emerge earlier, for emotional relative to neutral material (Friedman & Johnson, 2000; Yick et al., 2015). In fact, previous research investigating these effects in the context of memory for faces encoded with emotional expressions shows that emotional faces are more rapidly and efficiently processed than neutral faces, and this is especially true for fearful faces (Righi et al., 2012). The role of this preferential perceptual processing might be to enhance memory encoding and consolidation to allow better predictions when reencountering faces with a negative expression.

### 1.4. Emotional contexts and memory

Previous studies investigating ERPs in emotional memory tasks have shown that emotional stimuli, when compared to neutral stimuli, are associated with larger parietal old/new effects (Jaworek et al., 2014; Schaefer et al., 2011; Weymar et al., 2009, 2010a, 2010b, 2011; Wirkner et al., 2013), suggesting an important role for the recollection process in the retrieval of emotional stimuli (Dolcos et al., 2005). There is also an extensive body of ERP research suggesting that emotional bias for negative valence items occurs at each stage of information processing, from initial visual processing and attention allocation to higher cognitive processes (Smith et al., 2003; Carretié et al., 2001; Delplanque et al., 2004, 2005; Huang & Luo, 2006; Ito et al., 1998).

Several studies examined ERPs triggered by the recollection of neutral stimuli, which were linked to emotional contexts. These investigations (Jaeger et al., 2009; Maratos et al., 2001; Maratos & Rugg, 2001; Smith et al., 2004; Smith et al., 2005; Smith et al., 2006; Ventura-Bort et al., 2016; Ventura-Bort, et al., 2020) were motivated by two key reasons. First and foremost, these studies were inspired by their proximity to real-life scenarios, wherein neutral contextual details (such as the time or clothing colour of an individual involved in an emotional memory) could be incorporated into memory constructs through associative mechanisms (Davachi, 2006; Ventura-Bort et al., 2016), thereby leading to enhanced recall. Additionally, the analysis of ERPs during the recognition of neutral stimuli previously presented in emotional contexts serves to prevent the potential interference of ERP effects linked to encoding or perceptual processing of emotional stimuli during the testing phase. In essence, this approach safeguards against the emergence of typical associations related to emotional stimuli processing during recognition, ensuring more stringent data control for the investigation of memory retrieval.

Despite the considerable number of ERP investigations exploring the influence of emotional contexts on memory for associated information, a diverse range of behavioural and electrophysiological findings have emerged. Some studies revealed a positive emotional impact on neutral stimuli encoded in conjunction with emotional contexts compared to neutral settings (Takashima et al., 2016; Ventura-Bort et al., 2016). Others found that memory enhancement was only evident for items linked to positive contexts (Smith et al., 2004; Smith et al., 2005), while a subset of studies found null behavioural effects (Jaeger et al., 2009; Jaeger & Rugg, 2012). Recent evidence indicates that when context and target items are processed as an integrated unit, memory for emotional contexts might rely on familiarity-related processes, affecting frontal old/new effects differently from recollection-related ERPs (Diana et al., 2008; Bader et al., 2010).

Moreover, augmented parietal old/new effects have been observed concerning memory for items in emotional contexts when compared to neutral contexts (Smith et al., 2004; Maratos & Rugg, 2001). Early effects as demonstrated by Smith et al. (2004) and Jaeger et al. (2009) suggest differences emerging relatively rapidly (around 200 ms), characterized by the positivity elicited by items associated with emotional contexts vs. those associated with neutral contexts, implying an early emotional modulation linked to arousal. However, despite the exploration of various aspects of this connection between neutral items and emotional contexts through ERPs, a distinct differentiation between the impacts of arousal and valence remains elusive. Additionally, given the attentional competition between emotional contexts and associated neutral items, utilizing different neutral stimuli could offer insights into how attention allocation and integration during encoding leads to the array of varying emotional effects seen in prior studies. This encompasses both the temporal aspects of these effects and the processes of recognition memory they influence.

### 1.5. Faces and emotion

Another important perspective into understanding emotional memory for faces, is studying the influence that emotional expressions play in the recognition of facial identity. Facial emotion processing is a complex endeavour that involves many cerebral structures, including the amygdala, occipitotemporal cortex, and orbitofrontal cortex (Eimer & Holmes, 2007). In particular, the orbitofrontal cortex is known to play an important role in attention to emotional stimuli (Sander et al., 2005). Considering that correct facial emotion processing is necessary for successful human interactions (McCade et al., 2011), facial emotion processing is an important source of knowledge about the emotions of others and social information (for a review, see Hinojosa et al., 2015).

### 1.6. Overview

In this section I will succinctly outline the overall structure of this dissertation. This study encompasses three experiments, written in the format of scientific articles. After this Introduction and the following Objectives section, which refer to the whole dissertation, each experiment will have dedicated Introduction, Methods, Results, Discussion, and Conclusion sections. After the Conclusion of the third experiment, there will be a General Discussion and a Final Conclusion section.

## 2. Objectives

### General objective

The goal of the current dissertation is to investigate how emotional stimuli modulate the memory processes involved in encoding and retrieval of human faces.

### Experiment 1

In the first experiment, we investigated the role of emotional expressions during encoding and its effects on memory for faces. Our objectives with the first experiment were:

a) to investigate the influence of emotional expressions during encoding processes (SMEs).

b) to observe the modulations caused by emotional expressions during retrieval processes (old/new effects).

c) to understand what particularities exist in the use of human faces as target stimuli.

### Experiment 2

The second experiment explored how emotional contexts during encoding affect memory for faces. Our objectives with the second experiment were:

a) to observe the modulations of ERPs caused by arousal and valence, separately.

b) to observe the emotional modulations of ERPs in old/new effects.

c) to further understand the particularities of the influence of using faces as stimuli in recognition tasks.

## Experiment 3

The third experiment involved the examination of the effects of emotional contexts during encoding for memory of faces and objects. Our objectives with the third experiment were:

a) to observe the modulations of ERPs caused by negative emotional contexts, separately, for objects and faces.

b) to observe the emotional modulations of ERPs in old/new effects, separately, for objects and faces.

c) to investigate the influence of negative emotional contexts during encoding processes (i.e., SMEs), separately, for objects and faces.

# 3. Experiment 1 – Memory for faces encoded with emotional expressions

## Abstract

This experiment explores the interaction between emotional facial expressions and memory processes. Using electroencephalogram (EEG) recordings, event-related potentials (ERPs) were analysed as participants retrieved studied faces with fearful or happy expressions. All studied (and new) faces showed a neutral expression at test. Participants were asked to make a recognition judgment for each face, followed by a source memory task for the emotional expression each face presented at study (i.e., fearful/happy). Our results showed that fearful faces were recognized more accurately than happy faces, although there was no difference in source memory performance. During encoding, fearful faces elicited more positive ERP amplitudes than happy faces during early latencies, suggesting that they were quickly identified as threatening and posteriorly had more attentional allocation. At retrieval, fearful faces showed more positive ERP amplitudes during early-to-mid time-windows, indicating that the memory enhancements would have come from earlier recognition memory processes rather than recollection-specific processes.

### 3.1. Introduction

The ability to recognize and remember faces is essential for social interaction and communication. Faces provide a wealth of information about a person's identity, emotions, appearance, attention, and more. When a face is presented to an observer, she or he can differentiate the information presented into two categories, traits and states (Pascalis et al., 2011). Face traits are the permanent and stable visual information like gender, aesthetics, age, and identity. Face states, on the other hand, are dynamic facial cues used to convey emotional expressions, attention, and intentions.

A recent magnetoencephalography (MEG) study (Dobs et al., 2019) found that facial gender and age information emerged before identity information, suggesting a coarse-to-fine processing of face dimensions. The study also revealed that familiar faces trigger early enhancements in how identity and gender are represented, implying an advantage in early processing mechanisms. Previous facial recognition models by Burton et al. (1999), Breen et al. (2000), and Ellis & Lewis (2001) indicate that familiar faces induce arousal responses, measured through skin conductance. Although the study from Dobs et al. (2019) did not assess emotional effects, it is not far-fetched to think of the potential similarities between the impacts of familiarity and emotionally arousing facial expressions. Building on these findings, a hypothesis emerges: faces with emotional expressions may be identified even earlier than non-emotional faces due to similar enhancements in early processing mechanisms, mirroring what is observed with familiar faces.

Our current knowledge about the neural substrates for face perception in the human brain largely derives from ERP studies. Several components have been related to different stages of face processing and recognition (for a review see Schweinberger & Burton, 2003): (1) the N170, which is assumed to reflect the initial detection of a face, (2) the N250, which is thought to reflect mechanisms involved in face recognition, and (3) the N400, which reflects access to semantic knowledge about a person.

ERP experiments have also found that emotional faces are processed differently from neutral faces, starting with the N170 effects, which appears 100–200 ms after stimulus onset (Eimer & Holmes, 2007; Schupp et al., 2004). Emotional faces elicit higher N170 amplitudes (Blau et al., 2007). The early posterior negativity (EPN) is another facial perceptual component that presents higher amplitudes for anxious or angry faces when compared to happy or neutral ones and appears 150–300 ms after stimulus onset (Sato et al., 2001; Schupp et al., 2004). During emotional face processing, a late positive potential (LPP) effect also appears over central-parietal regions, with angry faces eliciting particularly large LPPs (Schupp et al., 2004). While the early emotional effects are thought to reflect emotional attention and perceptual tagging, the LPP reflects evaluation and memory processing (Schupp et al., 2003; Schupp et al., 2004). The LPP can be divided into an earlier P3a component, which indicates attentional orientation towards emotional stimuli, and a later P3b/LPP slow-wave, which is more related to evaluation and memory (Olofsson et al., 2008).

Another ERP analysis that can provide insight into the neural events at encoding is the difference wave elicited between stimuli that were later remembered vs. those that were later forgotten, which is typically termed subsequent memory effect (SME), or alternatively, difference due to memory (Dm) effect. SME offers an understanding of the neural activities during encoding that predict successful memory retrieval (Sanquist et al., 1980). This has been observed in a range of stimuli (Paller et al., 1987), including faces (Sommer et al., 1991; Yovel & Paller, 2004; Wolff et al., 2014). This effect is thought to arise because some stimuli receive superior perceptual analysis or elaborative processing (Paller, 1990). Studies comparing emotional and neutral faces have shown a larger SME for fearful faces when compared to neutral or happy faces (Paller & Wagner, 2002; Righi et al., 2012). This advantage in processing fearful faces was found to emerge early in the time course and was greater in the fronto-central region during the early stages of memory processing (220–350 ms) (Righi et al., 2012). During later stages of memory processing (600–800 ms), the SME was not influenced by the emotional content of the stimuli (Dolcos & Cabeza, 2002; Righi et al., 2012).

A possible brain structure involved with the SME is the amygdala, which is believed to play a role in altering the encoding of episodic memory, leading to more effective encoding of relevant emotional events (Phelps, 2004). The early frontal positivity observed in response to fearful faces (Ashley et al., 2004, Eimer & Holmes, 2002, Eimer & Holmes, 2007, Eimer et al., 2003; Righi et al., 2012) is thought to index the rapid detection of emotionally significant signals and may contribute to the enhancement of memory traces (Kilpatrick & Cahill, 2003). The ERP responses to emotional faces suggest distinct processing stages, with an early frontal positivity generated by prefrontal or orbitofrontal mechanisms involved in the rapid detection of fearful expressions (Eimer & Holmes, 2002) and a later, more broadly distributed sustained positivity reflecting higher-order processing related to more general memory encoding and decision processes (Eimer & Holmes, 2007). Overall, the literature indicates that emotional faces, especially fearful faces, are more rapidly and efficiently processed, and this preferential perceptual processing may enhance memory encoding and consolidation.

Regarding ERP modulations observed during retrieval, two other distinct ERP components, known as the FN400 and the late positive complex (LPC), have been identified for faces in the old/new effect (Curran & Hancock, 2007; Nessler et al., 2005). The FN400, which appears at 300–500 ms over anterior regions, represents the ERP difference wave between old and new items and is associated with familiarity processes. The LPC, which follows it, appears at 400–800 ms over parietal regions. The LPC is considered an indicator of recollection processes. It should be noted that the FN400 is not influenced by the recollection of details from the study episode (Rugg & Curran, 2007).

When observing these two components during the retrieval of emotional faces, conflicting results are found. In a 2004 study, Johansson et al. reported that negative faces (including fearful expressions) are recollected to a greater extent than both positive and neutral faces, as reflected in the parietal ERP old/new effect. Additionally, emotion-specific modulations were observed in frontally recorded ERPs elicited by correctly rejected new faces which indicated more liberal response criteria for emotional compared to neutral faces (Johansson et al., 2004). In another study, Schefter et al. (2012) found that negative and neutral faces evoked spatially dissociable ERP old/new effects, suggesting different retrieval mechanisms contributed to successful recognition of negative and neutral faces. Faces retrieved with a negative expression evoked an early parietal old/new effect, suggesting that negative emotion during retrieval facilitated memory access. Importantly, the chronology and topography of these emotional effects during retrieval are still unclear.

To further explore these issues, in the current experiment participants studied faces that were either showing fearful or happy expressions. At test, the studied “old” (as well as the “new”) faces were all shown with neutral expressions. Functional magnetic resonance imaging (fMRI) research supports this methodology. For instance, some studies have demonstrated that when neutral studied content is associated with emotional retrieval cues, there is greater activity in regions including the amygdala (Daselaar et al., 2008, Smith et al., 2004) and hippocampus (Ford et al., 2014). There is also enhanced connectivity between these two regions (Smith et al., 2006) compared to when the memory target is neutral. Finally, it was also observed that the encoding of faces associated with negative behaviours affected the subsequent spontaneous retrieval of this information when re-encountering the same face, activating neural regions involved in social cognition and emotions (Todorov et al., 2007). Thus, there is sufficient evidence from fMRI that our use of neutral retrieval cues for a recognition memory test is sound.

Additionally, in a more closely related fashion to our present experimental design, studies showed that ERP components were modulated by previously encoded facial expressions at time of retrieval (Righi et al., 2012; Lin et al., 2015). Also, later ERP components related to recognition memory were affected by emotional expressions shown earlier in the study phase (Righi et al., 2012). Importantly, these experiments had incongruent findings. While both studies conclude that encoding and recognition of target faces are affected by preceding contextual facial expressions, the Lin et al. study highlights that fearful expressions reduce attentional resources for target faces, limiting their encoding and recognition. In particular, recognition of target faces was independent of facial expression when the preceding (contextual) stimulus was neutral, but impaired when the preceding stimulus was encoded as fearful, reflected by a reduced N170 amplitude. On the other hand, the Righi et al. study revealed rapid and efficient processing of fearful faces, both during encoding and recognition. This conclusion was based on the larger SME for fearful faces, an enhanced positivity on early components during recognition, and larger old/new effects.

In conclusion, it is safe to say that the emotional characteristics present during the encoding of episodes can influence the processes that arise in response to neutral items at retrieval. This is true for faces and for a diverse range of other stimuli (see also Jaeger et al., 2009, Maratos et al., 2000, Smith et al., 2004a, Smith et al., 2004b). Finally, although this emotional influence has been repeatedly shown, the manner in which emotional facial expressions modulate memory processes for recognizing neutral faces is still unclear.

The goal of the current study is to investigate the electrophysiological components related to the encoding and retrieval of faces encoded with emotional expressions and later recognized with neutral facial expressions. Our aim is to observe the modulations caused by emotional expressions during encoding (SMEs) and retrieval (old/new effects). We also aim to observe the modulations caused by emotional expressions during retrieval processes of later successful and failed recollected source memory. This assessment will help us clarify the role of emotions on the different processes involved in recognition memory.

We predict that, relative to happy expressions, fearful expressions at encoding will enhance early SMEs without affecting late SMEs (Righi et al., 2012; Dolcos & Cabeza, 2002), and that at retrieval fearful faces will selectively amplify the FN400 (300–500 ms) and the parietal LPC (500–800 ms) (Righi et al. 2012). Finally, in terms of source recollection, we predict that fearful faces will be recognised more accurately and, critically, will yield higher source recollection than happy faces, because evolutionarily salient threat engages amygdala–hippocampal interactions that prioritise encoding and strengthen associative bindings for those faces (Johansson et al., 2004; Phelps, 2004).

## 3.2. Methods

### *Participants*

Thirty-three undergraduate students (15 women) aged 18–30 years (*M* = 24.96, *SD* = 2.64) participated voluntarily. All participants were native Brazilian Portuguese speakers with normal or corrected-to-normal vision. Data from 8 participants were excluded due to technical issues during EEG recording, leaving 25 participants (14 women; *M* = 24.72, *SD* = 2.83) for analysis. The study was approved by the Institutional Review Board of the Universidade Federal de Minas Gerais, Brazil.

### *Materials*

Stimuli consisted of 530 photos of faces. These included photos of 107 individuals (57 female) with happy face expressions, and photos of 107 individuals (56 female) with fearful face expressions. Each of these photos had a neutral counterpart. That is, these individuals were also depicted with neutral expressions, resulting in another set of 214 photos. Finally, a separate set of photos of 102 new individuals depicting neutral face expression only (47 males and 55 females) served as distractors. Photos were selected from the Chicago Face Database (Ma et al., 2015) and FACES Database (Ebner et al., 2010) to represent diverse ethnicities. All photos were cropped to an 8:10 aspect ratio and displayed at a screen resolution of 1920×1080 pixels. A full list of the selected photos is provided in Appendix A.

### ***Procedures***

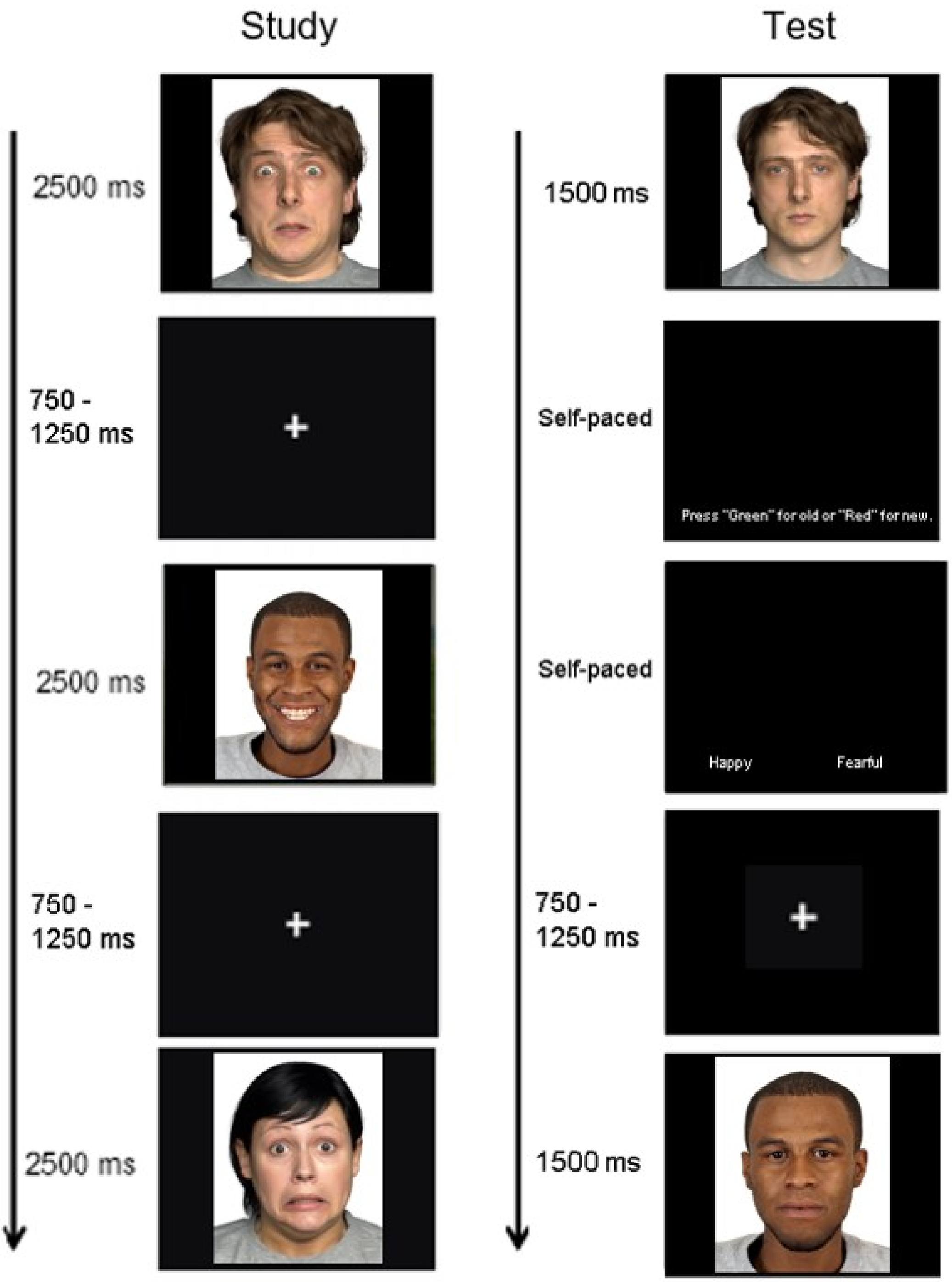
The experiment was conducted in a sound-attenuated, dimly lit room. Participants were seated 70 cm from a 17-inch computer monitor. A brief practice phase (6 study trials and 12 test trials) preceded the main task to familiarise participants with the procedure.

The experiment comprised 10 blocks, each including a study followed by a test phase. During the study phase of each block, 20 faces with happy (10) and fearful (10) expressions were randomly selected for each participant, and were presented in a random order, for 2500 milliseconds (ms) each. Participants were instructed to classify each face during this interval as "pleasant" or "unpleasant" using labelled keys on a keypad (green key = "pleasant", red key = "unpleasant"). After this interval, the face disappeared and was replaced by a white fixation cross, which stayed onscreen for an interval that randomly changed between 750 ms and 1250 ms before the next trial began.

At each block, immediately after each set of 20 faces were presented for study, the same 20 faces were presented again for the memory test. At this time, however, they were presented with neutral expressions and were intermixed with 10 unstudied new faces (distractors), also with neutral expressions. Participants first performed a recognition test on each face pressing a key to indicate that the face was seen at study, (i.e., "old") and another key to indicate that the face was being shown for the first time (i.e., "new"). Immediately after each "old" response, participants completed a source memory task wherein they indicated using a keypad the original emotional expression of each face (green key = "happy," red key = "fearful"). After each "new" response, participants were shown a fixation cross indicating the beginning of the next trial. Each face was presented for 1500 ms and followed by a blank screen. Participants could produce their responses as soon as the faces appeared onscreen, in a self-paced manner. Immediately after each source (or “new”) response was produced, a white fixation cross appeared for an interval that was randomly jittered between 750–1250 ms. As soon as the test phase of each block was finished, participants were warned that another block was about to begin and pressed the “space bar” whenever they were ready. The electroencephalogram (EEG) signal was recorded continuously, and the experiment lasted approximately 40 minutes.

**Figure 1**

*Schematic representation of the stimuli presentation during the study and test phases of Experiment 1*



### ***Behavioural data analysis***

The behavioural data were subjected to analysis using the statistical software R (version 2021). Responses to the recognition test were grouped as "happy" hits, "fearful" hits, correct rejections, and false alarms. Source memory accuracy was indexed by the proportion of source hits (i.e., correct “happy” and “fearful” responses) divided by the proportion of recognition hits (i.e., correct “old” and “new” responses), for each emotional expression. To explore the potential differences across emotional categories, recognition accuracy, reaction times (RTs) and source accuracy were contrasted according to emotional expressions using paired-sample *t* tests.

### ***ERP recording and analysis***

Electroencephalographic activity (EEG) was continuously recorded from 31 electrodes of Ag/AgCl inserted in an elastic cap (www.easycap.de/easycap). Electrode placement was based on the international 10-20 system (American Electroencephalographic Society, 1994), and corresponded to the medial locations (Fz, Pz and Oz) and the homotopic pairs (Fp1/Fp2, F3/F4, F7/F8, FT9/FT10, FC1/FC2, FC5/FC6, C3/C4, CP1/CP2, CP5/CP6, T7/T8, TP10/TP9, P3/P4, P7/P8, and O1/O2). For the correction of ocular movement, the interpolation of the Fp1 electrode was used for the vertical electrooculogram (VEOG), and the interpolation of the F7 and F8 electrodes was used for the horizontal electrooculogram (HEOG). Data were recorded using the actiCHamp amplifier (Brain Products GmbH – www.brainproducts.com) with a sampling rate of 250 Hz and an amplifier bandwidth of 0.01 to 100 Hz (-3 dB). Interelectrode impedances were adjusted for less than 5 kΩ.

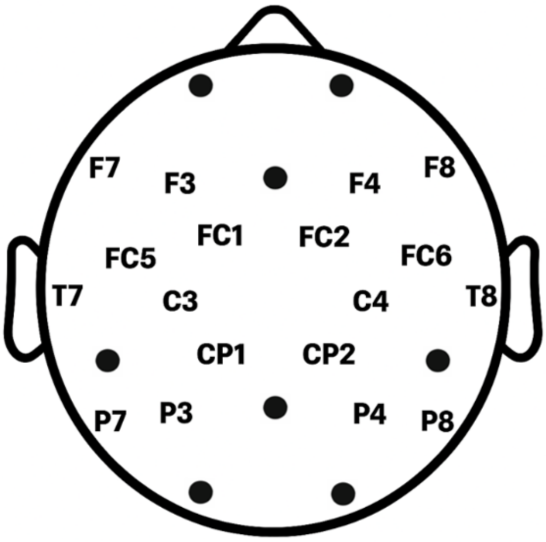
EEG and ERP data processing were conducted in Matlab R2024a (www.mathworks.com) using EEGLAB version 2024.0 (https://sccn.ucsd.edu/eeglab/index.php; Delorme & Makeig, 2004) and ERPLAB version 12.00 (https://erpinfo.org/erplab; Lopez-Calderon & Luck, 2014), and the statistical analyses of ERPs were conducted using *R* software version 3.3.2 (R Core Team, 2017). After data registration, the resulting waveforms were algebraically re-referenced to the electrodes located on the mastoids (TP10/TP9). Continuous EEG data were filtered using the 0.03–19.4 Hz with a zero-phase shift Butterworth filter (12 dB/octave roll-off, DC offset removed prior to filtering) and a 60 Hz notch filter. The continuous data were then segmented in 1300 ms epochs locked to stimulus onset, with a baseline of 200-ms pre-stimulus. Independent component analysis (ICA; Jung et al., 2000) was used to identify and remove blinking artefacts. Trials containing movement artefacts, eye movement artefacts, in addition to blinking, or any excessive baseline drifts were rejected.

To statistically verify the ERP differences between the relevant conditions, analysis of the ERP data was conducted on epochs time-locked to the onset of the study and test stimuli. Analyses were performed on intervals corresponding to the established visual and memory-sensitive components (Luck, 2014): 140–200 ms (N170, reflecting structural face encoding; Bentin et al., 1996), 200–300 ms (N250, associated with face individuation; Schweinberger et al., 2002), 350–600 ms (early LPP, marking sustained emotional attention; Hajcak et al., 2010), and 600–800 ms (late LPP, relating to elaborative encoding; Paller & Wagner, 2002) for the study phase. For the test phase, we selected latency regions in which prior studies found early effects of emotion during retrieval (i.e., 200-300 ms after stimulus onset; Smith et al., 2004; Jaeger et al., 2009) and regions wherein “midfrontal” (FN400) and “parietal” (LPC) old/new effects are typically elicited (i.e., 300–500 and 500–800 ms after stimulus onset; Rugg & Curran, 2007). ERP amplitude was computed within each time window as the mean voltage (μV) relative to the mean voltage in the 200 ms pre-stimulus baseline period. Statistical analyses were conducted on the data derived from the 18 electrode sites depicted in Figure 2.

Electrode-site factors for the statistical analyses were defined a priori to capture spatial variation along three anatomical axes: anterior–posterior (AP), superior–middle–inferior (ST), and hemisphere (HM). Mean amplitudes were computed for each subject and condition by averaging the ERP voltage across the electrodes assigned to each region. For the AP factor, “Anterior” included F7, F3, FC1, FC2, F4, and F8; “Central” included T7, FC5, C3, C4, FC6, and T8; and “Posterior” included P7, P3, CP1, CP2, P4, and P8. For the ST factor, “Superior” comprised FC1, C3, CP1, FC2, C4, and CP2; “Middle” comprised F3, FC5, P3, F4, FC6, and P4; and “Inferior” comprised F7, T7, P7, F8, T8, and P8. For the HM factor, the left-hemisphere set consisted of F7, F3, FC1, T7, FC5, C3, P7, P3, and CP1, whereas the right-hemisphere set consisted of F8, F4 FC2, T8, FC6, C4, P8, P4 and CP2.

**Figure 2**

*Electrode montage and sites employed for the ERP amplitude analyses*



*Note.* Schematic head (top view) showing electrode labels and the electrodes included in the statistical analyses. Electrode labels indicate the subset of channels used to carry out the statistical analyses (see Methods for electrode lists).

First, we proceeded to compare the data for the conditions recorded during the encoding process, namely, SME comparisons (hits vs. misses) and subsequent hits (fear vs. happy).

Second, we compared the data for the conditions recorded during the retrieval process, namely, old/new comparisons and hits (fear vs. happy). On this and all subsequent analyses, we included the aforementioned electrode sites as factors in the repeated-measures ANOVA. Finally, we conducted the statistical analysis on the same factors for the source data.

### 3.3. Results

#### *Behavioural data*

Mean recognition accuracy, response times (RT), and source memory accuracy are shown in Table 1. The analysis revealed greater recognition accuracy for faces encoded with fearful than with happy expressions, $t(24) = 4.38, p < .001, \eta^2 = 0.44$. Such advantage for fearful faces was not reflected in different RTs, $t(24) = 0.37, p = 0.71$, or greater source accuracy, $t(24) = 0.95, p = 0.35$. Thus, the only behavioural difference consisted in the recognition advantage for faces encoded with fearful over happy expressions (Table 1).

**Table 1**

*Means and standard deviations (in parentheses) for accuracy and reaction time (RT) for Recognition and Source Memory Tests*

| | Happy | Fearful | New |
|---|---|---|---|
| Accuracy | 0.62 (0.12) | 0.69 (0.17) | 0.79 (0.13) |
| RT (ms) | 1358 (490) | 1350 (517) | 1381 (484) |
| Source | 0.69 (0.12) | 0.66 (0.12) | - |

### *ERP data*

For each experimental condition, the mean number and range of trials that contributed to the average ERPs during encoding was 68 (36–89) for subsequent retrieval of fearful faces, 60 (39–80) for subsequent retrieval happy faces and 65 (27–123) for subsequent misses. During retrieval the mean number and range of trials that contributed to the average ERPs for each condition was 68 (36–91) for fearful hits, 62 (41–81) for happy hits, 76 (49–93) for correct rejections, 44 (14–75) for source fearful hits, 42 (16–72) for source happy hits, and 39 (23–54) for no-source hits. No comparisons using "no-source" conditions were used due to the small number of artefact-free trials.

### *Encoding*

**Subsequent memory hits fear vs. hits happy vs. misses fear vs. misses happy.** Item type effects (contrasting all four conditions: hit fear, miss fear, hit happy, miss happy) exhibited distinct spatiotemporal patterns (see Table 2). During the 140–200 ms N170 window, both a main item type (IT) and a significant IT × ST interaction emerged, indicating topographical variation along the superior-inferior axis. In the 350–600 ms early LPP window, an IT × AP interaction was observed, demonstrating anterior–posterior modulation. Following this, interactions persisted in the 600–800 ms late LPP window through an IT × ST significant effect, confirming sustained topographical organization of condition difference.

**Table 2**

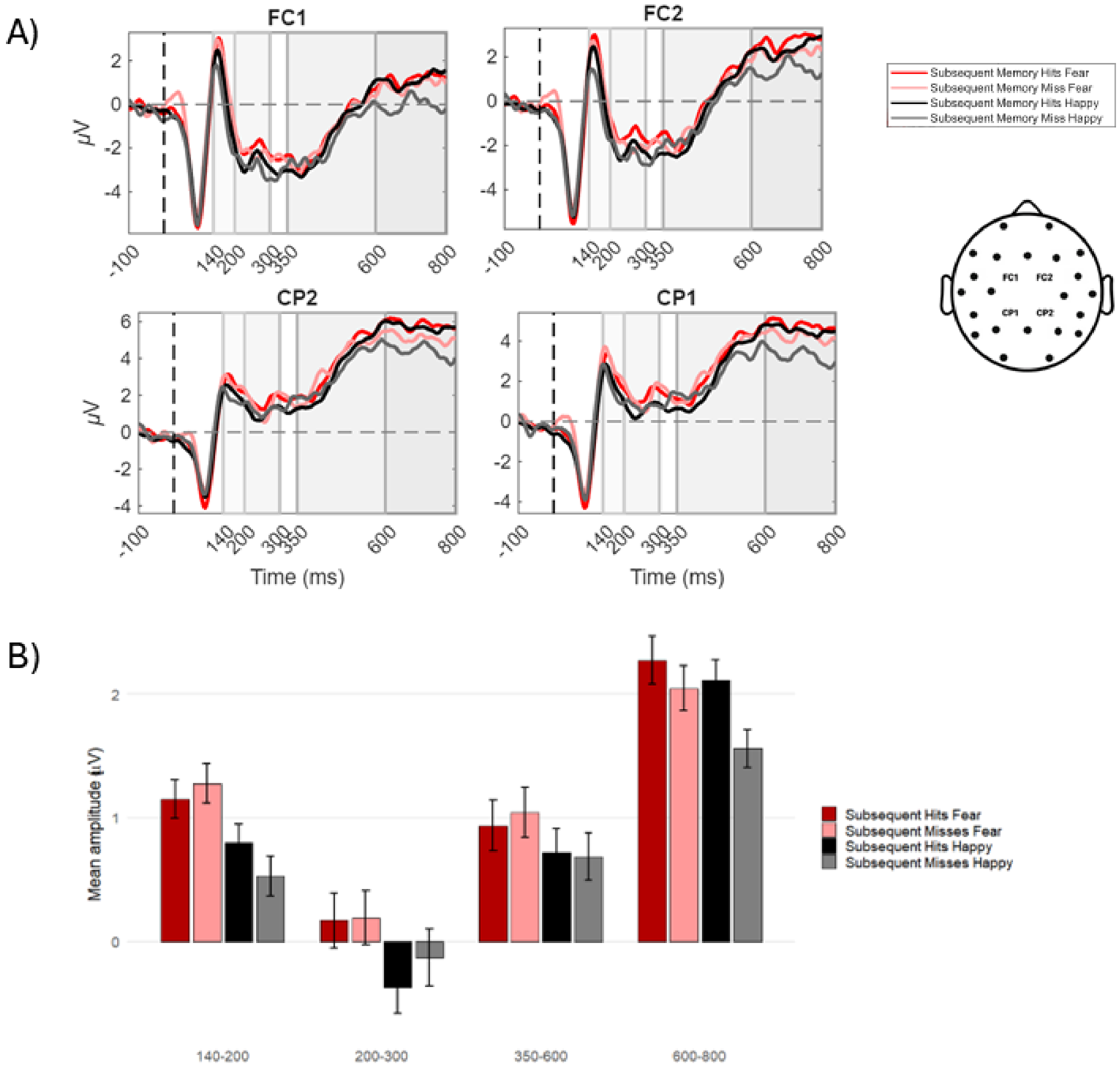
*Contrast of event-related potentials (ERPs) between subsequent hits and misses at different topographic sites and for different latency regions*

| Effect | Latency Regions (ms) | | | |
|---|---|---|---|---|
| | 140-200 | 200-300 | 350-600 | 600-800 |
| **Hit Fear × Miss Fear × Hit Happy × Miss Happy** | | | | |
| IT | *F*(2.00, 48.1) = 3.58, *p* < .035 | | | |
| IT × AP | | | *F*(2.97, 71.2) = 3.33, *p* < .024 | |
| IT × ST | *F*(2.96, 71.0) = 6.39, *p* < .001 | | | *F*(2.69, 64.7) = 3.99, *p* < .014 |
| **Hit × Miss** | | | | |
| IT × AP | *F*(1.29, 30.9) = 6.13, *p* < .01 | | | |
| IT × ST | | | | *F*(1.10, 26.3) = 12.6, *p* < .001 |
| IT × AP × ST | | | | *F*(2.45, 58.8) = 3.33, *p* < .03 |
| IT × ST × HM | | | | *F*(1.41, 33.8) = 4.74, *p* < .02 |
| **Hits Fear × Hits Happy** | | | | |
| IT | *F*(1, 24) = 6.55, *p* < .017 | *F*(1, 24) = 4.44, *p* < .045 | | |
| IT × AP | | | *F*(1.37, 32.9) = 6.68, *p* < .008 | |
| IT × ST | *F*(1.18, 28.3) = 10.2, *p* < .002 | | | |
| IT × AP × ST | | | *F*(3.58, 86.0) = 3.96, *p* < .007 | |
| IT × AP × ST × HM | | | *F*(2.59, 62.3) = 3.26, *p* < .03 | |

*Note.* AP (anterior/central/posterior chain), ST (inferior/middle/superior site), HM (left/right hemisphere), Item type (Hit Fear/Miss Fear/Hit Happy/ Miss Happy).

**Figure 3**

*Grand average ERPs and mean amplitudes for subsequent emotional hits and misses*

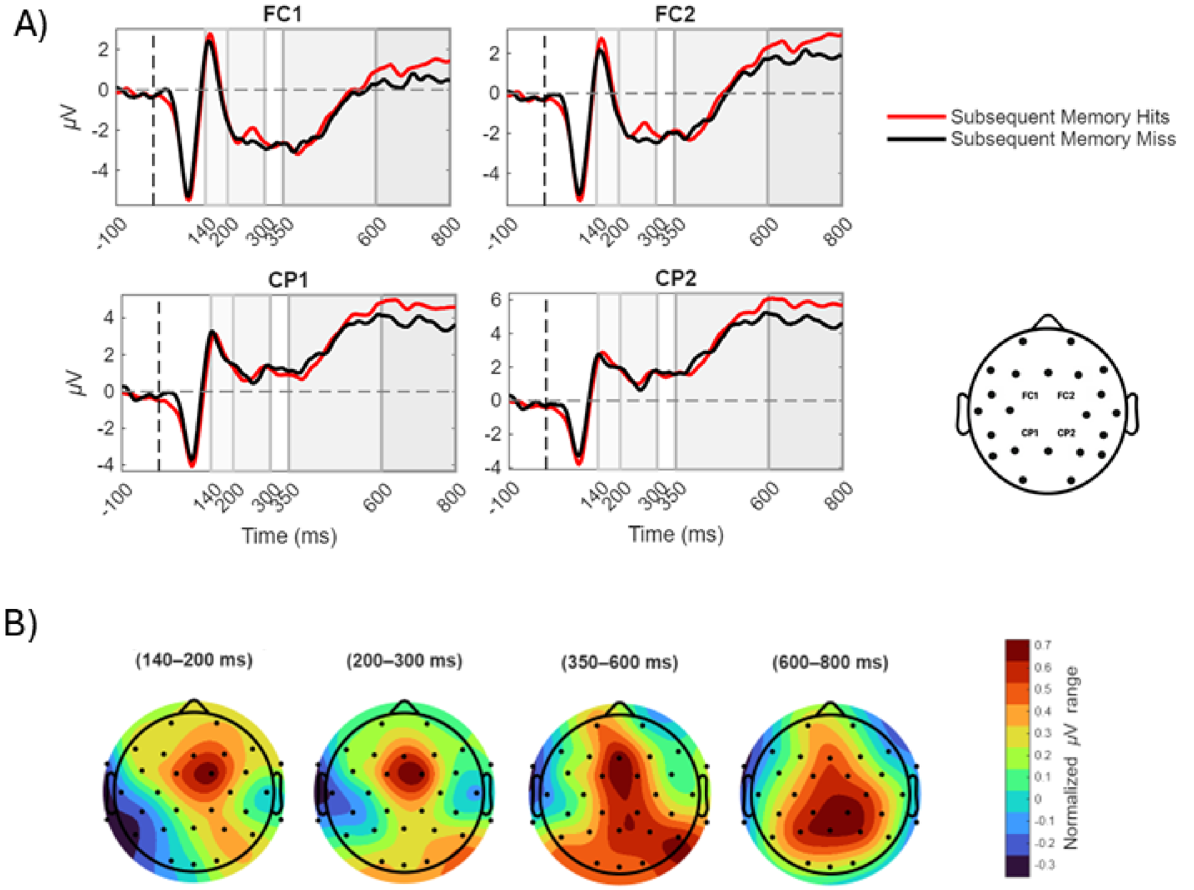


**Panel A.** Grand average waveforms elicited by subsequent fearful hits, subsequent happy hits, subsequent fearful misses, and subsequent happy misses. Locations of the electrode sites are depicted on the inset. **Panel B.** Group mean amplitudes (± standard error across participants) for subsequent hits fear, subsequent hits happy, subsequent misses fear, and subsequent misses happy in each window; horizontal bars and asterisks mark the windows emphasised by the omnibus ANOVAs and follow-up contrasts (see Table 2 for test statistics and p values). All amplitudes are in microvolts (µV).

**Subsequent memory hits vs. Subsequent memory misses.** Memory effects (subsequently remembered vs. forgotten items) emerged in early and late processing stages. During the 140–200 ms N170 window, an interaction effect of IT × AP revealed larger amplitudes for remembered items at frontal electrodes (Table 2), indicating early perceptual discrimination predictive of memory success. This effect re-emerged in the 600–800 ms late LPP window, where it was modulated by an IT × ST interaction alongside IT x AP x ST and IT x ST x HM, demonstrating superior-inferior, anterior–posterior and hemispheric topographical variation during elaborative encoding (Figure 4).

**Figure 4**

*Grand average ERP waveforms and topographies for subsequent hits and misses*

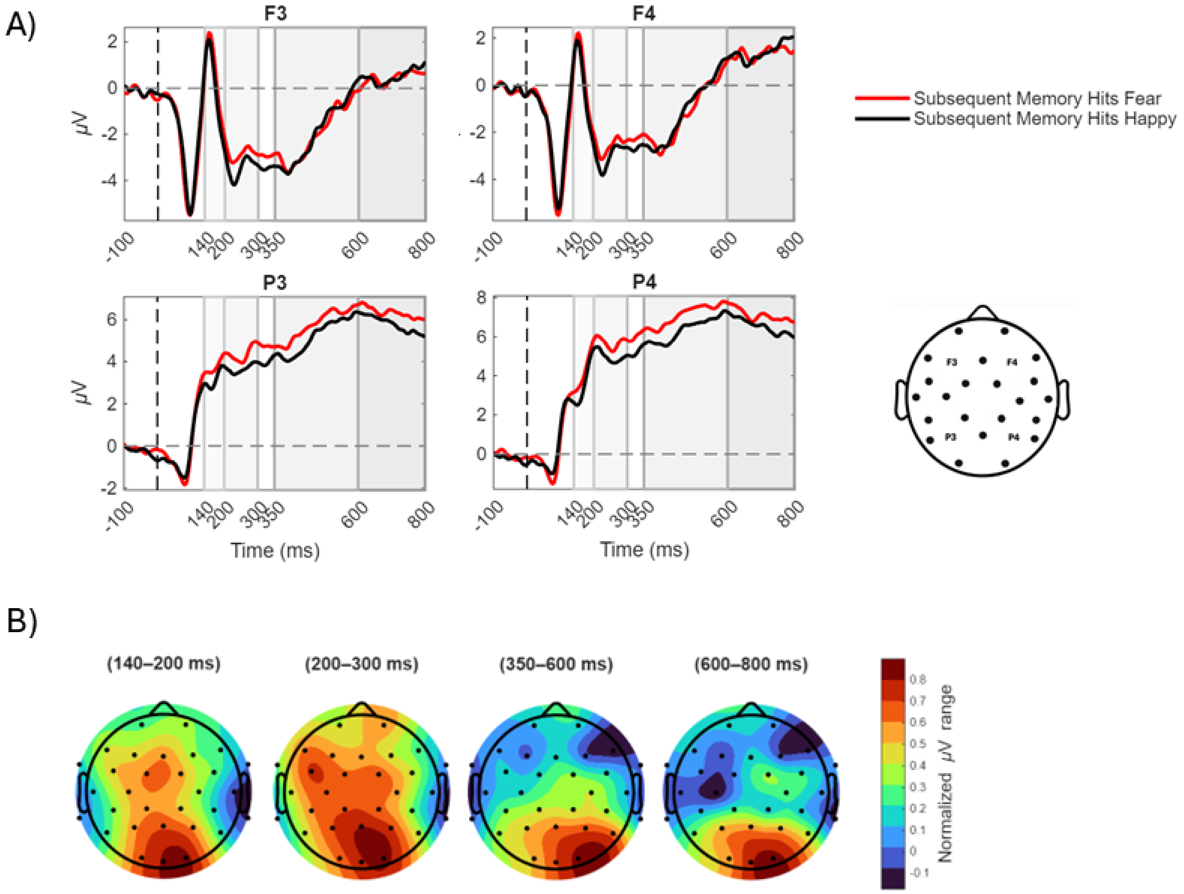


**Panel A.** Grand-average ERP waveforms at the electrodes FC1, FC2, CP1, and CP2 used for the analysis of subsequent hits and subsequent misses. Vertical shaded regions indicate the three analysis windows used for statistics (140–200, 200–300, 350–600, 600–800 ms); the electrode montage is shown in the inset. **Panel B.** Topographic maps displaying the mean amplitude differences between subsequent hits vs. misses, where red represents greater positive effects for subsequent hits relative to subsequent misses, and blue the opposite pattern (colour scale at right, Z-score difference).

**Subsequent fearful hits vs. Subsequent happy hits.** Emotional effects (fearful vs. happy faces) showed time-dependent topographical specificity. In the 140–200 ms N170 window, an emotion main effect reflected larger amplitudes for fearful faces, qualified by an IT × ST interaction localising emotion differentiation to inferior sites (Table 2). In the N250 window (200–300 ms) the main effect seen previously persisted. During the 350–600 ms early LPP window, an IT × AP interaction, and IT × AP × ST interaction revealed emotional differences at posterior/superior sites (Figure 5), while an IT × AP × ST × HM interaction indicated hemispheric asymmetries.

**Figure 5**

*Grand average ERP waveforms and topographies for subsequent fearful and happy hits*



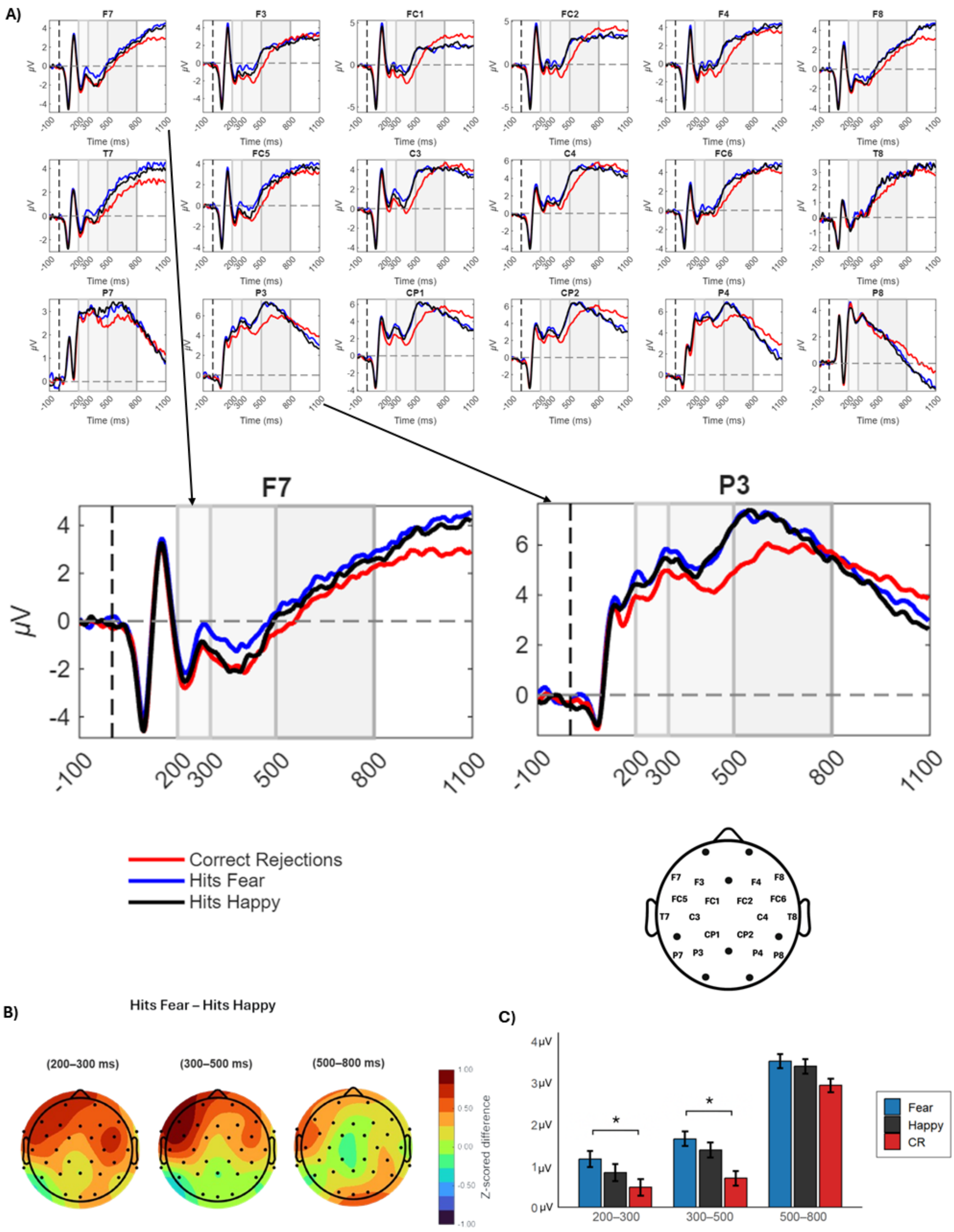
**Panel A.** Grand-average ERP waveforms at the electrodes F3, F4, P3, and P4 used for the analysis of subsequent fearful hits and subsequent happy hits. Vertical shaded regions indicate the three analysis windows used for statistics (140–200, 200–300, 350–600, 600–800 ms); the electrode montage is shown in the inset. **Panel B.** Topographic maps displaying the mean amplitude differences between fearful vs. happy subsequent hits, where red represents greater positive effects for fearful relative to happy hits, and blue the opposite pattern (colour scale at right, Z-score difference).

### *Retrieval*

**Fearful hits vs. Happy hits vs. Correct rejection.** The ANOVA on fearful hits vs. happy hits vs. CR revealed a significant main effect of item type in the 200–300 and 300–500 ms windows (Table 3). Visually, the grand-average waveforms (Fig. 6A) show that both hit conditions begin to rise above CR about 200 ms after stimulus onset, and that such difference was larger in the 300–500 ms interval. The ANOVA also found significant topographic interactions (Table 2: IT×AP, IT×ST, IT×HM and higher-order combinations), indicating that this observed effect is not spatially uniform. The bar plot (Fig. 6C) summarises these larger means for fear and happy relative to CR in the 200–300 and 300–500 ms windows.

**Figure 6**

*Grand average ERP waveforms, topographies and mean amplitudes for fearful and happy hits, and correct rejections*



**Panel A.** Grand-average ERP waveforms at the 18 electrodes used for the analysis of correctly recognised items studied with fearful (blue) and happy (black) expressions, and for correctly rejected new items (red). Vertical shaded regions indicate the three analysis windows used for statistics (200–300, 300–500, 500–800 ms); the electrode montage is shown in the inset. **Panel B.** Topographic maps displaying the mean amplitude differences between hits for faces encoded with fearful vs. happy expressions, where red represents greater positive effects for fearful relative to happy hits, and blue the opposite pattern (colour scale at right, Z-score difference). **Panel C.** Group mean amplitudes (± standard error across participants) for hits fear, hits happy and correct rejections in each window; horizontal bars and asterisks mark the windows emphasised by the omnibus ANOVAs and follow-up contrasts (see Table 3 for test statistics and p values). All amplitudes are in microvolts (μV).

**Fearful hits vs. Correct rejection.** The fearful hits vs CR contrast produced significant item-type effects in the 200–300, 300-500 ms and 500–800 ms windows (Table 3). As can be seen in Figure 6, Panel A, fearful hits are visibly more positive than CR beginning at approximately 200 ms and show a larger difference at frontal sites during 300–500 ms. From 500 to 800 ms, this effect remained significant and was accompanied by interactions suggesting that the largest difference was observed at parietal left-hemisphere sites. These patterns evince the typical mid frontal and left parietal "old/new" effects, along with an early difference emerging at 200-300 ms.

**Happy hits vs. Correct rejection.** No main effect was significant at 200–300 ms, but an interaction involving antero-posterior chain and hemisphere emerged. Happy hits showed a later and somewhat smaller separation from CR, when compared to fearful hits. As for the 300–500 ms window the ANOVA indicated a significant main effect reflecting a mid-frontal FN400 old/new effect (Table 3). By 500–800 ms, only interaction effects showed significant differences, suggesting that the largest difference was observed at left-hemisphere sites. These results are consistent with the LPC old/new effect.

**Fearful vs. Happy hits.** Direct comparisons between hits for faces with fearful vs. happy expressions reached significance only in the 300–500 ms window (IT×AP and IT×AP×ST; Table 2). As can be seen in Figure 6 A and B, the interactions indicate that fearful hits elicited greater positive effects over frontal-lateral electrodes on the left hemisphere relative to happy hits. Notably, this effect was elicited in electrodes that are not typically involved in the N250, FN400, and LPC effects.

**Table 3**

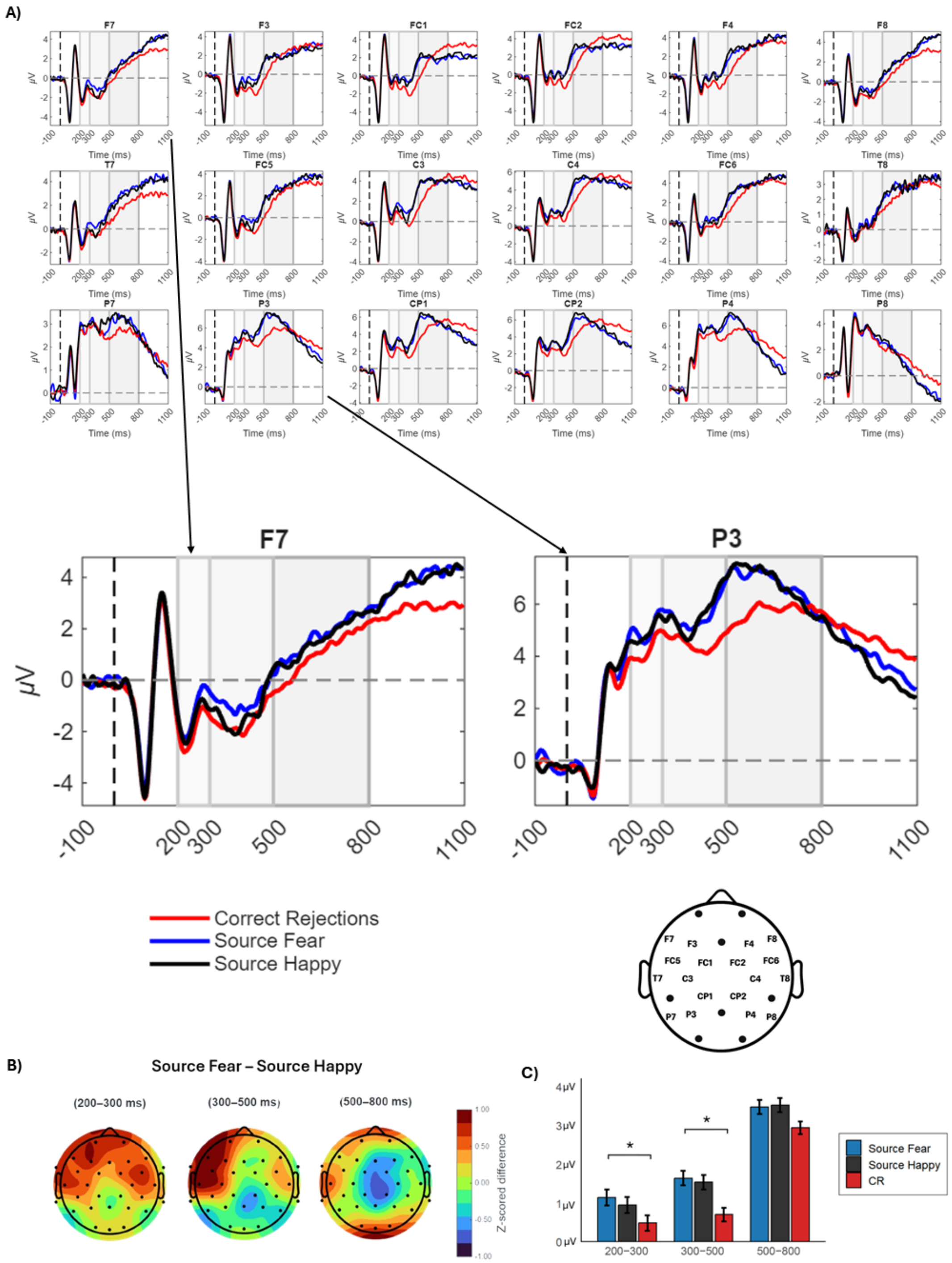
*Contrast of event-related potentials (ERPs) between hits and correct rejections (CRs) at different topographic sites and for different latency regions*

| Effect | 200–300 ms | 300–500 ms | 500–800 ms |
|---|---|---|---|
| **Fearful × Happy × CR** | | | |
| IT | *F*(1.57, 37.6) = 5.86, *p* = .010 | *F*(1.83, 43.9) = 11.3, *p* < .001 | |
| IT × AP | | *F*(2.49, 59.6) = 3.11, *p* = .041 | |
| IT × ST | | *F*(2.25, 54.0) = 11.1, *p* < .001 | |
| IT × HM | | *F*(1.87, 44.9) = 4.73, *p* = .015 | |
| IT × AP × ST | *F*(5.32, 128.0) = 3.12, *p* = .009 | *F*(5.42, 130.0) = 3.41, *p* = .005 | *F*(5.33, 128.0) = 6.09, *p* < .001 |
| IT × AP × HM | *F*(3.00, 72.0) = 2.96, *p* = .038 | *F*(2.86, 68.7) = 3.14, *p* = .033 | *F*(2.89, 69.5) = 10.6, *p* < .001 |
| IT × ST × HM | | | *F*(2.75, 66.0) = 5.40, *p* = .003 |
| IT × AP × ST× HM | | | *F*(5.18, 124.0) = 3.16, *p* = .009 |
| **Fearful × CR** | | | |
| IT | *F*(1, 24) = 8.91, *p* = .006 | *F*(1, 24) = 17.10, *p* < .001 | *F*(1, 24) = 5.31, *p* = .030 |
| IT × ST | *F*(1.09, 26.2) = 6.57, *p* = .015 | *F*(1.11, 26.6) = 19.80, *p* < .001 | |
| IT × HM | *F*(1, 24) = 4.59, *p* = .043 | *F*(1, 24) = 5.47, *p* = .028 | |
| IT × AP × ST | *F*(3.28, 78.7) = 6.94, *p* < .001 | *F*(2.70, 64.7) = 3.69, *p* = .020 | *F*(2.79, 67.1) = 12.00, *p* < .001 |
| IT × AP × HM | *F*(1.80, 43.3) = 6.54, *p* = .004 | *F*(1.61, 38.6) = 4.48, *p* = .024 | *F*(1.61, 38.8) = 15.60, *p* < .001 |
| IT × ST × HM | | | *F*(1.53, 36.7) = 8.18, *p* = .003 |
| IT × AP × ST × HM | | | *F*(3.14, 75.3) = 3.94, *p* = .011 |
| **Happy × CR** | | | |
| IT | | *F*(1, 24) = 8.34, *p* = .008 | |
| IT × ST | | *F*(1.15, 27.6) = 14.70, *p* < .001 | |
| IT × AP × ST | | *F*(2.86, 68.6) = 2.90, *p* = .043 | *F*(3.02, 72.4) = 7.90, *p* < .001 |
| IT × AP × HM | *F*(1.68, 40.3) = 8.16, *p* = .002 | *F*(1.58, 37.9) = 5.01, *p* = .017 | *F*(1.57, 37.7) = 19.10, *p* < .001 |
| IT × ST × HM | | | *F*(1.31, 31.4) = 4.77, *p* = .028 |
| IT × AP × ST × HM | | | *F*(3.15, 75.5) = 3.40, *p* = .020 |
| **Fearful × Happy** | | | |
| IT × AP | | *F*(1.25, 30.0) = 5.27, *p* = .022 | |
| IT × AP × ST | | *F*(3.13, 75.1) = 3.16, *p* = .028 | |

**Source fearful vs. Source happy vs. Correct rejection.** The source hits (fearful vs. happy) vs. CR analysis yielded a main item type effect in the 200–300 and 300–500 ms windows and interactions involving ST, AP and HM in the 500–800 ms interval (Table 4). Both source-hit waveforms diverged from CR around 200 ms, with source-related positivity most pronounced at superior/anterior and left-hemisphere sites in the 300–500 ms window. The bar plot (Fig. 7C) summarises larger mean amplitudes for both source-hit conditions in the 200–300 ms and 300–500 ms windows. Although no main effect was evident in the 500–800 ms window, higher-order interactions emerged, which will be elucidated by the pairwise comparisons below.

**Figure 7**

*Grand average ERP waveforms, topographies and mean amplitudes for fearful and happy source hits, and correct rejections*



**Panel A.** Grand-average ERP waveforms at the 18 electrodes used for the analysis of correctly identified source items studied with fearful (blue) and happy (black) expressions, and for correctly rejected new items (red). Vertical shaded regions indicate the three analysis windows used for statistics (200–300, 300–500, 500–800 ms); the electrode montage is shown in the inset. **Panel B.** Topographic maps display the mean differences between correctly identified source items studied with fearful faces vs. correctly identified source items studied with happy faces wherein red represents greater positive effects for source fear relative to source happy, and blue the opposite pattern (colour scale at right, Z-score difference). **Panel C.** Group mean amplitudes (± standard error across participants) for source fear, source happy, and correct rejections in each window; horizontal bars and asterisks mark the windows emphasised by the omnibus ANOVAs and follow-up contrasts (see Table 4 for test statistics and p values). All amplitudes are in microvolts (μV).

**Source hits for fearful expressions vs. Correct rejection.** At 200–300 ms, there was significant main effect between source hits for fearful faces and correct rejections (Table 4). Figure 4A displays this early positivity for fearful source hits. The old/new difference persisted in 300–500 ms and interacted with superior-inferior electrodes sites (IT × ST; Table 4). From 500 to 800 ms, only interaction effects were found (AP × ST and IT × AP × HM) (Table 3), which reflected a sustained positivity larger at anterior–superior, left-hemisphere sites (Fig. 7A). An additional IT × ST × HM interaction further corroborates this effect on left-hemisphere superior electrodes.

**Source hits for happy expressions vs. Correct rejection.** In contrast to fearful, there was no item type main effect at 200–300 ms. Between 300 and 500 ms, the ANOVA showed a significant item type main effect (source hits > CR), accompanied by an IT × ST interaction (Table 4). Consistent with this interaction, Figure 4A shows the largest separation at superior electrode sites. In 500–800 ms, the ANOVA again yielded a significant item type main effect along with three- and four-way significant interactions (Table 4), indicating that the late old/new positivity is amplified over superior sites and attenuated over inferior sites, with additional distributional nuances captured by the higher-order terms.

**Source hits for fearful vs. Source hits for happy expressions.** The comparison between the two source conditions produced a divergence that appears in the 300–500 ms window, with an IT×HM interaction. This interaction indicates that there is greater amplitude for fearful expressions when compared to happy expressions over left-hemisphere electrodes (Table 4; Fig. 7A-B). The topographical maps, however, suggest that this effect is greater over frontal electrodes of the left hemisphere, a pattern that is consistent with the effects for recognition.

**Table 4**

*Contrast of event-related potentials (ERPs) for source by expression interactions and fearful × happy conditions across different latency regions*

| Effect | 200–300 ms | 300–500 ms | 500–800 ms |
|---|---|---|---|
| **Source fearful × Source happy × CR** | | | |
| IT | $F(1.80, 43.2) = 4.48, p = .020$ | $F(1.82, 43.7) = 9.23, p < .001$ | |
| IT × ST | | $F(2.21, 53.1) = 9.19, p < .001$ | |
| IT × AP × ST | | | $F(5.40, 130.0) = 3.90, p = .002$ |
| IT × AP × HM | | | $F(2.66, 63.8) = 5.90, p = .002$ |
| IT × ST × HM | | | $F(3.49, 83.6) = 4.02, p = .007$ |
| IT × AP × ST× HM | | | $F(5.76, 138.0) = 2.22, p = .047$ |
| **Source fearful × CR** | | | |
| IT | $F(1, 24) = 9.55, p = .005$ | $F(1, 24) = 13.40, p = .001$ | |
| IT × ST | | $F(1.11, 26.7) = 10.90, p = .002$ | |
| IT × AP × ST | $F(3.09, 74.1) = 5.37, p = .002$ | $F(2.81, 67.4) = 3.25, p = .030$ | $F(3.02, 72.4) = 6.78, p < .001$ |
| IT × AP × HM | | | $F(1.54, 37.1) = 5.36, p = .014$ |
| IT × ST × HM | | | $F(1.96, 47.0) = 5.14, p = .010$ |
| **Source happy × CR** | | | |
| IT | | $F(1, 24) = 10.40, p = .004$ | $F(1, 24) = 4.51, p = .044$ |
| IT × ST | | $F(1.14, 27.4) = 15.30, p < .001$ | |
| IT × AP × ST | | | $F(2.87, 68.8) = 5.33, p = .003$ |
| IT × AP × HM | | | $F(1.46, 35.1) = 11.80, p < .001$ |
| IT × ST × HM | | | $F(1.65, 39.5) = 6.38, p = .006$ |
| IT × AP × ST × HM | | | $F(3.20, 76.8) = 3.14, p = .028$ |
| **Source fearful × Source happy** | | | |
| IT × HM | | $F(1, 24) = 5.50, p = .028$ | |

**Summary.** Our findings revealed that fearful expressions enhanced recognition accuracy and elicited a larger amplitude at 140–200 ms, which persisted at both the 200–300 ms and 350–600 ms time windows during encoding. During retrieval, fearful expressions elicited larger 300–500 ms mid-frontal/left-lateral positivity but did not confer an advantage in source memory. By contrast, LPC (500–800 ms) old/new activity was present but did not differ by emotional expression, mirroring the null result for source memory. Taken together, the results indicate that fear biases retrieval primarily by amplifying early to mid-latency processes possibly linked to familiarity or even rapid access to face representations, rather than by selectively amplifying late recollection, providing novel evidence for threat-related modulation of retrieval processes under neutral test cues.

### 3.4. Discussion

In this first experiment, we investigated the influence of emotional facial expressions on recognition memory and the underlying neural mechanisms by using ERPs. Our behavioural results included a significant effect on recognition accuracy, in which participants exhibited higher accuracy in recognizing faces encoded with fearful expressions compared to faces encoded with happy expressions. Also, we observed that during encoding, fearful faces showed significantly larger positivities when compared to happy faces in the N170, N250, and early LPP time-windows. We can interpret this as fearful faces being rapidly categorized as threat, dampening early structural/emotion-discrimination processing (smaller N170/N250), while amplifying sustained evaluative attention (larger early LPP), thereby prioritizing their encoding and later memory. As for retrieval, we found that fearful faces elicited a larger 300–500 ms mid-frontal/left-lateral positivity. This indicates that fear enhanced retrieval primarily by amplifying early to mid-latency processes linked to familiarity (and possibly rapid access to face representations), rather than by selectively amplifying late recollection

### *The processing of facial emotional expressions*

Our visual inspection and statistical analysis of the ERP waves during encoding demonstrated the presence of the subsequent memory effect (SME), where faces that were later recognized elicited a more positive amplitude than those later missed. This effect appeared in two time-windows, the initial 140–200 ms and from 600–800 ms, indicating a robust neural response associated with successful memory retrieval which is on par with results from memory experiments using faces as stimuli (Guillem et al., 2001).

Later successfully retrieved fearful faces elicited early differences (140–200, 200–300 and 350–600 ms) when compared to happy faces. This finding suggests that emotional content influences processing beginning at a very early stage. A meta-analysis indicated that the N170 component (140–200 ms) is sensitive to emotion, which supports the idea of an integrated, or at least not strictly separated, processing of facial identity and facial expressions (Hinojosa et al., 2015). Typically, threat-related faces (fearful or angry) enhance early visual responses like N170 (Schindler et al., 2023) which suggests a heightened early analysis of salient features (e.g., wide eyes of fear). However, a smaller N170 negativity for fearful faces (relative to happy), such as what has been found in this experiment, implies that the salience of fearful expressions alters the normal pattern of neural responses. One interpretation is that the brain rapidly detects the threat in a fearful face (possibly via a subcortical route through the amygdala) and thus requires less effort during encoding, effectively bypassing some of the structural/perceptual analysis. In other words, the presence of fear might trigger quick category detection (threat) that overlaps with or dampens the typical N170 face-processing spike.

The N250 (200–300 ms), sometimes overlapping with the early posterior negativity (EPN), represents a deeper stage of face processing. This component has been linked to higher-order decoding of facial information, such as recognizing identity or categorizing emotional expression (Schweinberger et al., 2002). Given this, the finding in this experiment that fearful faces elicited a more positive N250 compared to happy faces suggests that the processing of fear at this stage is qualitatively different. One possibility is that because the fearful expression is detected so rapidly (by approximately 250 ms) the brain has already identified it as a high priority threat, and thus, the ERP amplitude for encoding is reduced. In essence, the system may require less incremental neural effort to categorize a fearful face (the threat is obvious), resulting in a smaller N250 deflection.

Finally, in the 350–600 ms (Early LPP), fearful faces evoked a more positive early LPP than happy faces. The LPP is a sustained positive wave associated with attention and evaluative processing of stimulus significance. Emotional stimuli reliably produce a larger (more positive) LPP than neutral stimuli (Brown et al., 2012). Therefore, our results can be interpreted as fearful faces having a higher engagement of attentional resources and sustained processing when compared to happy faces. In other words, once the initial perception registers the face as salient, the brain allocates ongoing attention to it in a manner that is not evident for happy faces.

### ***The effect of emotional expressions on recognition memory***

Overall, the behavioural data indicated a significantly higher accuracy in recognizing faces encoded with fearful compared to happy expressions. This observation aligns with proposals that negative emotion enhances item-specific memory (Kensinger & Kark, 2018). Also, these findings reinforce prior reports of enhanced performance for fearful facial expressions under neutral retrieval (cf. Righi et al., 2012) and for negative facial expressions more generally (e.g., Grady et al., 2007), as well as negative valence advantages for words and scenes (e.g., Kensinger & Corkin, 2003; Ochsner, 2000).

However, it is worth noting that there were no significant differences in accuracy for source memory responses between fearful and happy faces, indicating that the different emotional content did not influence the recollection of the contextual information coming from the facial expressions. These results are in opposition to previous research that showed that contextual attributes of negative events are better remembered than those of neutral or positive events (Kensinger & Schacter, 2007; Kensinger & Schacter, 2005; Mather & Nesmith, 2008). For instance, participants remember the location of arousing negative stimuli better than that of positive and non-arousing stimuli (Mather & Nesmith, 2008). However, these experiments did not use facial expressions as the emotional characteristic of the stimuli, which can lead to important differences in regard to experimental design and cognitive processes engaged.

One example that is more similar to the present study is the series of studies (Bell & Buchner, 2011; Buchner et al., 2009) that found an enhanced source memory for faces associated with socially threatening behaviour descriptions (cheating, trustworthy, or neutral behaviour). Interestingly, the effect found seemed to be confined to socially threatening information and not simply due to the negative valence or arousal of the descriptions. Based on that conclusion we can assume, firstly, that source memory for emotional information associated with facial stimuli cannot be simply explained by attentional allocation. Our findings show that subjects better recognise faces that were fearful, but fail to better recollect their facial expressions. If heightened attention drawn to the fearful stimuli was the only modulation causing the better recognition of fearful faces, then it would be expected to see a better memory for their respective fearful source expressions. It may contribute to the observed difference in recognition memory, but there are certainly other cognitive processes involved.

Secondly, the emotional source effect may not apply to all negative expressions. It may instead prioritize memory for socially threatening information that helps to avoid a potentially dangerous encounter (Bell & Buchner, 2011; Buchner et al., 2009). If so, fearful faces might not elicit this memory mechanism. I would argue that it would not be as advantageous to remember the terrified expression of someone who has just encountered a terrible thing compared to the facial expression of someone who has just told you about having committed a socially threatening behaviour. In the latter example, evaluating whether or not the person who committed the act feels remorse or guilt could be significantly advantageous in future social interactions. Furthermore, I would hypothesise that fearful faces could enhance source memory for contextual information that would help the subject to assess the nature and cause of the expressed fear.

Following this line of thought, it would be interesting to explore if other facial expressions (e.g., anger) might evoke an advantage in source memory. In addition, another interesting experiment might involve investigating to what extent emotional information presented in contextual cues (instead of facial expressions) involve the same cognitive mechanisms observed in emotional memory for faces.

Another study involving memory for facial expressions (Shimamura et al., 2006) found an advantage in terms of source memory for happy expressions. They hypothesised that these results could be due to increased attentional allocation directed to the identity of a person who is smiling, given that a smile often communicates a social bond (familiarity, attractiveness, kinship). The specific responses to various emotional expressions are thus illustrative of the many ways in which attention and memory interact during social interactions. Finally, this effect on source memory based on emotional facial expressions may depend on factors such as delay between exposure and retrieval (Pazderski & McBride, 2018) and whether encoding is intentional or incidental (D’Argembeau et al., 2003). Further research is warranted.

The ERP results showed a pattern involving a frontally distributed early old/new divergence (200–300 ms) that is more apparent for fearful faces, a fear-selective left frontal amplitude positivity in the 300–500 ms window, and an emotional-invariant LPC. This frontal topography is consistent with previous findings showing that emotional context can elicit early anterior ERP modulations during retrieval, possibly reflecting context reactivation, enhanced monitoring, or familiarity-biased processing (Smith et al., 2004; Jaeger et al., 2009), while the later parietal old/new effect that indexes recollection, is similarly engaged by both fearful and happy facial expressions (Rugg & Curran, 2007; Yonelinas & Ritchey, 2015).

At the earliest stage, we observed a 200–300 ms old/new positivity for fearful hits relative to correct rejections over frontal scalp sites, whereas happy faces did not show a main effect in this window (only a distributional interaction), indicating a later onset of the old/new separation for happy items. Although this latency overlaps the classic EPN/N250 range, canonical EPN and N250 effects are typically posterior/occipito-temporal (with the N250r often right-lateralised), rather than frontal (Schupp et al., 2004; Schweinberger et al., 2004). Accordingly, we describe the present effect cautiously as an early old/new difference, without assigning it to a typical EPN/N250. Functionally, such an effect is compatible with rapid access to stored fearful face representations under neutral test cues (Tanaka et al., 2006; Sommer et al., 2021), while faces encoded with happy expressions reached a comparable old/new separation later in time. Critically, this early difference varying by emotional expression indicates that fearful encoding facilitated initial access for the studied faces, setting the stage for later emotion-sensitive differences.

In the 300–500 ms latency window, fearful-encoded faces elicited a larger mid-frontal positivity than happy-encoded faces, that difference was most focal over left centro-frontal electrodes. Because the canonical FN400 is typically broader and relatively symmetric (Rugg & Curran, 2007), we interpret this as a emotion-sensitive left-frontal modulation rather than a prototypical FN400. This stance is consistent with evidence that the 300–500 ms interval can reflect overlapping processes (familiarity and semantic conceptual facilitation) whose scalp expression depends on task demands (Curran, 2000; Voss & Paller, 2009). Importantly, where the 300–500 ms difference was largest, later parietal activity was not correspondingly enhanced, reinforcing that the emotional effect was not driven by recollection processes (Rugg & Curran, 2007). This finding goes into the direction of previous studies that showed that an item's emotional context during encoding can bias early/mid-frontal retrieval signals in the absence of emotional cues at retrieval (Righi et al., 2012). Converging evidence indicates that when emotion is confined to encoding, recognition ERPs can diverge from 200 ms with neutral test cues and that such contextual encoding emotion effects may even appear for misses, consistent with a rapid, fluency-like trace partly dissociable from later recollection (Jaeger et al., 2009; Jaeger & Rugg, 2012).

By contrast, the LPC (500–800 ms), a neural correlate for recollection, was robust for both emotions but did not differ in amplitude for fearful vs. happy faces, paralleling the absence of emotional effects in source accuracy. This parity supports accounts in which arousal, rather than valence per se, is the principal driver of recollection strength when arousal is matched across conditions (Yonelinas & Ritchey, 2015; Kensinger & Kark, 2018). The comparable LPCs therefore suggest that both high-arousal expressions engaged hippocampal-cortical recollection networks to a similar degree, with the sustained parietal positivity reflecting equivalent contextual reinstatement (Rugg & Curran, 2007). Such an outcome is compatible with arousal-based models of late elaborative processing (Lang et al., 1997) and indicates that valence-specific influences are more likely to manifest at earlier familiarity-related stages.

At first, the absence of valence effects in LPC and source memory may seem inconsistent with reports that negative emotion can enhance recollection or source accuracy (e.g., Johansson et al., 2004; Mather & Nesmith, 2008). Two features of the present design make parity likely. First, our "source" was intrinsic to the face (its expression) yet absent at test. Intrinsic features attended at encoding tend to be strongly bound to the item, which can elevate recollection for both valences and compress between-valence differences (Kensinger & Kark, 2018). Second, fear and happiness were both high-arousal in our materials; when arousal is matched, recollection advantages by valence are often weak or inconsistent, whereas familiarity-stage differences persist (Yonelinas & Ritchey, 2015; Kensinger & Kark, 2018).

These considerations clarify why we observed a fear advantage mid-frontally but no LPC/source difference.

Additionally, another plausible explanation for the lack of emotional difference in the LPC, differently from what was observed in the Righi et al. (2012) study, is the interference of the late posterior negativity (LPN). The LPN is a negative-going, posteriorly maximal ERP that overlaps temporally with the LPC (500–1000 ms). It is often linked to reconstructive/post-retrieval operations, searching for source details, evaluating partial information, or monitoring when the cue is underspecified (Sommer et al., 2018). Because the LPN is negative and posterior, a stronger LPN can partially cancel a positive-going LPC at the same electrodes and latencies, making any true LPC difference between conditions harder to see. Since our task encouraged effortful source search in both fear and happy conditions, the resulting LPN could have been comparable across emotions and thereby flattened potential LPC valence differences. Either way, a superposition between LPN and LPC is a credible explanation for "no emotion effect in the LPC." Importantly, the study from Righi et al. (2012) did not ask for source retrieval.

The removal of emotional cues at retrieval minimised perceptual confounds and forced the participant to rely on memory for the emotional context present during encoding, a situation that tends to privilege early familiarity/fluency (Righi et al., 2012; Rugg & Curran, 2007). Because test faces were neutral, recovery of the expression depended on mnemonic reinstatement rather than cue-driven re-perception, favouring a generic sense of oldness at immediate test (Voss & Paller, 2009; Yonelinas & Ritchey, 2015). Immediate retrieval further minimises consolidation-related divergences often posited to favour negative material. Several accounts predict that valence-linked recollection differences can strengthen after delays or sleep (Payne & Kensinger, 2010; Yonelinas & Ritchey, 2015; Kensinger & Kark, 2018). This timing helps explain our pattern: robust LPC for both emotions, with valence effects confined to earlier mid-frontal dynamics.

The left-lateralised scalp distribution of the 300–500 ms fear effect aligns with imaging data. Meta-analytic fMRI shows that fearful faces reliably engage the amygdala along with medial/inferior frontal cortices, and that explicit emotion tasks preferentially recruit left medial and inferior frontal gyri, which were precisely the topographies expected to contribute to a left fronto-central enhancement during explicit recognition of threat-associated faces (Fusar-Poli et al., 2009). Together with the ERP literature showing fronto-central enhancements for fear-encoded items under neutral cues (Righi et al., 2012) and early emotion effects even without overt recognition (Jaeger & Rugg, 2012), a plausible account is that interactions between the amygdala and the mPFC that were established at encoding bias left-lateralised familiarity/fluency at retrieval (Fusar-Poli et al., 2009; Kensinger & Kark, 2018).

The present perspective on our data clarifies both convergence and divergence with prior work. Like Righi et al. (2012), we observed fear-related enhancements in earlier retrieval stages under neutral cues, consistent with a familiarity modulation. Unlike reports of broader late positivities for fear, we did not detect an LPC advantage. Differences in the operationalization of source (intrinsic expression here vs. extrinsic context elsewhere), retention interval (immediate here vs. longer delays), and the topography of mid-frontal effects can shift where valence influences emerge (Righi et al., 2012; Voss & Paller, 2009; Jaeger et al., 2009; Yonelinas & Ritchey, 2015). These conditions suggest that parietal emotional effects are most likely when there are arousal differences, when the emotional contextual features are reinstated, or when consolidation has time to differentially strengthen traces (Jaeger et al., 2009; Jaeger & Rugg, 2012; Kensinger & Kark, 2018).

In sum, fearful expressions at encoding selectively enhanced early–mid retrieval operations linked to familiarity/fluency under neutral cues, whereas late recollection indexed by the LPC and by source accuracy was equivalently engaged by high-arousal fear and happiness (Rugg & Curran, 2007; Righi et al., 2012; Jaeger et al., 2009; Jaeger & Rugg, 2012; Yonelinas & Ritchey, 2015; Kensinger & Kark, 2018). This stage-specific architecture helps reconcile mixed findings and underscores that the impact of emotion on memory depends not only on what is retrieved (item vs. context) but when in the retrieval processes emotion exerts its influence.

Several limitations warrant consideration. The restricted trial counts in no-source conditions, while analytically necessary, constrained our ability to fully explore source-specific ERP dynamics. Future studies should employ optimised learning paradigms to ensure sufficient trials across conditions without compromising ecological validity. The exclusive focus on happy and fearful expressions, while theoretically justified, limits generalizability to other emotional categories. Angry expressions might elicit different effects due to approach-related motivations, while sad faces might show reduced arousal effects despite similar valence.

### 3.5. Conclusion

In conclusion, our first experiment highlights the differential impact of emotional facial expressions on memory encoding and retrieval processes. Fearful expressions enhance recognition accuracy and result in early engagement of emotional effects during encoding. This initial emotional distinction affects ERP components related to perception and attentional mechanisms that may alter the encoding of hippocampal-dependent episodic memory. During retrieval, fearful expressions selectively amplified a left-lateralised mid-frontal positivity in the 300–500 ms window, possibly related with some kind of initial modulation of familiarity processes, while leaving the parietal LPC and source accuracy indistinguishable from those for happy faces. These findings contribute to our understanding of how emotional expressions modulate memory-related neural processes, helping us to understand how emotion, perception and memory work in the human brain. However, further research is needed to explore the underlying mechanisms and potential functional significance of these effects in memory encoding and retrieval processes. Other experiments assessing the effects of different emotional expression would be useful in building a more complete picture of the studied phenomena.

In order to investigate the effects of valence in a more controlled manner we developed a second experiment in which arousal levels could be manipulated to not differ significantly for the distinct valence emotional conditions. The recognition task was modified to employ emotional contexts and neutral faces during encoding, instead of different emotional facial expressions.

# 4. Experiment 2 – Memory for faces encoded over emotional contexts

## Abstract

In this study, we explored the impact of different emotional encoding contexts on the retrieval processes for faces. Employing electroencephalogram (EEG), we analysed the event-related potentials (ERPs) elicited during the recognition of neutral faces that at encoding were associated with pictures of emotional scenes (negative, positive, or neutral). Behavioural analysis revealed no significant differences in accuracy or reaction times across emotional conditions. ERP data demonstrated the expected old/new effect, with the largest old/new positivity over centro-parietal sites, preceded by earlier divergences at frontal electrodes for collapsed all hits compared to correct rejections. Comparisons between negative and neutral hits showed significant differences from 200–800 ms, larger over right-central electrodes. We argue that this arousal-related modulation is a context-reactivation effect carried over from the negative studied scenes. Overall, these results suggest that arousing contexts modulates memory for faces through implicit processes, that are not dependent on memory retrieval.

### 4.1. Introduction

Several experiments demonstrate greater memory retention for emotional relative to neutral stimuli (e.g. Bradley et al., 1992; Dolcos et al., 2004; Dolcos et al., 2005). In these experiments, emotional stimuli are typically categorized based on two primary dimensions. The arousal dimension is described as physiological and subjective reactivity, while the valence dimension is described as a continuum between pleasant and unpleasant emotions (Lang et al., 1993). In other words, valence refers to how positive or negative a given stimulus or experience is, and arousal refers to how exciting or calming that stimulus or experience is. Several studies have highlighted the importance of valence and arousal in the experience and perception of emotion and affect (for a review, see Barrett & Bliss-Moreau, 2009; Mattek et al., 2017).

It has been observed that emotion affects memory differently depending on the stimulus valence and arousal levels. Several studies point out differences regarding arousal and valence emotional effects during encoding processes. For example, there is ample ERP evidence supporting the notion that arousal is processed earlier than valence (Jhean-Larose et al., 2014; Recio et al., 2014; Styliadis et al., 2015). Furthermore, when considering attention during the encoding process, arousing stimuli draw more attentional resources than non-arousing stimuli (Bröckelmann et al., 2011; Schmidt et al., 2015). Regarding the differences between negative and positive valence, it is suggested that negative stimuli lead to better encoding of sensory details compared to positive stimuli (Bowen et al., 2018).

Upon examination of previous studies investigating ERP correlates in emotional memory tasks during retrieval, it becomes evident that emotional stimuli, in comparison to neutral stimuli, exhibit greater old/new parietal effects, which manifest later than the typical old/new effects (Jaworek et al., 2014; Schaefer et al., 2011; Weymar et al., 2009, 2010a, 2010b, 2011; Wirkner et al., 2013, 2015). This seems to suggest an important role for the recollection process during the retrieval of emotional stimuli (Dolcos et al., 2005). However, this emotional effect is not exclusive to recollection processes.

An extensive body of ERP research suggests that the emotional effect for negatively valenced items occurs throughout each information processing step. This is evident from the initial visual processing and attention allocation to higher cognitive processes (Smith et al., 2003; Carretié et al., 2001; Delplanque et al., 2004, 2005; Huang & Luo, 2006; Ito et al., 1998). This effect for negatively valenced items can lead to the concurrent encoding of neutral contextual details. For instance, contextual details (e.g., the time or colour of the clothes of a burglar) related to an emotional event (e.g., a robbery) can be integrated into the memory representation through associative processes, leading to better retrieval of the associated information (Davachi, 2006; Ventura-Bort et al., 2016).

Several studies have used ERPs to study the retrieval of neutral stimuli associated with emotional contexts during the study phase of recognition memory tasks (Jaeger et al., 2009; Maratos et al., 2001; Maratos & Rugg, 2001; Smith et al., 2004; Smith et al., 2005; Smith et al., 2006; Ventura-Bort et al., 2016; Ventura-Bort et al., 2020). Using neutral retrieval items that have been encoded in association with emotional contexts avoids generating confounding ERP effects during the test phase, allowing for more rigorous control during data collection. That is, when seeking to investigate only the emotional effects on memory retrieval, using neutral retrieval items prevents the typical ERP correlates associated with encoding or perceptual processing of emotional stimuli from being elicited during recognition.

ERP studies about emotional memory on associated contextual information have generated diverse behavioural and electrophysiological results. Considering the behavioural findings, some studies have found memory improvements for neutral stimuli encoded in both positive and negative emotional contexts (Davachi, 2006; Ventura-Bort et al., 2016), other studies have demonstrated memory improvements for items associated with positive contexts only (Smith et al., 2004; Smith et al., 2005), and still other have found no behavioural effects of emotion whatsoever (Jaeger et al., 2009; Jaeger & Rugg, 2012).

In terms of ERP findings, we see diverging results. Some studies found that old/new parietal effects were enhanced for items associated with emotional relative to neutral contexts (Maratos & Rugg, 2001; Ventura-Bort et al., 2016). On the other hand, other studies found differences in initial effects (approximately 200 ms) and were characterized by the positivity of the items associated with emotional contexts when compared to items associated with neutral contexts, implying an initial and quicker emotional modulation linked to arousal (Smith et al., 2004; Jaeger et al., 2009).

Some key factor could have been the reason for which such plurality of results was found. First, while these previous studies (Maratos & Rugg, 2001; Ventura-Bort et al., 2016; Smith et al., 2004; Jaeger et al., 2009) have used ERPs to investigate memory for neutral items encoded in emotional contexts, the effects of arousal and valence have not been clearly differentiated, potentially contributing to the wide range of results with respect to timing of retrieval processes. Second, most neutral-cue paradigms have used words (Maratos & Rugg, 2001) or objects (Ventura-Bort et al., 2016; Smith et al., 2004; Jaeger et al., 2009), as their target stimuli. Considering the competition for attentional allocation between the emotional context and the associated neutral item, using different neutral stimuli (in this case, neutral faces) could provide insights into how attentional allocation and integration between target-context stimuli occur during encoding.

Recent studies have shown that memory for facial identity is strongly influenced not only by facial expressions (D'Argembeau et al., 2003; D'Argembeau & Van Der Linden, 2007; Shimamura et al., 2006; Righi et al., 2012) but also by the emotional context in which the face was inserted (Van den Stock et al., 2007; Righart & de Gelder, 2008a, 2008b). Also, previous studies have shown that these contexts can influence face perception (Wieser & Brosch, 2012, for review). In addition, social interactions occur within contexts of varying emotional arousal, indicating that memory for faces is subjected to integration with contextual details in real-life scenarios.

The manner in which contextual emotional guides attentional allocation for neutral items (faces) affects memory for both facial identity and the contextual information (Bradley et al., 1992; LaBar & Cabeza, 2006). There is also evidence that the processing of faces is systematically influenced by context through the activation of prefrontal structures, such as the anterior cingulate cortex (ACC), operationalizing rapid face-context integration (Van Den Stock et al., 2014).

Previous studies (Van Den Stock et al., 2014) underline the importance of how stimuli are linked. According to the Arousal Biased Competition Theory (ABC) (Mather & Sutherland, 2011), the level of emotional arousal can lead to either an attentional boost or an attentional impairment for the contextual information associated with the arousing stimulus. Due to an increase in attentional allocation, emotional arousal could enhance the associative memory for certain high-priority contextual features (i.e., colour, location, etc.). At the same time, arousal can cause memory impairment for other lower-priority features, such as neutral stimuli associated with an emotionally arousing context. We seek to reduce the attention competition pressure between the emotional contexts and the target stimuli, as faces are handled by a specialised, rapid system with robust early ERP neurocognitive markers (e.g., N170) and very early decoding of coarse facial dimensions (Bentin et al., 1996; Haxby et al., 2000; Dobs et al., 2019). In addition, emotion engages amygdala–fusiform interactions that can facilitate face processing even under attentional load, further protecting targets from contextual competition (Vuilleumier et al., 2001; Herrington et al., 2011).

Therefore, to investigate more about the emotional influence of contexts in memory for faces, we examined the ERPs elicited during the testing phase of a recognition memory task in which faces with neutral expressions were studied in positive, negative, and neutral contexts. We analysed the ERPs elicited by faces correctly recognized as old that were encoded in arousing and non-arousing contexts, as well as positive and negative contexts, with the objective of describing the differences in the old/new effect modulation for both arousal and valence, separately. Based on previous research that explored the emotional effects on memory (Jaeger et al., 2009; Smith et al., 2004; Ventura-Bort et al., 2016), we anticipate observing different influences on old/new effects depending on arousal and valence, with arousal effects occurring initially and faster, and valence effects occurring later.

## 4.2. Methods

### *Participants*

Thirty-five university students (15 women) aged 18–32 years (*M* = 24.37 years, *SD* = 3.61) voluntarily participated in the study. All participants were native Brazilian Portuguese speakers who had normal or corrected-to-normal vision and signed a consent form attesting their agreement to voluntarily participate in the study. Of these 35 participants, 5 were rejected from the electrophysiological analysis, due to equipment failure during EEG recording. Therefore, analyses were carried out on data from 30 participants (11 women) with ages 18–32 (*M* = 24.20 years, *SD* = 3.47). All procedures were approved by the Institutional Review Board of the Federal University of Minas Gerais, Brazil.

### *Materials*

Stimuli consisted of 360 photos of faces and 180 photos of scenes. At a viewing distance of the 70 cm, the photos of scenes subtended a maximum vertical angle of 17° 13’ and a maximum horizontal angle of 30° 7’ and were presented on a black background on a 17-inch computer screen. The face photos had a white background and subtended a maximum vertical angle of 7 ° 26' and a maximum horizontal angle of 4 ° 57' and were presented in the centre of the computer screen, superimposed over the scenes (see Figure 8). The faces were taken from the *Chicago Face Database* (Ma et al., 2015). They all exhibited neutral expressions and were randomly assigned to each experimental condition for all participants individually. The scenes consisted of pictures of people, animals, objects, and landscapes and were taken from three international databases: IAPS (*International Affective Picture System*; Lang et al., 1997); GAPED (*Geneva Affective Picture Database*; Dan-Glauser & Scherer, 2011), and NAPS (*Nencki Affective Picture System*; Marchewka et al., 2014). The 180 scenes included 60 scenes from each valence category (i.e., positive, negative, and neutral). To examine whether the valence categories differed (Table 5), we conducted *t*-tests comparing these categories for arousal and valence. For the dimension of arousal, the neutral scenes were less arousing than both the positive, $t(59) = 28.02$, $p < 0.001$, $d = 3.43$, and the negative scenes, $t(59) = 39.4$, $p < 0.001$, $d = 4.24$, while the positive and negative scenes were indistinguishably arousing, $t(59) = 1.71$, $p = 0.09$, $d = 0.13$. As expected, for the valence dimension, positive scenes scored higher than neutral, $t(59) = 23.12$, $p < 0.001$, $d = 2.28$, and neutral higher than negative, $t(59) = 19.79$, $p < 0.001$, $d = 3.09$. All stimuli used in the experiment are listed in Appendices C and D.

**Table 5**

*Mean (and Standard Deviation) of the valence and arousal scores of the images selected as contexts*

| | Neutral | Positive | Negative |
|---|---|---|---|
| Arousal | 3.51 (0.57) | 5.84 (0.77) | 5.93 (0.57) |
| Valence | 5.27 (0.82) | 6.94 (0.63) | 2.73 (0.85) |

### *Procedures*

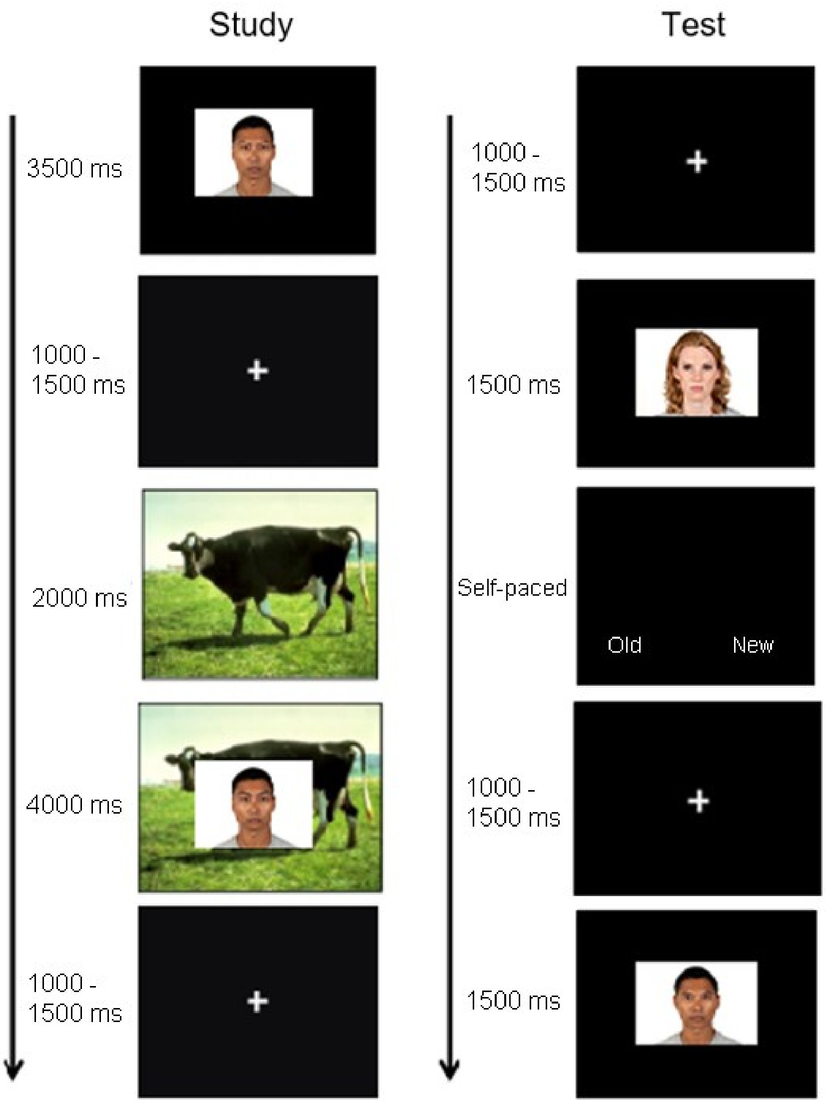
The study was conducted in the same setting as Experiment 1. The experimental task comprised of nine blocks comprising a study and test phase. Immediately before the beginning of the first block, a brief practice phase analogous to the actual experiment was conducted (with 6 study and 12 test trials). During practice, participants became familiar with the task and judged whether they felt comfortable seeing the type of emotional images that would be shown during the actual study.

For each study task, 20 pairs of faces and scenes were randomly produced for each participant. Each study trial began with the presentation of a face for 3500 ms, and participants were asked to classify it as pleasant or unpleasant using green and red keys on a response keypad, respectively. Immediately after the offset of each face, a white fixation cross was presented on the centre of the screen for a randomly assigned time ranging from 1000 ms to 1500 ms, followed by the presentation of the scene for 2000 ms. Finally, the scene remained on screen for an additional 4000 ms with the corresponding face superimposed on its centre (see Figure 8). At this moment, the participant's task was to imagine a story involving the face and background scene. The next trial was preceded by a fixation cross presented on the centre of the screen for a randomly assigned time ranging from 1000 ms to 1500 ms (stimulus onset asynchrony = 7500 to 8500 ms). Although this task was performed covertly, during the practice phase, participants were asked to verbally describe the imagined scenes to ensure that they understood the task. Also, on randomly determined trials (probability = 0.025 per trial), a screen appeared asking the participant to verbally describe their imagined story.

During the test, all 20 faces that were presented on each study block were presented again but this time shuffled randomly between 20 other new faces. Each face was presented in the centre of the screen for 1500 ms and were followed by a text stimulus indicating that the participant should produce their answer. The participant's task was to judge whether each face was "old" or "new" by pressing the green and red keys, respectively (Fig. 8). This task was self-paced, but participants were asked to respond as quickly as possible, without sacrificing accuracy. After each old/new response, a fixation cross was presented for a randomly assign time ranging from 1000 ms to 1500 ms. ERP recording was performed throughout the test phase.

**Figure 8**

*Schematic representation of the presentation of stimuli during the study and test phase of Experiment 2*



### *ERP recording and analysis*

Electroencephalographic activity (EEG) was continuously recorded from 31 electrodes of Ag/AgCl inserted in an elastic cap (www.easycap.de/easycap). Electrode placement was based on the international 10-20 system (American Electroencephalographic Society, 1994), and corresponded to the medial locations (Fz, Pz and Oz) and the homotopic pairs (Fp1/Fp2, F3/F4, F7/F8, FT9/FT10, FC1/FC2, FC5/FC6, C3/C4, CP1/CP2, CP5/CP6, T7/T8, TP10/TP9, P3/P4, P7/P8, and O1/O2). For the correction of ocular movement, the interpolation of the Fp1 electrode was used for the vertical electrooculogram (VEOG), and the interpolation of the F7 and F8 electrodes was used for the horizontal electrooculogram (HEOG). Data were recorded using the actiCHamp amplifier (Brain Products GmbH – www.brainproducts.com) with a sampling rate of 250 Hz and an amplifier bandwidth of 0.01 to 100 Hz (-3 dB). Interelectrode impedances were adjusted for less than 5 kΩ.

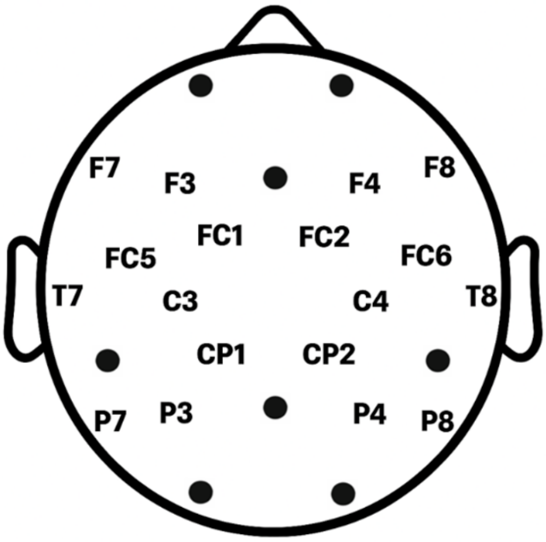
EEG and ERP data processing were conducted in Matlab R2024a (www.mathworks.com) using EEGLAB version 2024.0 (https://sccn.ucsd.edu/eeglab/index.php; Delorme & Makeig, 2004) and ERPLAB version 12.00 (https://erpinfo.org/erplab; Lopez-Calderon & Luck, 2014), and the statistical analyses of ERPs were conducted using *R* software version 3.3.2 (R Core Team, 2017). After data registration, the resulting waveforms were algebraically re-referenced to the electrodes located on the mastoids (TP10/TP9). Continuous EEG data were filtered using the 0.03–19.4 Hz with a zero-phase shift Butterworth filter (12 dB/octave rolloff, DC offset removed prior to filtering) and a 60 Hz notch filter. The continuous data were then segmented in 1300 ms epochs locked to stimulus onset, with a baseline of 200-ms pre-stimulus. Independent component analysis (ICA; Jung et al., 2000) was used to identify and remove blinking artefacts. Trials containing movement artefacts, eye movement artefacts, blinking, or any excessive baseline drifts were rejected.

To statistically verify the ERP differences between the relevant conditions, analysis of the ERP data was conducted on epochs time-locked to the onset of the test stimuli. Analysis was performed in three latency windows, 200–300 ms (N250), 300–500 ms (FN400), and 500–800 ms (LPC). We selected the latency regions in which prior studies found early effects of emotion during retrieval (i.e., 200–300 ms after stimulus onset; Smith et al., 2004; Jaeger et al., 2009) and regions wherein "midfrontal" and "parietal" old/new effects are typically elicited (i.e., 300–500 and 500–800 ms after stimulus onset; Rugg & Curran, 2007). ERP amplitude was computed within each time window as the mean voltage (μV) relative to the mean voltage in the 200 ms pre-stimulus baseline period. Statistical analyses were conducted on the data derived from the electrode sites depicted in Figure 9.

Electrode-site factors for the statistical analyses were defined *a priori* to capture spatial variation along three anatomical axes: anterior–posterior (AP), superior–middle–inferior (ST), and hemisphere (HM). Mean amplitudes were computed for each subject and condition by averaging the ERP voltage across the electrodes assigned to each region. For the AP factor, "Anterior" included F7, F3, FC1, FC2, F4, and F8; "Central" included T7, FC5, C3, C4, FC6, and T8; and "Posterior" included P7, P3, CP1, CP2, P4, and P8. For the ST factor, "Superior" comprised FC1, C3, CP1, FC2, C4, and CP2; "Middle" comprised F3, FC5, P3, F4, FC6, and P4; and "Inferior" comprised F7, T7, P7, F8, T8, and P8. For the HM factor, the left-hemisphere set consisted of F7, F3, FC1, T7, FC5, C3, P7, P3, and CP1, whereas the right-hemisphere set consisted of F8, F4 FC2, T8, FC6, C4, P8, P4, and CP2.

**Figure 9**

*Electrode montage and sites employed for the ERP amplitude analyses*



*Note.* Schematic head (top view) showing electrode labels and the electrodes included in the statistical analyses. Electrode labels indicate the subset of channels used to carry out the statistical analyses (see Methods for electrode lists).

We proceeded to compare the data for the conditions recorded during the test phase, namely, old/new comparisons (hits/correct rejections) and comparisons between negative, positive, and neutral hits. For these and all subsequent analyses, we included the above electrode site factors as covariates in the repeated-measures ANOVA.

### 4.3. Results

#### *Behavioural data*

The mean accuracy and reaction time (RT) for items correctly identified as "old" or "new" are shown in Table 6. A repeated-measures analysis of variance (ANOVA) on the accuracy data produced a non-significant item type effect, $F(1.50, 36.06) = 3.42$, $p = 0.056$, $\eta_p^2$

= 0.12. A repeated-measures ANOVA on RT data associated with the four response categories revealed no significant differences, $F(3, 72) = 1.41, p = 0.244, \eta_p^2 = 0.05$.

**Table 6**

*Means and standard deviations (in parentheses) for the proportion of correct answers and for reaction time (RT) in milliseconds of correct answers for neutral, positive, negative and new items*

| | Neutral | Positive | Negative | New |
|---|---|---|---|---|
| Accuracy | 0.84 (0.10) | 0.86 (0.09) | 0.86 (0.07) | 0.79 (0.13) |
| RT (ms) | 733 (164) | 741 (156) | 769 (190) | 771 (173) |

### *ERP data*

For each experimental condition, the mean number (and range) of trials that contributed to the average ERP for each response type was 51 (57–41), 51 (59–40), and 60 (60–37) for negative, positive, and neutral hits, respectively; and 143 (174–98) for correct rejections.

ERP analyses were conducted by the following steps. Initially, ERP effects elicited by correctly recognized studied faces were contrasted with ERPs elicited by correctly recognized new faces. Specifically, the ERPs elicited by all collapsed hits (Fig. 10), and by negative, positive, and neutral hits (Fig. 12) were contrasted with the ERPs elicited by correctly rejected items. Next, we examined possible effects elicited by the valence differences in the contextual pictures, and the ERPs elicited by correctly recognized faces associated with positive and negative contexts were contrasted. No significant effects were found. Also, to examine arousal differences, ERPs elicited by correctly recognized faces associated with positive and negative contexts were collapsed into an “emotional” condition and compared with ERPs elicited by neutral faces (Fig. 11).

**Table 7**

*Contrast of event-related potentials (ERPs) between experimental conditions at different topographic sites and for different latency regions*

| Effect | 200–300 ms | 300–500 ms | 500–800 ms |
|---|---|---|---|
| **All Hits vs. Correct rejections** | | | |
| IT × AP × HM | | *F*(1.83, 53.32) = 3.60, *p* < .003, $\eta^2$p = 0.11 | |
| **Emotional Hits vs. Neutral Hits** | | | |
| IT × AP | | *F*(1.92, 55.95) = 4.69, *p* < .014, $\eta^2$p = 0.13 | |
| **Negative Hits vs. Positive Hits vs. Neutral Hits** | | | |
| IT × AP | | *F*(3.23, 93.73) = 2.86, *p* < .037, $\eta^2$p = 0.09 | |
| **Negative Hits vs. Neutral Hits** | | | |
| IT | *F*(1, 29) = 9.62, *p* < .004, $\eta^2$p = 0.249 | *F*(1, 29) = 5.06, *p* < .032, $\eta^2$p = 0.149 | |
| IT × AP | *F*(1.91, 55.59) = 3.88, *p* < .028, $\eta^2$p = 0.11 | *F*(1.86, 54.18) = 5.59, *p* < .007, $\eta^2$p = 0.162 | *F*(1.98, 57.48) = 3.61, *p* < .034, $\eta^2$p = 0.11 |
| **Neutral Hits vs. Correct rejections** | | | |
| IT | | *F*(1, 29) = 5.92, *p* < .021, $\eta^2$p = 0.16 | |
| IT × HM | | | *F*(1, 29) = 5.23, *p* < .030, $\eta^2$p = 0.15 |
| IT × AP × ST | | *F*(2.63, 76.39) = 3.86, *p* < .016, $\eta^2$p = 0.11 | |
| IT × ST × HM | | *F*(1.46, 42.45) = 42.45, *p* < .029, $\eta^2$p = 0.13 | |
| IT × AP × ST × HM | | *F*(2.79, 80.96) = 3.63, *p* < .019, $\eta^2$p = 0.11 | |

### *All Hits vs. Correct Rejections*

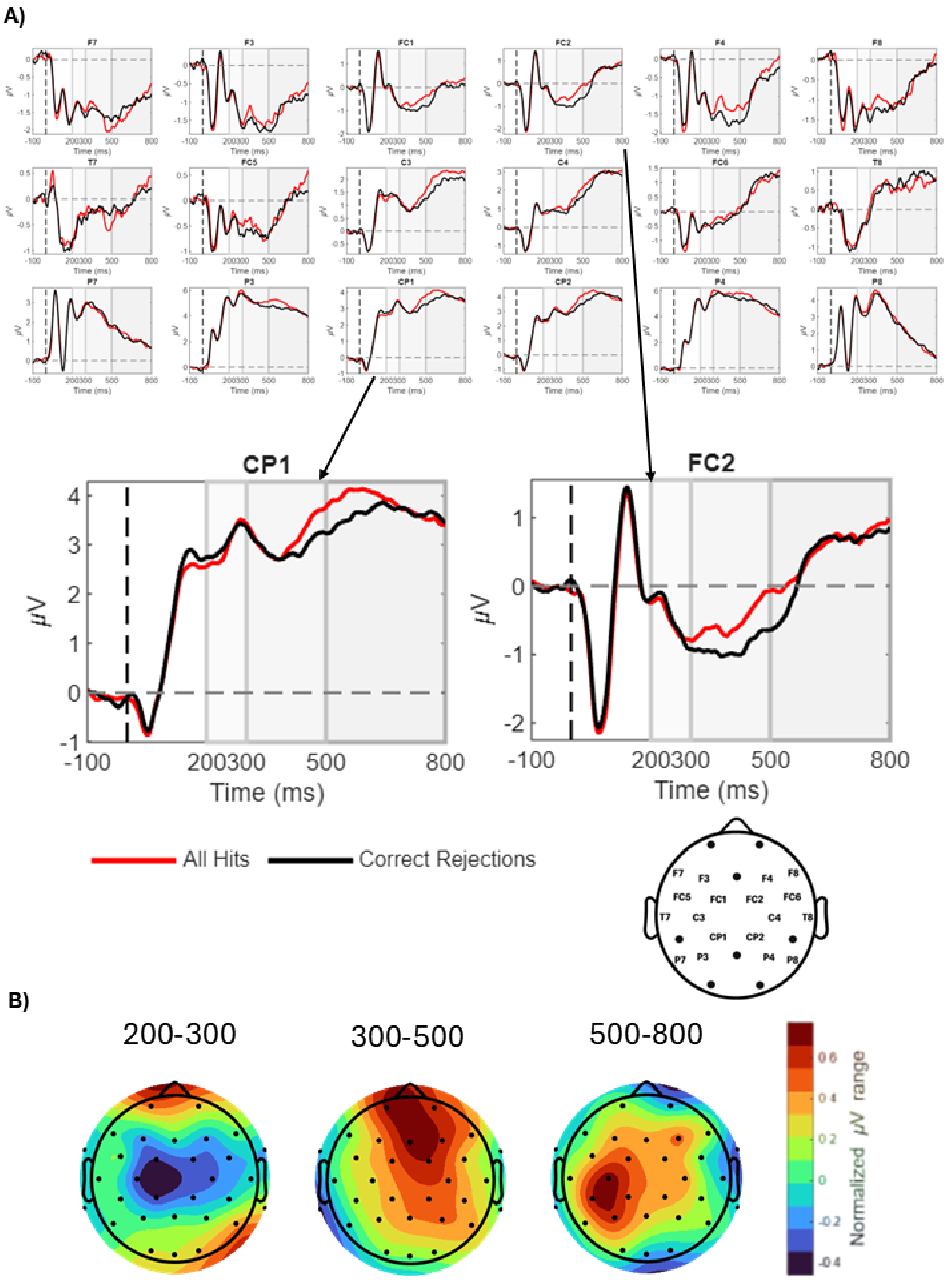
The omnibus contrast of all correctly recognized old items (hits) vs. correctly rejected new items produced a significant topographic modulation: an IT × AP × HM interaction (Table 7). This statistical outcome is reflected in the waveforms and maps (Figure 10): hits begin to separate from correct rejections in a more robust manner across the mid-to-late intervals, with the largest amplitude differences evident at mid-frontal and centro-parietal sites. In the FC2 and CP1 plots, the old/new positivity for hits is visible in the parietal electrode a little later between 300–500 ms and in the beginning of the 500–800 ms window, while frontal sites show divergences squarely in the 300–500 ms window (Figure 10). Taken together, the statistics and scalp distributions indicate a canonical old/new effect. However, it is apparent that the parietal effects seem to be earlier than what typically found (see Table 7).

### *Neutral hits vs. Correct Rejections*

Neutral hits were distinguished from correct rejections primarily in the mid-latency window, where a main item type effect was observed (Table 7). In addition, hemisphere and topography interactions were present (IT × HM; IT × AP × ST; IT × ST × HM and IT × AP × ST × HM; Table 7). The IT × HM and higher-order interactions indicate that the neutral old/new effect exhibits hemispheric and superior-inferior variation, consistent with the expected mid-frontal familiarity-related effect and the parietal recollection-related old/new component that is not strictly symmetric across the scalp. Old/new comparisons for positive (vs. correct rejections) and negative hits (vs. correct rejections) yielded no significant differences.

**Figure 10**

*Grand average ERP waveforms and topographies for all hits and CR*



**Panel A.** Comparison of grand averages of all hits and correct rejections. Positive is plotted up.

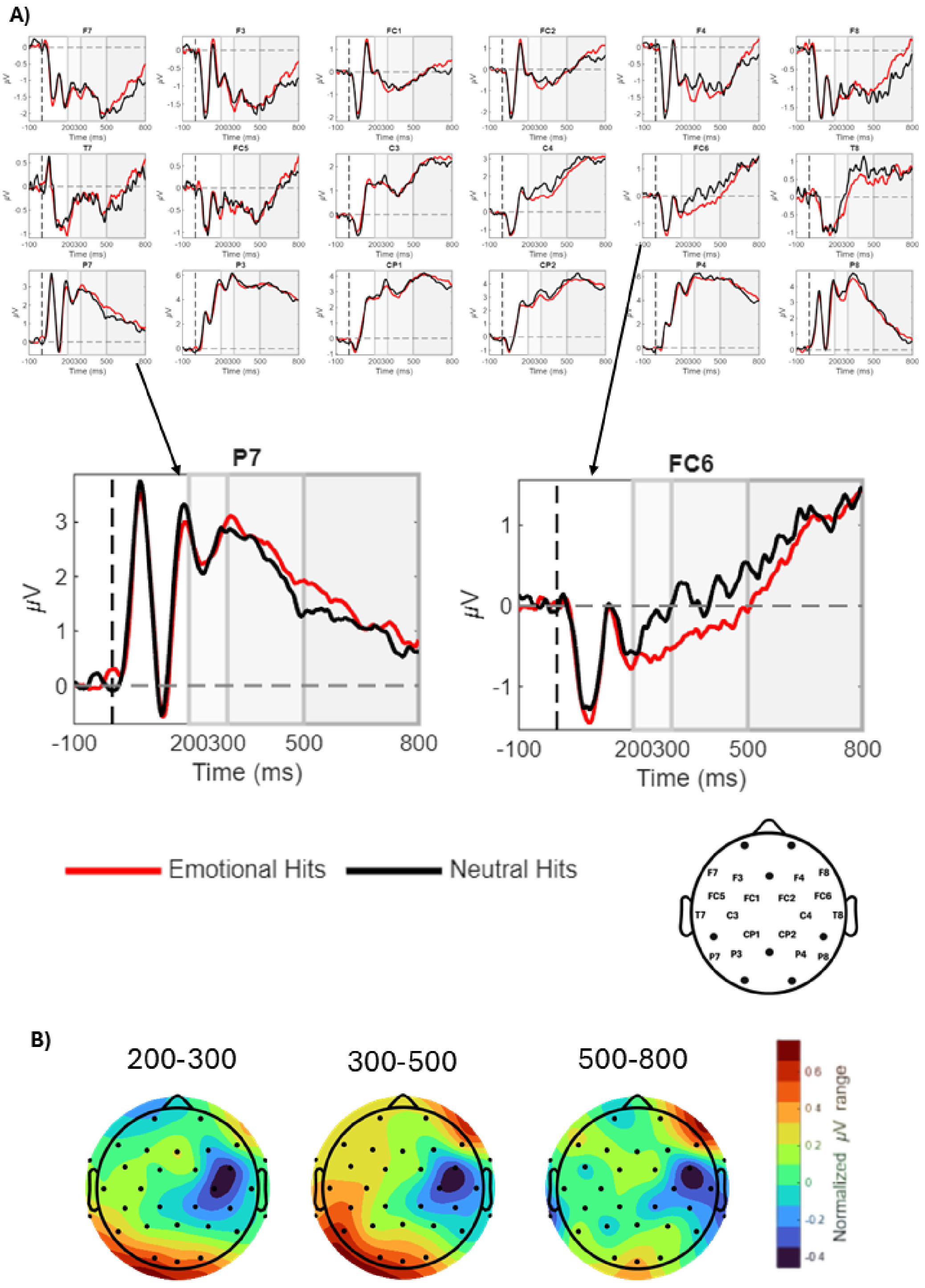
**Panel B.** Topographic maps displaying the mean difference between all hits and correct rejections for each window, wherein red indicates greater positive effects for all hits relative to correct rejections, while blue indicates greater positive effects for correct rejections relative to all hits (colour scale at right). All amplitudes are in microvolts (μV).

### *Emotional vs. neutral hits (arousal comparison)*

The comparison of emotional (collapsed positive and negative) vs. neutral hits produced a significant item type × anterior–posterior interaction (Table 7) in the 300–500 ms time window, indicating emotion modulated retrieval activity in an anterior–posterior dependent fashion. Inspection of the waveforms shows that neutral hits are more positive than emotional hits primarily over fronto-central sites in the mid-latency window (300–500 ms), whereas parietal differences are minimal and occur the other way around, with larger positivity for emotional hits (Figure 11). The topographic maps emphasise this anterior–posterior interaction: neutral > emotional effects are strongest over central electrodes, specifically in the right hemisphere (Figure 11B). These results therefore support a right-central distribution of the emotional modulation of retrieval rather than a broad centro-parietal effect (Table 7; Figure 11).

**Figure 11**

*Grand average ERP waveforms and topographies for emotional and neutral hits*



**Panel A.** Comparison of grand averages of emotional and neutral hits. Positive is plotted up.

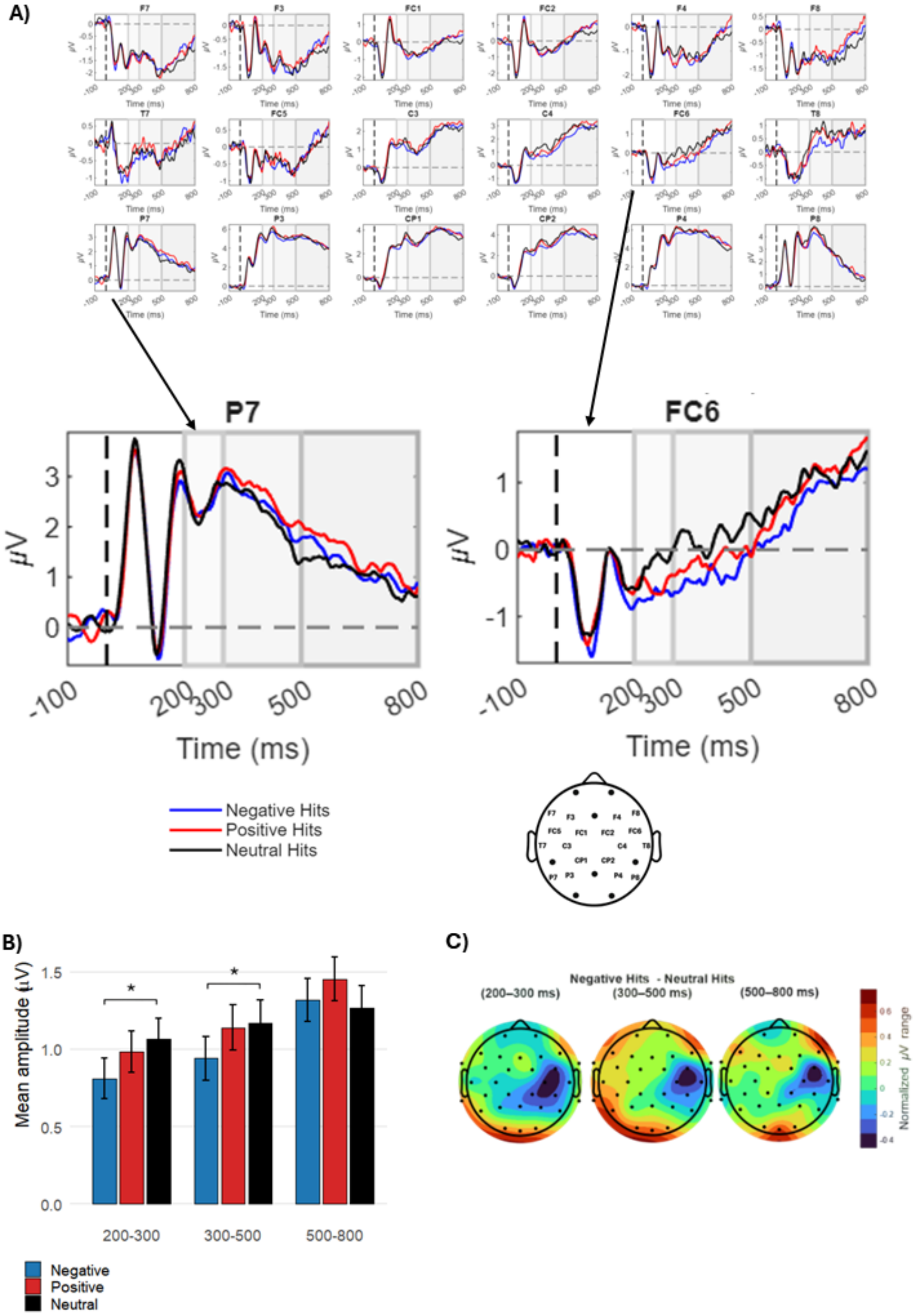
**Panel B.** Topographic maps displaying the mean difference between emotional and neutral hits for each window, wherein red indicates greater positive effects for emotional relative to neutral hits, while blue indicates greater positive effects for neutral relative to emotional hits (colour scale at right). All amplitudes are in microvolts (μV).

### *Negative vs. positive vs. neutral hits*

A three-level valence comparison revealed a modest but reliable topographic modulation (IT × AP; Table 7) in the 300–500 ms window. Visual inspection of the waveform set (Figure 12) suggests that this effect is driven primarily by negative items. Negative hits show greater frontocentral negativity than the other two valence categories in the mid-latency range. In short, the valence analysis indicates a negative-specific negativity at anterior sites, followed by positive and neutral hits (see Table 7 and Figure 12 B). Follow-up comparisons between negative vs. positive hits were not significantly different. The same is true for positive vs. neutral hits comparisons.

**Figure 12**

*Grand average ERP waveforms, topographies and mean amplitudes for negative, positive and neutral hits*



**Panel A.** Comparison of grand averages of negative, positive and neutral hits, and correct rejections. **Panel B.** Group mean amplitudes (± standard error across participants) for negative (blue), positive (red), and neutral hits (black) in each window (see Table 7 for test statistics and *p* values). **Panel C.** Topographic maps displaying the mean difference between hits negative and neutral hits for each window, wherein red indicates greater positive effects for negative relative to neutral hits, while blue indicates greater positive effects for neutral relative to negative hits (colour scale at right). All amplitudes are in microvolts (μV).

### *Negative hits vs. neutral hits*

Direct contrasts between hits were only significant for negative and neutral hits. This comparison produced a main effect of item type in the 200–300 ms and 300–500 ms windows (Table 7). Significant IT × AP interactions were present across windows (200–300, 300–500, and 500–800 ms). The waveform and scalp plots make this pattern clear: negative hits elicited a more negative ERP effect than neutral hits beginning in the early window (200–300 ms) and this difference is larger over right frontal/fronto-central electrodes (Figures 12). The combination of early onset and anterior distribution indicates an arousal-sensitive modulation at retrieval (Jaeger et al., 2009; Jaeger & Rugg, 2012).

### *Summary*

Behavioural data revealed no significant differences in accuracy and reaction times. ERPs exhibited a canonical old/new pattern, with hits diverging from correct rejections primarily in the mid-to-late intervals (300–500 and 500–800 ms) and the largest old/new positivity over centro-parietal sites, alongside earlier divergences at frontal electrodes. Collapsing across valence, emotional relative to neutral hits produced an anterior modulation in the 300–500 ms window and greater right-central activity with minimal parietal change, consistent with a region-specific influence of emotion on retrieval. A three-level valence test indicated that this anterior weighting was driven by negative items; direct contrasts between negative and neutral hits showed prominent positive effects emerging for neutral relative to emotional hits between 200–300 ms and persisting through the 300–500 and 500–800 ms windows, larger over right-central scalp. By contrast, neutral hits vs. correct rejections expressed the classic parietal old/new profile in the mid to late time windows, accompanied by hemispheric and superior–inferior topographic interactions.

## 4.4. Discussion

There were no differences in the accuracy and reaction times for the recognition of faces studied in negative, positive, and neutral contexts. Despite ample literature indicating that emotionally arousing information is better remembered than neutral information (Kensinger, 2004; LaBar, 2007; Bradley et al., 1992; Dolcos et al., 2004; Dolcos et al., 2005; Doerksen & Shimamura, 2001; Guillet & Arndt, 2009; Jaworek et al., 2014; Maratos et al., 2001; Mather & Nesmith, 2008; Nashiro & Mather, 2011; Pierce & Kensinger, 2011; Smith et al., 2004; Weymar et al., 2009; 2010a; 2010b; 2011; Wirkner et al., 2013, 2015), our results are consistent with the findings of Smith et al. (2004) and Jaeger et al. (2009; 2012). Neither study found behavioural effects for items associated with emotional contexts when compared to items associated with neutral contexts. One possible explanation for this finding, proposed by Smith et al. (2004), is that attention is preferentially allocated to the emotionally arousing components of the scene over the emotionally neutral items, especially when stimuli presented together (Mather, 2007; Kensinger et al., 2007). Therefore, the positive emotional effects on memory found in the studies mentioned earlier could have been generated by the emotional stimuli during the test phase of the recognition task; with the use of neutral items associated with emotional contexts, this positive effect might not be observed.

In another study, Ventura-Bort et al. (2016) used similar stimulus encoding procedures to ours, aiming to avoid attentional competition according to the theory of arousal-biased competition (Mather & Sutherland, 2011). The authors observed a significant difference in recognition accuracy for items encoded with emotional compared to neutral contexts, although it was a small effect size difference (*d* = 0.19) obtained through a one-tailed *t*-test. Our hypothesis for this phenomenon, therefore, is that even when asking participant to create a story in which they inserted the target item in the contextual background as a method that facilitates context-item association, distraction occurred at the expense of the neutral item by the more salient negative contexts.

Despite the lack of behavioural effects, event-related potentials (ERPs) revealed robust neural signatures of memory retrieval. We found the expected old/new effect for neutral hits, which elicited greater parietal positivity than correct rejections, particularly in the mid-latency window, alongside hemispheric and superior–inferior. When collapsed across contextual conditions, all hits also showed the expected old/new effect, with greater positivity than correct rejections from 300–500 ms. Although the parietal effects seem to be earlier than what is typically found, both the earlier mid-frontal modulation and later parietal LPC were observed (Rugg & Curran, 2007; Weymar & Hamm, 2013).

Notably, neither negative hits nor positive hits differed significantly from correct rejections in ERP amplitude, contrasting with some prior findings. For instance, Bowen et al. (2019) and Ventura-Bort et al. (2016) reported enhanced old/new effects for items encoded in negative contexts. However, methodological differences, such as stimulus type (faces vs. words/objects), timing, and encoding-test congruency, may account for these discrepancies. Crucially, the expected old/new effects were not found for items encoded in emotional contexts. As detailed below, an early central negativity related to emotional (collapsed) and negative hits possibly counteracted the usual positivity.

Importantly, direct emotional comparisons showed that, when collapsing across emotional valence, emotional (vs. neutral) hits elicited greater central/right-central positivity in the 300–500 ms window, suggesting anterior modulation in the emotional effects for hits. This topography is consistent with previous findings showing that emotional context can elicit early anterior ERP modulations during retrieval, possibly reflecting context reactivation, enhanced monitoring, or familiarity-biased processing (Smith et al., 2004; Jaeger et al., 2009).

Comparisons between the emotional conditions only found significant differences between negative and neutral hits. Negative hits diverged from neutral hits as early as 200–300 ms and remained distinct through 500–800 ms, with differences larger over central/right-central electrodes. This early difference is similar to previous reports that emotional, especially negative; study contexts bias early retrieval under neutral test cues (Smith et al., 2004; Jaeger et al., 2009) and the observation that similar anterior modulations can also appear for misses (Jaeger & Rugg, 2012). Therefore, it is likely that it reflects an arousal-related modulation that is not specific to explicit recognition. This interpretation is further supported by an effective arousal trend favouring negative over positive scenes despite nominal matching (see Table 5) and the absence of a positive–negative difference that a purely valence-specific account would predict. We argue that this arousal-related modulation is a context-reactivation/fluency signal carried over from the negative studied scenes. Notably, these neural modulations were not accompanied by superior recognition accuracy, consistent with dissociations between emotion-sensitive neural signals and behaviour (Bisby & Burgess, 2017; Clewett & Murty, 2019).

From a mechanistic perspective, these findings align with dual-systems models of emotional memory. Positive emotion is often linked to dopaminergic modulation of hippocampal networks, promoting associative binding and integration (Murty & Adcock, 2014; Clewett & Murty, 2019). In contrast, negative emotion tends to recruit amygdala-based arousal mechanisms, which can impair hippocampal binding while enhancing item salience (Bisby & Burgess, 2017). Thus, our observation of larger right-central negativity for ERP signals for negative hits and lack of behavioural gains may reflect amygdala-driven tagging of negative context during encoding, which can bias retrieval dynamics but fails to improve associative recognition.

This pattern is further supported by findings that negative arousal diminishes hippocampal engagement (Schwabe & Wolf, 2012) and impairs contextual memory (Simon-Kutscher et al., 2019). The early modulations seen here are consistent with such models, suggesting that retrieval of items encoded in negative contexts may involve increased context-reactivation, rather than successful recollection per se. Therefore, it would be interesting to test whether source advantage could be seen for negative contexts.

In summary, we observed the expected old/new effect for neutral hits, but not for positive or negative hits. We also observed an early central negativity for items studied in negative contexts. This emotion-related negativity attenuated the expected old/new positivities for emotionally encoded items, demonstrating that emotional context during encoding qualitatively shapes the neural dynamics of face recognition, with negative contexts engaging an implicit, arousal-weighted reactivation/fluency signal that modulates, but does not strengthen, explicit remembering.

### 4.5. Conclusion

In this second experiment, we investigated the electrophysiological correlates of the memory retrieval processes for faces encoded in negative, neutral, and positive contexts, thus examining the relationship between emotional valence, arousal, and memory for faces. Recognition performance did not differ across contexts, although ERPs revealed that emotional contexts modulate retrieval for faces. The old/new effect was evident for neutral hits, but an early central negativity for negative hits emerged and attenuated the old/new positivity under emotional contexts. The timing and scalp distribution of this emotional negativity point to an early, implicit, arousal-weighted context-reactivation/fluency signal that can modulate later retrieval without enhancing recollection related ERPs or behaviour, consistent with prior observations after delayed testing (e.g., Jaeger & Rugg, 2009). Thus, negative contexts leave a distinct neural tagging at test, detectable as this early central modulation, while failing to enhance explicit recognition, underscoring the value of neural indices for revealing affective influences on face memory when behavioural measures are absent. Future work incorporating explicit source/associative measures, indices of affective reactivity, and eye-tracking during study may help explicate whether these anterior effects reflect strategy, fluency, or rapid access to context-tagged face representations.

# 5. Experiment 3 – Memory for faces and objects encoded in negative and neutral contexts

## Abstract

Emotional contexts often affect memory for neutral items, but the direction and timing of this modulation appear to depend on stimulus class (faces vs. objects) and processing stage (encoding vs. retrieval). We used event-related potentials (ERPs) with a remember/know procedure to compare how negative vs. neutral background scenes influence encoding- and retrieval-related neural activity for neutral faces and objects. Behaviourally, objects yielded larger recollection and familiarity estimates than faces, while negative faces showed better familiarity estimates than neutral faces. During encoding, ERP effects of subsequently remembered items showed that neutral-context trials produced greater positive amplitudes than negative-context trials for both stimulus classes. Faces showed earlier and more sustained frontal effects for subsequently remembered items encoded in neutral relative to negative context. Object subsequently remembered trials also showed neutral larger than negative effects, these differences were smaller in terms of amplitude, emerged later and were topographically posterior. At retrieval, emotional-context effects diverged by stimulus class: objects exhibited earlier, parietal modulation in mid-latency windows, consistent with reinstatement of contextual information, whereas faces showed earlier, frontal modulations. In sum, emotional background contexts did not uniformly enhance encoding-related neural activity for neutral items. Instead, neutral backgrounds were more predictive of later recollection, and faces and objects showed distinct temporal and topographic signatures at both encoding and retrieval. These results underscore a stimulus-dependent interaction between emotion and episodic memory, consistent with models in which arousal and attentional allocation differentially affect item-context binding and later reinstatement.

## 5.1. Introduction

The influence of emotion on memory is a well-established phenomenon, with extensive research demonstrating that emotionally arousing stimuli are typically remembered more vividly and accurately than their neutral counterparts (Kensinger, 2009; Phelps, 2004). This enhancement is widely attributed to neurobiological mechanisms through which arousal activates the amygdala, subsequently modulating hippocampal and cortical processes essential for encoding and consolidation, thereby prioritizing information salient for survival (McGaugh, 2018). However, real-world memories are rarely so simple; often, we must remember a neutral item that was encountered within an emotional context, such as where we left our house keys after a long day of work or the facial features of a person that greeted us at a Halloween party the previous year. This raises a more nuanced question: how does the emotional valence of a background scene influence memory for a foreground, neutral item?

Research into this question has yielded a complex and sometimes contradictory set of findings. Some studies suggest emotional contexts can enhance memory for associated neutral items (Ventura-Bort et al., 2016), while others report null or even impairing effects (Mather & Sutherland, 2011). These inconsistencies highlight the role of critical moderating variables, chief among them being the category of the foreground stimulus and the stage of memory processing. The arousal-biased competition theory (Mather & Sutherland, 2011) posits that emotional arousal does not uniformly enhance all elements of a scene but instead prioritizes the processing of the most salient stimuli, potentially at the expense of peripheral details. This suggests that the nature of the foreground item is paramount. Typically, research in which emotional contexts are associated with neutral stimuli do not employ faces. Research has focused on objects (Smith et al., 2004; Jaeger et al., 2009; Ventura-Bort et al., 2016) or words (Maratos & Rugg, 2001). Importantly, there are big differences between how visual processing occurs for different classes of stimuli.

A crucial distinction exists between common objects and faces. Faces represent a special stimulus category due to their profound social and biological significance. They engage specialized, rapid perceptual and evaluative neural pathways, including the fusiform gyrus and superior temporal sulcus (Haxby et al., 2000), and are processed more automatically and rapidly than objects. This dedicated processing stream suggests that faces may compete for attentional resources or integrate with emotional background processing in a manner fundamentally distinct from objects.

Event-related potentials (ERPs) provide a powerful methodological tool to disentangle these dynamics with high temporal precision. Subsequent memory effects (SMEs), differences in encoding-phase ERPs based on subsequent memory performance, can reveal how emotional contexts influence the initial neural processes predictive of successful retrieval (Paller & Wagner, 2002). Similarly, retrieval-related ERPs, such as the late positive component (LPC) associated with recollection, can help explain how emotional contexts modulate the reinstatement and evaluation of memories (Rugg & Curran, 2007).

A review of the literature reveals a significant gap. While a body of work has established that emotional contexts can modulate ERPs for neutral items, the focus has been predominantly on neutral objects embedded in emotional scenes (e.g., Jaeger et al., 2009, 2012; Ventura-Bort et al., 2016; Weymar et al., 2013). In contrast, research on faces has largely investigated faces with intrinsic emotional expressions (Schupp et al., 2004; Blau et al., 2007; Rellecke et al., 2012; Righi et al., 2012 ) rather than neutral faces presented within an emotional context. Given the neurocognitive distinctions between face and object processing, such as faces early integrative encoding (Maurer et al., 2002; Farah et al., 1998) versus objects more heavily reliance on feature-based representations embedded in distributed semantic systems (Haxby et al., 2000; Gobbini & Haxby, 2007) it is safe to assume that the different patterns of emotional contextual modulation would apply to each category. The mechanisms by which a negative scene influences memory for a neutral object are likely different from those for a neutral face, due to the face's inherent social salience and its rapid, specialized neural processing.

The present study was designed to directly address this gap by conducting a comparative investigation of how negative vs. neutral emotional backgrounds influence the encoding and retrieval of neutral faces and objects. We employed a paradigm in which participants imagined stories linking neutral faces or neutral objects to background scenes, thereby encouraging item-context binding, while ERPs were recorded. Memory for the faces and objects was assessed using the remember/know procedure to differentiate the contributions of recollection and familiarity (Yonelinas, 2002).

We predicted a behavioural dissociation where objects are better retrieved when compared to faces (Steel & Silson, 2022; Brady et al., 2008; Caudek, 2013; Burton et al., 2019). At the neural level, we hypothesized that negative contexts would reduce encoding-related neural activity (SMEs) for neutral items, as attention is drawn to the scene itself (Mather & Sutherland, 2011; Hajcak et al., 2010; Olofsson et al., 2008). We expected this suppressive effect to be more significant and earlier for faces due to their rapid processing (Mather & Sutherland, 2011). During retrieval, we hypothesize that, for objects, we are going to find an emotional modulation of parietal old/new effects linked to contextual reinstatement (Ventura-Bort et al., 2016, although see Smith et al., 2004; Jaeger et al., 2009; Jaeger & Rugg, 2012). Our central hypothesis is that the temporal and topographic ERP signatures of emotional contextual modulation will be fundamentally distinct for faces and objects, reflecting their different neural processing pathways and social significance.

## 5.2. Methods

The experimental procedures described below were approved by the Institutional Review Board of the University of Texas at Dallas. All participants provided written informed consent prior to the participation in the experiment.

### *Participants*

Twenty-eight healthy adults (18 women) aged 18–27 years (*M* = 22.32 years, *SD* = 2.67) voluntarily participated in the study. Participants were compensated at the rate of $30 per hour for the experimental session and were reimbursed for travel. The participants were recruited from the University of Texas at Dallas and surrounding metropolitan Dallas communities. All participants were right-handed, learned English from birth or in early childhood, and reported normal or corrected-to-normal vision. Exclusion criteria included a history of cardiovascular disorder (except for treated hypertension), psychiatric disorder, disorder of the central nervous system, substance abuse, and current or recent use of psychotropic medications or sleeping aids. An additional four participants were tested but excluded from the present analyses because of insufficient artefact-free trials for one or more critical trial types.

### *Materials*

#### *Critical stimuli*

Twenty-eight individual lists of stimuli were created for each participant using 300 photos of faces from the *Chicago Face Database* (Ma et al., 2015) and 180 contextual scenes from two international databases, IAPS (*International Affective Picture System*; Lang et al., 1997) and NAPS (*Nencki Affective Picture System*; Marchewka et al., 2014). Face photos included men and women of diverse ethnicities. They all exhibited neutral expressions and were randomly assigned to each experimental condition for each participant. The contextual scenes consisted of pictures of people, animals, objects, and landscapes. The 240 scenes included 120 scenes from each valence category (i.e., negative and neutral). To examine whether the valence categories differed (Table 8), we conducted *t*-tests comparing these categories for arousal and valence. For the dimension of arousal, the neutral scenes were less arousing than negative, $t(119) = 35.01, p < 0.001, d = 4.60$. As for the valence dimension, negative scenes scored lower than neutral, $t(119) = 82.97, p < 0.001, d = 10.51$. The list of all stimuli used is available in Appendices F, G, and H.

**Table 8**

*Mean (and Standard Deviation) of the valence and arousal scores of the images selected as contexts*

| | Neutral | Negative |
|---|---|---|
| Arousal | 4.86 (0.59) | 7.79 (0.65) |
| Valence | 4.90 (0.14) | 1.62 (0.41) |

### *Experimental procedure*

The duration of the experimental task (not including practice phase and electrode checking/adjusting) ranged from 72–95 minutes, (*M* = 79 minutes, *SD* = 6 minutes). The experimental task consisted of four blocks, two using exclusively object stimuli, and two using exclusively face stimuli. Each of these four blocks comprised a study and test phase. Importantly, block order was counterbalanced between subjects.

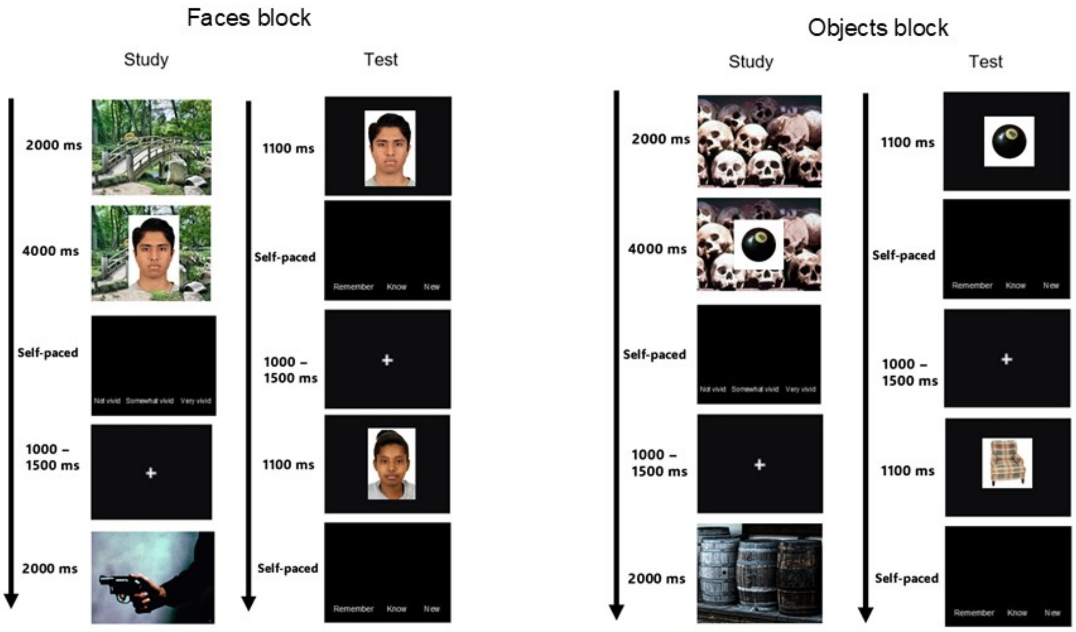
Immediately before the beginning of the first block, a brief practice phase (with 6 study and 12 test trials) analogous to the actual experiment was conducted. During practice, participants became familiar with the task and judged whether they felt comfortable seeing the type of emotional images that would be shown during the actual experiment.

For each study task block, 60 pairs of either faces or objects (depending on the set condition for the block), and scenes were randomly produced for each participant. Each study trial began with a white fixation cross on the centre of the screen for a randomly assigned time ranging from 1000 to 1500 ms, followed by the presentation of a contextual scene for 2000 ms, after which the target stimulus appeared superimposing the contextual scene. Both the contextual scene and target stimulus remained on screen for 4000 ms. During that time, participants were asked to create a story connecting the face/object and the background image. Although this task was performed covertly, in the practice phase, participants were asked to verbally describe the imagined scenes to ensure that they understood the task. Immediately after the offset of each face/object and contextual scene pair, participants were asked to assess the vividness of their imagined scenario in a 3-point scale of vividness (1= “Not vivid”, 2 = “Somewhat vivid”, 3 = “Very vivid”).

Following each study block, there was a rest interval of three minutes before the beginning of the test block. During the test block, all 60 faces/objects that were presented during the previous study block were presented again, but this time shuffled randomly between 30 other new faces/objects. Each test trial began with a white fixation cross on the centre of the screen for a randomly assign time ranging from 1000 to 1500 ms. Each face/object was presented in the centre of the screen for 1100 ms and was followed by a text stimulus indicating that the participant should respond. Participants were instructed to first make an R/K/N judgment for each test stimulus. They were to respond R if they recognized the face/object and were able to recollect one or more specific details from the study episode (e.g., which imagined scenario they made up for the face/object at study, a thought that came to mind as they studied the face/object, or an association made with the face/object). The instructions emphasized that an R response should only be given if the participant could explain to the experimenter what specific detail(s) they had recollected about the study episode. Participants were to respond K when they were confident that they had seen the face/object at study but were unable to recollect any specific detail from the study episode. A "new" (N) response was to be given when participants did not believe the face/object had been studied, or if they were uncertain about the picture's study status. Responses were self-paced, although participants were asked to respond as quickly as possible without sacrificing accuracy. After each response, a fixation cross was presented for a randomly assigned time ranging from 1000 to 1500 ms. Importantly, ERP recordings were performed throughout at both the study and test phases. In addition, participants were allowed to rest for 30 seconds after every 30 trials, both at study and test.

**Figure 13**

*Schematic representation of the presentation of stimuli during the study and test phase of Experiment 3*



### *EEG Recording*

EEG was recorded continuously during the study and test phases. Data were recorded from 32 Ag/AgCl electrodes. Twenty-nine of the electrodes were embedded in an elastic cap (EasyCap; Herrsching-Breitbrunn, Germany; www.easycap.de; montage 22), while the remaining 3 electrodes were adhered directly to the skin. The electrode sites in the cap covered 3 midline locations (Fz, Cz, PZ) and 26 homotopic lateral locations (Fp1/2, F3/4, F7/8, FC1/2, FC5/6, C3/4, T7/8, CP1/2, CP5/6, TP9/10, P3/4, P7/8, and O1/ O2). Two additional electrodes were affixed to the left and right mastoid processes. Vertical and horizontal EOG were monitored with bipolar electrode pairs placed above and below the right eye, and on the outer canthi of the left and right eyes, respectively. The ground and reference electrodes were embedded in the cap at sites AFz and FCz, respectively. EEG and EOG channels were digitized at 250 Hz using an amplifier bandpass of .01–70 Hz (3dB points) and the BrainVision Recorder software package (version 1.20.0601, www.brainvision.com). Electrode impedances were adjusted to be ≤ 5 kΩ prior to the start of the study phase and were readjusted as necessary.

### *EEG/ERP Preprocessing*

EEG data were processed offline in Matlab R2024a (www.mathworks.com) using EEGLAB version 2024.0 (https://sccn.ucsd.edu/eeglab/index.php; Delorme & Makeig, 2004) and ERPLAB version 12.00 (https://erpinfo.org/erplab; Lopez-Calderon & Luck, 2014). The continuous EEG data were digitally filtered between .03 and 19.4 Hz with a zero-phase shift Butterworth filter (12 dB/octave rolloff, DC offset removed prior to filtering) using ERPLAB. Epochs with a total duration of 1300 ms (from −200 ms to +1100 ms relative to onset of the test word) were extracted from the raw EEG data. The epoched data were subjected to Independent Components Analysis (ICA; Jung et al., 2000) to identify artefactual EEG components (e.g., blinks, eye movements, muscle artefacts, etc.). Prior to ICA, the epochs were baseline corrected to the average voltage across the epoch to improve estimation of ICA components (Groppe et al., 2009), and epochs with non-stereotypical artefacts (e.g., coughs or sneezes) were rejected. When necessary, rejection of an entire electrode channel was conducted prior to ICA. Data from rejected electrodes were replaced using Spline interpolation after removal of artefactual ICA components. The SASICA (Chaumon et al., 2015) and ADJUST (Mognon et al., 2011) software packages were used to aid with the identification of artefactual components. After ICA artefact correction, the epoched EEG data were re-referenced to averaged mastoids (recovering the FCz electrode) and baseline corrected to the average voltage of the 200 ms preceding the time-locked event (onset of the target stimuli). Epochs were rejected for averaging if: (1) voltage in the epoch exceeded ±100 μV, (2) baseline drift exceeded 40 μV (determined as the absolute difference in amplitude between the average amplitude of the first and last 250 ms of each epoch), or (3) an artefact was present based on visual inspection.

ERPs for each electrode site and event (onset of target stimuli) were created by averaging all artefact-free epochs according to the recognition memory judgment. For the study items, subsequently correctly endorsed items were segregated into eight bins: R responses for faces studied in neutral contexts, R responses for faces studied in negative contexts, R responses for objects studied in neutral contexts, R responses for objects studied in negative contexts, K responses for faces studied in neutral contexts, K responses for faces studied in negative contexts, K responses for objects studied in neutral contexts, and K responses for objects studied in negative contexts.

For the test items, correctly endorsed studied items were also segregated into eight bins: R responses for faces studied in neutral contexts, R responses for faces studied in negative contexts, R responses for objects studied in neutral contexts, R responses for objects studied in negative contexts, K responses for faces studied in neutral contexts, K responses for faces studied in negative contexts, K responses for objects studied in neutral contexts, and K responses for objects studied in negative contexts. Correctly rejected new items (CR) were also included, separated into correct rejections for faces and correct rejections for objects. Due to low trial numbers, ERPs for misses and false alarms (R or K responses to new items) were not included in any analyses.

### *Statistical Analyses*

The overall design used in this study is within-participants factors (memory judgment). Statistical analyses were conducted using $R$ software version 3.3.2 (R Core Team, 2017). ANOVA models were computed using the functions from the afex package version 0.16-1 (Singmann et al., 2016). Degrees of freedom for repeated-measures factors were corrected for non-sphericity using the Greenhouse-Geisser procedure in all reported ANOVAs (Greenhouse & Geisser, 1959). Effect size measures for ANOVA results are reported as partial-$\eta^2$ (Cohen, 1988). The threshold for statistical significance was $p < .05$.

### *Behavioural Analysis*

The dependent variables of interest from the behavioural data included eight estimates of memory performance. These included estimates of recollection and familiarity derived from the R/K/N procedure separated between the emotional and target stimuli conditions. Estimates of recollection and familiarity were calculated using independent remember/know estimation procedure (Yonelinas & Jacoby, 1995). Recollection was calculated using the following formula:

$$Recollection = R_{old} - R_{new}$$

$R_{old}$ and $R_{new}$ represent the proportion of R responses to old and new items, respectively. Familiarity estimates were derived from the following set of formulas:

$$F_{old} = \frac{K_{old}}{1 - R_{old}}$$

$$F_{new} = \frac{K_{new}}{1 - R_{new}}$$

$$Familiarity = F_{old} - F_{new}$$

In the above formulae, $K_{old}$ and $K_{new}$ represent the proportion of K responses to old and new items, respectively.

### *ERP analysis*

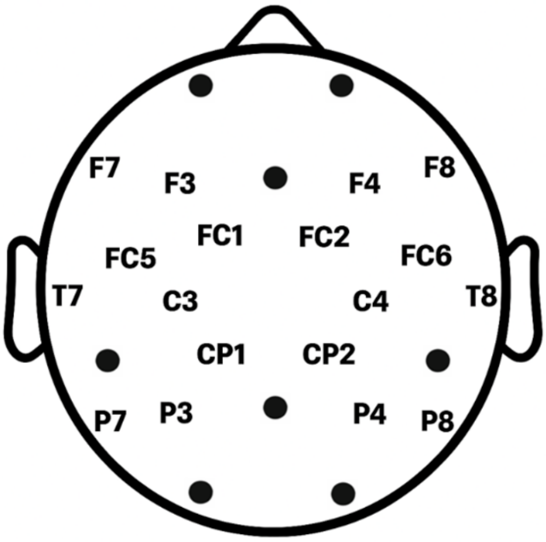
Analyses of the ERP data were conducted on epochs time-locked to the onset of the target stimuli for study items and on the onset of the test stimuli for test items. For each experimental condition, the mean number and range of trials that contributed to the average ERP during encoding was 26 (12–50) for subsequently remembered negative faces, 25 (10–43) for remembered neutral faces, 43 (26–57) for subsequently remembered negative objects, and 44 (22–57) for subsequently remembered neutral objects. No comparisons using the know or miss conditions were used due to the small number of artefact-free trials. As for retrieval trials, the mean number and range of trials that contributed to the average ERP during retrieval was 26 (13–50) for remembered negative faces, 25 (12–45) for remembered neutral faces, 41 (17-59) for correctly rejected faces, 43 (26–57) for remembered negative objects, 45 (27–59) for remembered neutral objects, and 53 (41–60) for correctly rejected objects. No comparisons using know conditions were used due to the small number of artefact free trials.

The windows for study trials were selected to correspond to the subsequent memory effect (SME). The ERPs were investigated in four time-windows: 200–300 ms, 300–500 ms, 500–800 ms, and 800–1100 ms. The 200–300 ms window was considered due to recent studies (Lucas et al., 2011) having reported a subsequent memory effect around 200 ms, named the early fronto-central SME (N200). The 300–500 ms window was chosen according to extensive electrophysiological literature (Lucas et al., 2011; for review see Paller & Wagner, 2002, Wagner et al., 1999) describing the SME as a widespread positivity, larger in the centro-parietal sites, with a peak latency somewhere between 300 and 500 ms post-stimulus onset. Moreover, both the 500–800 ms and 800–1100 ms windows (later SMEs) were analysed since effects of emotion on SMEs may vary as a function of time (Dolcos & Cabeza, 2002). The ERP analyses were computed for mean amplitude for all time windows. For all time windows, data were analysed with a repeated measures ANOVA with two levels of subsequent correctly remembered trials (negative and neutral) due to the lack of missed trials.

Test trial analyses were performed on time-windows selected to correspond to familiarity and recollection-related ERP effects typically reported in the literature at 300–500 ms (FN400) and 500–800 ms (left parietal effect), and the late posterior negativity at 800–1100 ms (Mark & Rugg, 1998; Rugg et al., 2002). Other ERP component analysed was the N250 (200–300 ms), which is an index for face familiarity. ERP amplitude was computed within each time window as the mean voltage (μV) relative to the mean voltage in the 200 ms pre-stimulus baseline period. Statistical analyses were conducted on the data derived from the electrode sites depicted in Fig. 14.

**Figure 14**

*Electrode montage and sites employed for the ERP amplitude analyses*



*Note.* Schematic head (top view) showing electrode labels and the electrodes included in the statistical analyses. Electrode labels indicate the subset of channels used to carry out the statistical analyses (see Methods for electrode lists).

### 5.3. Results

***Behavioural results***

Table 9 lists the proportions of R, K, and N responses by item type (face or object) and emotional condition (neutral or negative). Figure 15 displays estimates of recollection and familiarity for faces and objects. These estimates were contrasted using paired-sample *t*-tests. No significant differences were found between emotional conditions for recollection estimates for either faces or objects. However, faces encoded in negative contexts showed significantly greater familiarity estimates when compared to faces encoded in neutral contexts, $t(27) = 3.76$, $p < 0.001$, $d = 0.57$. That emotional difference was not found for objects. Finally, collapsed data from both emotional conditions showed that the estimates of both recollection, $t(55) = 18.93$, *p*

< 0.001, *d* = 1.73, and familiarity, *t*(55) = 6.83, *p* < 0.001, *d* = 1.08, were greater for objects than for faces.

**Table 9**

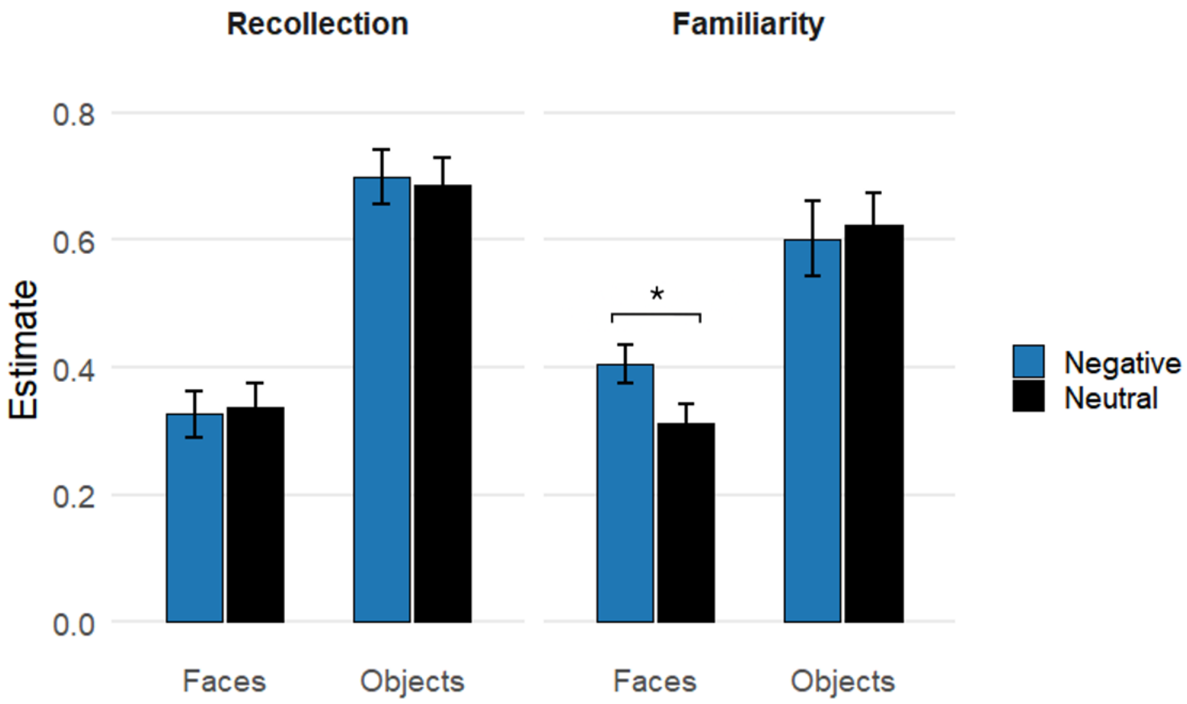
*Means and standard deviations (in parentheses) for remember, know and new (false alarm) proportions and reaction time (RT) for the remember/know task*

| | Faces | | Objects | |
|---|---|---|---|---|
| | Negative | Neutral | Negative | Neutral |
| **Proportions** | | | | |
| Remember | 0.40 (0.19) | 0.41 (0.18) | 0.71 (0.22) | 0.70 (0.22) |
| Know | 0.30 (0.12) | 0.32 (0.12) | 0.21 (0.19) | 0.23 (0.18) |
| New (False Alarms) | 0.31 (0.14) | 0.27 (14) | 0.07 (0.07) | 0.08 (0.07) |
| **Reaction time – RT (ms)** | | | | |
| Remember | 869 (551) | 824 (430) | 725 (394) | 693 (427) |
| Know | 1314 (699) | 1302 (768) | 1293 (825) | 1424 (906) |
| New (False Alarms) | 1199 (827) | 1246 (863) | 1621 (1662) | 2306 (6232) |

Table 9 also lists the averages and standard deviations of RTs for the R/K/N (negative and neutral) task by item type (face and object). RTs were contrasted using paired-sample *t*-tests. No significant differences were found between emotional conditions for RTs for either faces or objects in both R responses and K responses. Finally, collapsed data from both emotional conditions showed that R responses for objects were significantly quicker when compared to faces, *t*(55) = 2.48, *p* = 0.01, *d* = 0.30.

**Figure 15**

*Recollection and familiarity estimates for faces and objects encoded in negative and neutral contextual scenes*



### *ERP Results*

Encoding related ERP effects for the two item types and two emotional conditions are illustrated for six electrodes in Figure 16. To provide an overview of the recognition related ERP effects for the two item types, ERP waveforms for the three response categories of interest (negative R, neutral R, and CR) are illustrated for the 18 *a priori* electrode sites used for the statistical analyses in Figures 17 and 18.

### ***Encoding***

The ERP data were analysed with repeated-measures ANOVAs conducted in multiple stages (see Table 10). First, subsequent memory effects (SMEs) were examined by contrasting ERPs elicited by subsequently remembered items according to their emotional context (negative vs. neutral) and stimulus category (faces vs. objects). The ANOVAs were performed with the factors: item type (subsequently remembered negative faces, subsequently remembered neutral faces, subsequently remembered negative objects, subsequently remembered neutral objects) and electrode site factors AP (anterior–posterior), ST (inferior–middle–superior), and HM (left vs. right hemisphere). Here and in all subsequent ANOVAs, the degrees of freedom associated with effects involving factors with more than two levels were corrected for nonsphericity by the Greenhouse–Geisser procedure. The results of this analysis are summarized in Table 10 and illustrated in Figure 16.

**Table 10**

*Contrast of event-related potentials (ERPs) between subsequent "remember" trials at different topographic sites and for different latency regions*

| Effect | 200–300 ms | 300–500 ms | 500–800 ms | 800–1100 ms |
|---|---|---|---|---|
| **Subsequently Remembered Negative Faces vs. Subsequently Remembered Neutral Faces** | | | | |
| IT | *F*(1, 23) = 24.24, *p* < .001 | *F*(1, 23) = 18.26, *p* < .001 | F(1, 23) = 16.37, p < .001 | *F*(1, 23) = 13.71, *p* < .001 |
| IT × ST | *F*(1.19, 27.31) = 7.76, *p* < .007 | *F*(1.19, 27.36) = 5.52, *p* < .021 | F(1.42, 32.66) = 5.95, p < .012 | *F*(1.23, 28.31) = 6.44, *p* < .012 |
| IT × AP × ST | *F*(2.92, 67.05) = 3.76, *p* < .016 | *F*(2.56, 58.89) = 3.94, *p* < .017 | F(2.81, 64.62) = 6.92, p < .001 | *F*(2.18, 50.04) = 5.56, *p* < .005 |
| **Subsequently Remembered Negative Objects vs. Subsequently Remembered Neutral Objects** | | | | |
| IT | | *F*(1, 23) = 7.76, *p* = .011 | *F*(1, 23) = 9.59, *p* = .005 | *F*(1, 23) = 4.51, *p* = .045 |
| IT × ST | | *F*(1.26, 29.01) = 4.64, *p* = .032 | *F*(1.28, 29.37) = 7.08, *p* = .008 | *F*(1.33, 30.69) = 9.69, *p* = .002 |
| IT × HM | *F*(1, 23) = 4.34, *p* = .049 | | | |
| IT × AP × ST | | | *F*(2.51, 57.84) = 4.25, *p* = .013 | *F*(3.19, 73.38) = 5.91, *p* < .001 |
| IT × AP × HM | | | *F*(1.89, 43.46) = 4.19, *p* = .023 | |
| **Subsequently Remembered Faces vs. Subsequently Remembered Objects** | | | | |
| IT | | *F*(1, 23) = 6.34, *p* = .019 | *F*(1, 23) = 13.40, *p* = .001 | *F*(1, 23) = 9.88, *p* = .034 |
| IT × ST | | *F*(1.17, 26.87) = 4.66, *p* = .035 | *F*(1.32, 30.37) = 5.17, *p* = .022 | *F*(1.39, 32.02) = 5.05, *p* = .022 |
| IT × HM | *F*(1, 23) = 10.17, *p* = .004 | *F*(1, 23) = 11.91, *p* = .002 | | *F*(1, 23) = 5.05, *p* = .034 |
| IT × AP × ST | *F*(2.52, 57.89) = 4.97, *p* = .006 | *F*(2.43, 55.96) = 13.85, *p* < .001 | *F*(2.31, 53.04) = 14.44, *p* < .001 | *F*(2.37, 54.47) = 10.09, *p* < .001 |
| IT × ST × HM | | | *F*(2.87, 65.93) = 3.68, *p* = .018 | *F*(3.03, 69.76) = 3.61, *p* = .017 |

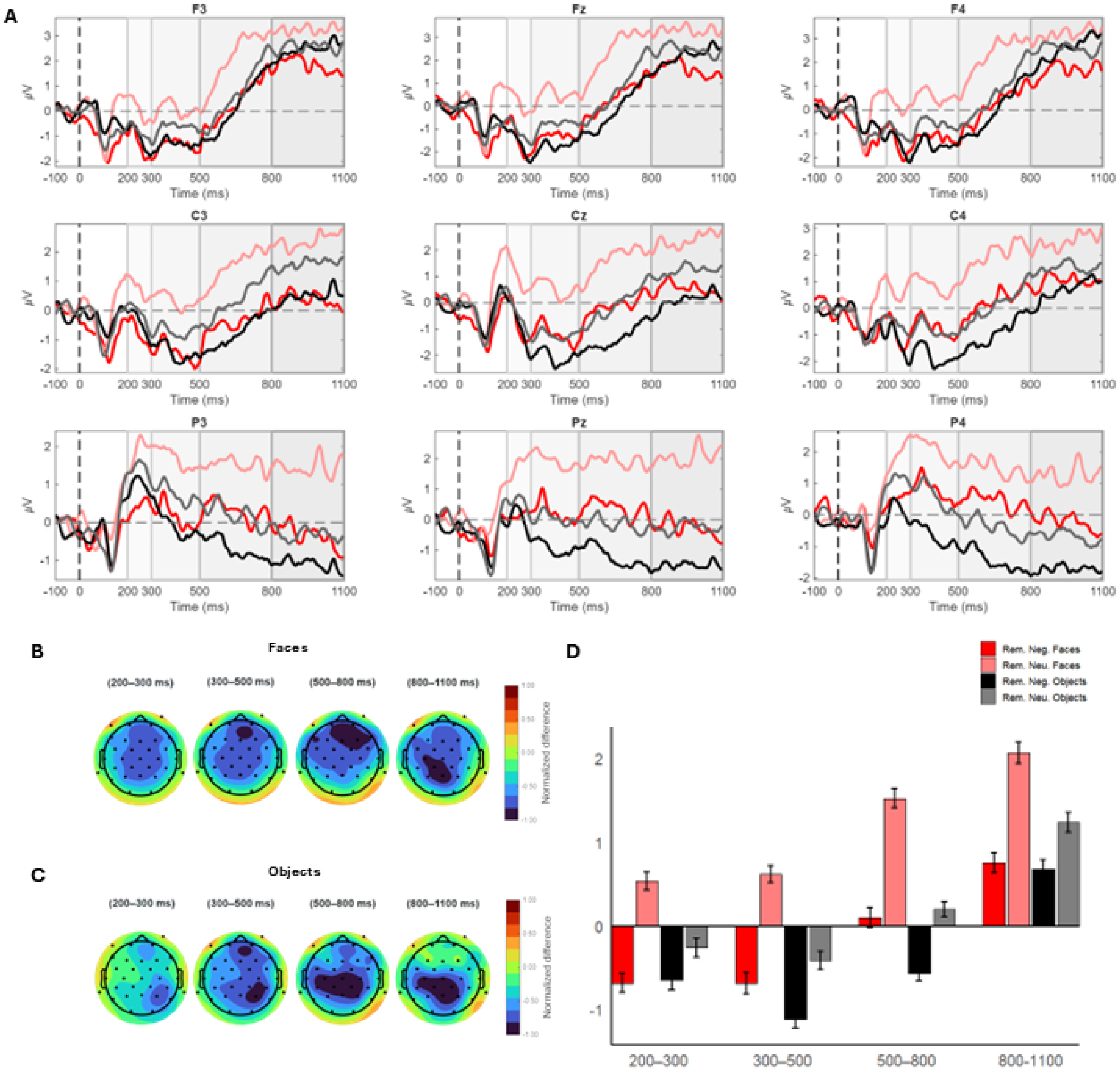
**Subsequently remembered negative faces vs. Subsequently remembered neutral faces.** Direct contrasts between subsequently remembered negative and neutral faces revealed robust differences across all latency windows (Table 10). Significant main effects of item type (IT) were observed from 200–300 ms through 800–1100 ms, accompanied by interactions with ST and AP factors. As illustrated in Figure 16A, the waveform for neutral faces (light red) was more positive than for negative faces (dark red) beginning around 200 ms, with clear divergences visible across frontal, central, and parietal electrodes. The topographic maps (Figure 16B) confirm the development of this effect: an initial frontally distributed positivity (200–300 ms) was followed by a shift toward centro-parietal sites in the 300–500 ms and 500–800 ms intervals. By the 800–1100 ms window, the difference was still visible but less pronounced, consistent with a sustained late positive component. The group mean amplitudes (Figure 16D) further illustrate the consistent advantage of neutral over negative faces across windows. Together, these results indicate that emotional context exerted a strong and enduring suppressive effect on memory-related ERP activity for faces studied in negative contexts.

**Subsequently remembered negative objects vs. Subsequently remembered neutral objects.** For objects, the differences between negative and neutral subsequent memories were weaker and more temporally restricted than for faces. No reliable effects were observed in the earliest 200–300 ms interval (Table 10), consistent with overlapping waveforms for negative (black) and neutral (grey) objects in Figure 16A. Significant IT effects and IT × ST interactions emerged in the 300–500 ms and 500–800 ms windows, indicating that neutral objects elicited greater positivity than negative objects, particularly over posterior scalp sites. This pattern is visible in Figure 16A, where the grey trace begins to diverge upward from the black trace around 400 ms, and in Figure 16C, which shows posterior positivity for neutral vs.

negative objects in these mid-latency windows. By 800–1100 ms, the same effect observed in the previous time windows continued, although more concentrated over posterior electrodes (Figure 16C). Mean amplitude plots (Figure 16D) confirm that, although objects showed emotional modulation, the suppressive effect of negative contexts was smaller in magnitude and less consistent than for faces.

**Figure 16**

*Grand average ERP waveforms, topographies and mean amplitudes for subsequently remembered faces and objects*



**Panel A.** Grand-average ERP waveforms for the electrodes F3, Fz, F4, C3, Cz, C4, P3, Pz, and P4 with subsequently remembered negative (dark red), and neutral (light red) faces, subsequently remembered negative (black) and neutral (grey) objects. Vertical shaded regions indicate the four analysis windows used for statistics (200–300, 300–500, 500–800, 800–1100 ms). **Panel B-C.** Topographic maps displaying the mean amplitude differences between hits for faces and objects encoded in negative vs. positive contexts, where red represents greater positive effects for negative relative to neutral hits, and blue the opposite pattern (colour scale at right, Z-score difference). **Panel D.** Group mean amplitudes (± standard error across participants) for subsequently remembered negative (dark red) and neutral (light red) faces and subsequently remembered negative (black) and neutral (grey) objects in each window (see Table 10 for test statistics and p values). All amplitudes are in microvolts (µV).

**Subsequently remembered faces vs. Subsequently remembered objects.** Direct comparisons between faces and objects revealed greater ERP positivity for faces across all latency windows (Table 10). As shown in Figure 16A, the traces for faces (red lines) are consistently more positive than those for objects (black/grey lines), particularly at centro-parietal electrodes. The earliest divergence (200–300 ms) suggests that faces that were later remembered benefited from an early rapid mnemonic advantage relative to objects. That difference is more easily seen in the case of faces encoded in neutral contexts. These differences increased in the 300–500 ms and 500–800 ms windows, where parietal positivity for faces was prominent and remained visible through the 800–1100 ms interval. The topographic maps (Figure 16B-C) highlight this distinction: while faces showed robust neutral > negative differences extending from frontal to parietal sites, objects displayed smaller and more localized effects. The mean amplitude bar plots (Figure 16D) quantify this overall advantage, showing higher values for faces than objects in all windows. These results indicate that faces not only elicited stronger ERP correlates of successful memory encoding than objects but were also more strongly and consistently suppressed by negative emotional contexts.

### *Retrieval*

The analyses of ERPs were conducted in multiple stages (see Table 11). First, the differences in amplitude of the ERPs elicited by correctly classified old items were contrasted in regard to their stimulus type (faces vs. objects), than correctly classified old items and correctly rejected new items were contrasted to investigate old/new effects. Finally, correctly classified old items were contrasted according to their emotional status (negative vs. neutral studied context). An overall ANOVA was performed, factored according to item type (remembered faces negative, remembered faces neutral, remembered objects negative, remembered objects neutral, correctly rejected faces, and correctly rejected objects) and electrode site factors AP (anterior–posterior), ST (inferior–middle–superior), and HM (left vs. right hemisphere). The results of this analysis can be seen in Table 11.

**Table 11**

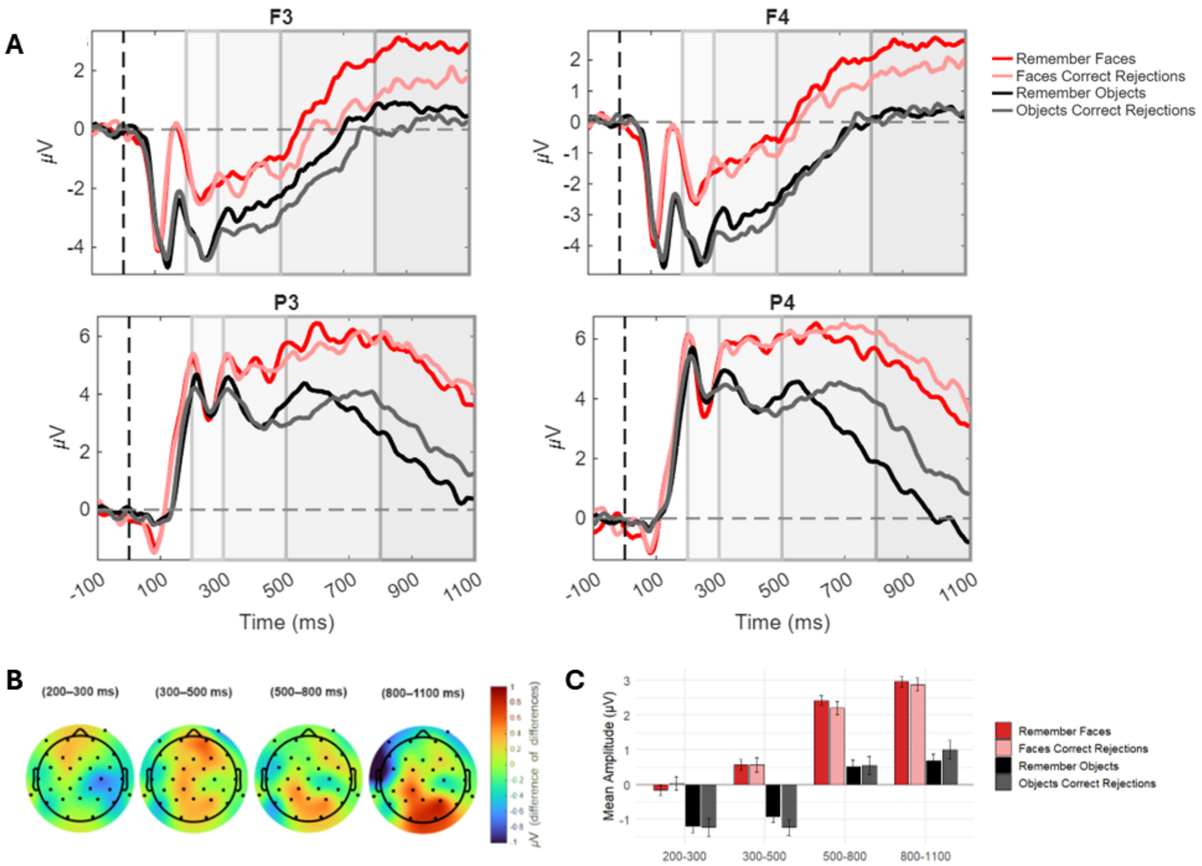
*Contrast of event-related potentials (ERPs) between Remembered faces and objects and correct rejections (CRs) at different topographic sites and for different latency regions*

| Effect | | | | |
|---|---|---|---|---|
| | 200–300 ms | 300–500 ms | 500–800 ms | 800–1100 ms |
| **Remembered Faces vs. Remembered Objects** | | | | |
| IT | $F(1, 23) = 8.44, p < .008$ | $F(1, 23) = 23.95, p < .001$ | $F(1, 23) = 31.21, p < .001$ | $F(1, 23) = 28.88, p < .001$ |
| IT × AP | $F(1.06, 24.46) = 15.25, p < .001$ | | | |
| IT × ST | $F(1.63, 37.59) = 9.83, p < .001$ | $F(1.27, 29.19) = 5.79, p < .017$ | $F(1.22, 28.13) = 9.05, p < .004$ | $F(1.14, 26.11) = 13.92, p < .001$ |
| IT × AP × ST | | $F(2.18, 50.04) = 24.29, p < .001$ | $F(2.38, 54.72) = 23.91, p < .001$ | $F(2.27, 52.29) = 12.63, p < .001$ |
| IT × ST × HM | | | $F(1.30, 29.87) = 5.25, p < .021$ | $F(1.45, 33.26) = 4.97, p < .021$ |
| IT × AP × ST × HM | | | $F(2.53, 58.13) = 4.33, p < .012$ | $F(3.15, 72.36) = 3.61, p < .016$ |
| **Remembered Faces vs. Correctly Rejected Faces** | | | | |
| IT | | | $F(1.51, 34.62) = 4.57, p < .026$ | $F(1.28, 29.42) = 7.49, p < .007$ |
| IT × AP | | | $F(1, 23) = 5.31, p < .031$ | |
| IT × AP × ST | | | $F(2.87, 66.08) = 3.25, p < .029$ | |
| **Remembered Negative Faces vs. Remembered Neutral Faces** | | | | |
| IT × ST × HM | | | $F(1.22, 28.00) = 5.45, p < .021$ | $F(1.19, 27.41) = 6.68, p < .012$ |
| **Remembered Objects vs. Correctly Rejected Objects** | | | | |
| IT × AP | | | | $F(1.16, 26.69) = 8.46, p < .005$ |
| IT × ST | | | | $F(1.42, 32.63) = 5.25, p < .018$ |
| IT × HM | | | $F(1, 23) = 9.45, p < .005$ | $F(1, 23) = 4.44, p < .046$ |
| IT × AP × ST | | | | $F(2.77, 63.65) = 3.91, p < .015$ |

**Remembered faces vs. Remembered objects.** Direct comparisons showed significantly greater positivity for remembered faces across all latency windows (Table 11). This robust statistical effect is supported by the grand-average waveforms (Figure 17A), where the remembered faces trace (dark red) is visibly more positive than the remembered objects trace (black) at all electrode sites, particularly at the parietal locations (P3, P4). The earliest differences (200–300 ms) suggest that face processing confers a rapid mnemonic advantage. Differences were amplified in the 300–500 ms interval and extended across parietal regions in later windows (500–1100 ms), consistent with stronger recollection-related activity for faces.

**Figure 17**

*Grand average ERP waveforms, topographies, and mean amplitudes for remembered and correctly rejected faces and objects*

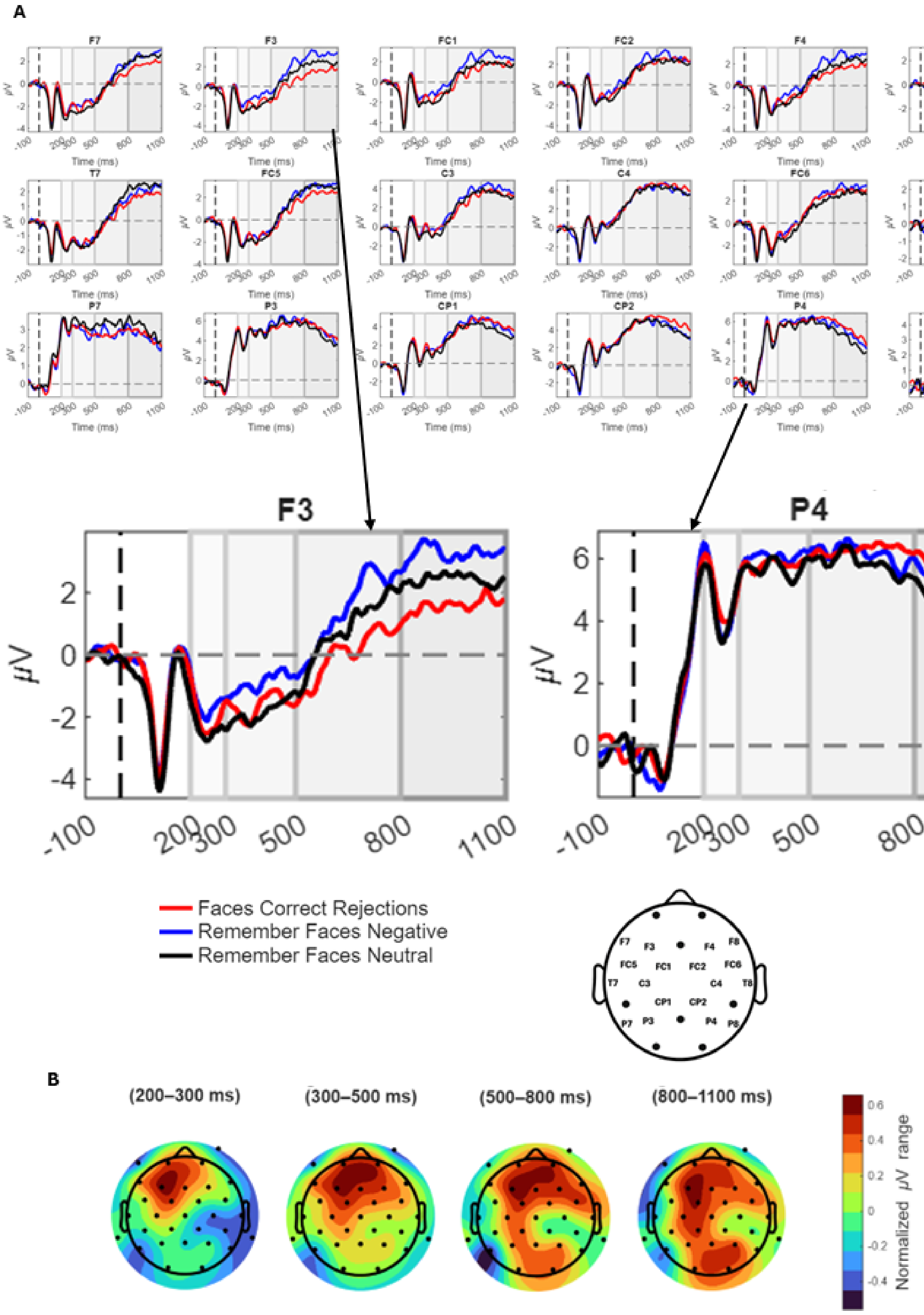


**Panel A.** Grand-average ERP waveforms for the electrodes F3, F4, P3, and P4 with remembered faces (dark red), correct rejections for faces (light red), remembered objects (black), and correct rejections for objects (grey). Vertical shaded regions indicate the four analysis windows used for statistics (200–300, 300–500, 500–800, 800–1100 ms). **Panel B.** Topographic maps displaying the mean difference between old/new for faces (remembered faces - correct rejections for faces) and old/new for objects (remembered objects − correct rejections for objects) for each window where red represents greater old/new effects for faces relative to objects, and blue the opposite pattern (colour scale at right, Z-score difference). **Panel C.** Group mean amplitudes (± standard error across participants) for remembered faces (dark red), correct rejections for faces (light red), remembered objects (black), and correct rejections for objects (grey) in each window (see Table 11 for test statistics and p values). All amplitudes are in microvolts (µV).

**Remembered faces vs. Correctly rejected faces.** No reliable main effects emerged until the 500–800 ms interval, when remembered faces showed greater positivity than correct rejections, accompanied by AP and ST interactions (Table 11). This is visually confirmed in Figure 17A and 17C; the waveform for remembered faces diverges from correct rejection for faces primarily in the later time windows, and the mean amplitude plot (Fig. 17C) shows no difference in the early epochs (200–500 ms). This late-onset effect suggests that recollection processes mediated recognition for faces. The spatial distribution, visible in Figure 17B as a parietal maximum for the face old/new effect, supports the view that retrieval of face memories engages recollection networks.

**Figure 18**

*Grand average ERP waveforms and topographies for negative and neutral remembered faces, and correct rejections*



**Panel A.** Grand-average ERP waveforms for the 18 electrodes used for statistical analyses of remembered negative (blue) and neutral (black) faces, and correct rejection for faces (red).

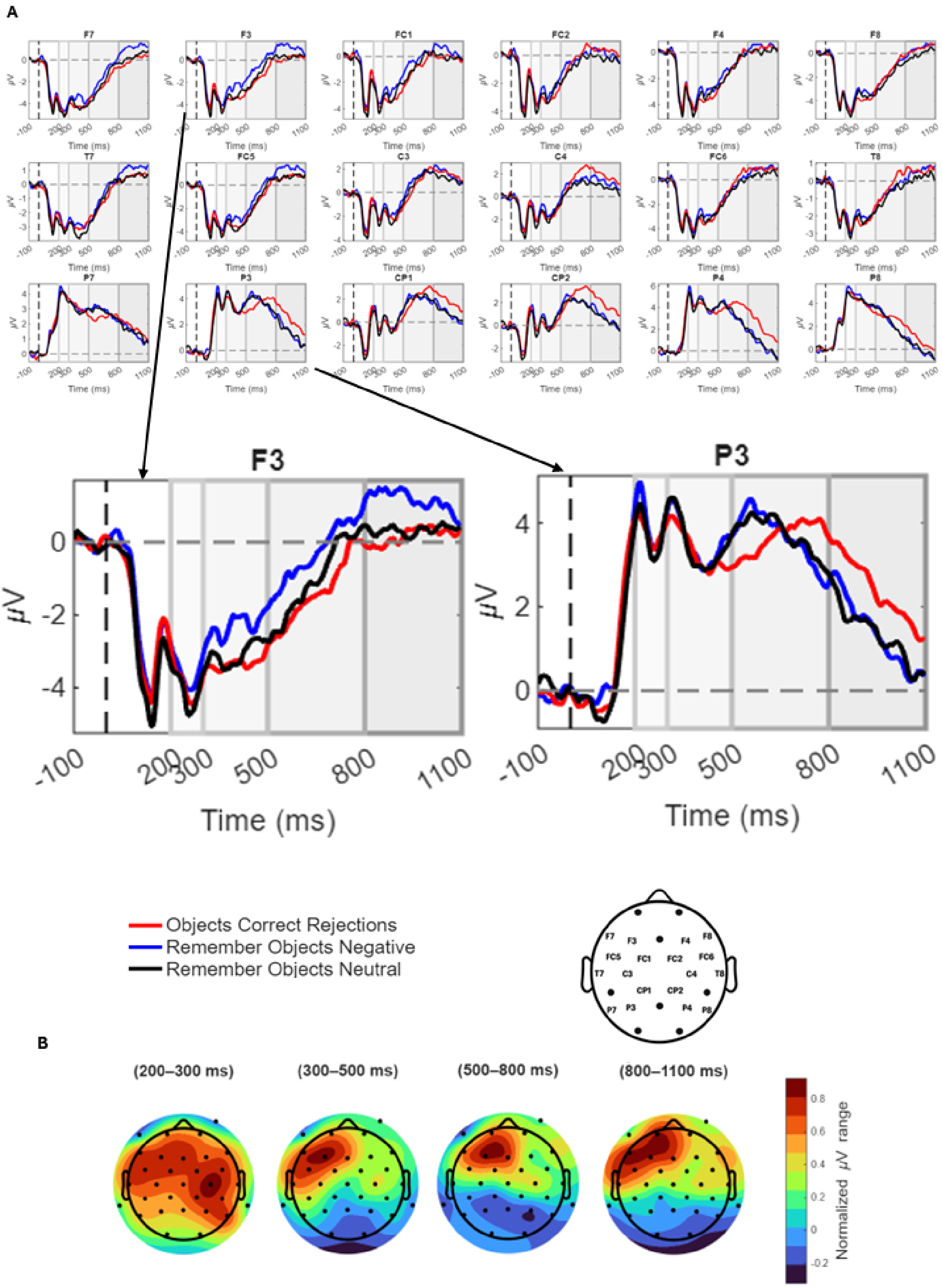
Vertical shaded regions indicate the four analysis windows used for statistics (200–300, 300–500, 500–800, 800–1100 ms). **Panel B.** Topographic maps displaying the mean normalized difference between negative vs. neutral remembered faces where red represents greater positive effects for negative relative to neutral, and blue the opposite pattern (colour scale at right). All amplitudes are in microvolts (μV).

**Remembered negative faces vs. Remembered neutral faces.** Direct comparisons between negative and neutral remembered faces revealed significant IT×ST×HM interactions in the 500–1100 ms range. As demonstrated in Figure 18A, negative faces elicited larger late positivities than neutral faces. Crucially, the topographic map of this difference (Figure 18B) confirms that this emotional effect is larger over fronto-central electrodes in both the 500–800 ms and 800–1100 ms windows. This frontal distribution highlights that the status of negative emotional content during retrieval is linked to frontal evaluative or monitoring processes during recollection.

**Remembered objects vs. Correctly rejected objects.** For objects, no main IT effects appeared in early windows, indicating that early perceptual and familiarity-based processes did not significantly contribute to object recognition. However, significant IT×AP, IT×ST, and crucially, IT×HM interactions emerged in the 500–800 ms interval (Table 11). The significant IT×HM interaction specifically indicates that the old/new effect for objects was left lateralized. This statistical finding, combined with the waveform in Figure 18A, suggests that successful recognition of objects relied primarily on late, recollection-based processes. The waveform shows the old/new difference for objects (black vs. grey lines) is indeed a late-onsetting positivity. The left-hemisphere emphasis is a conclusion drawn from the significant IT×HM interaction and is consistent with the typical lateralization of recollection-related activity.

**Figure 19**

*Grand average ERP waveforms and topographies for negative and neutral remembered objects, and correct rejections*



**Panel A.** Grand-average ERP waveforms for the 18 electrodes used for statistical analyses of remembered negative (blue) and neutral (black) objects, and correct rejection for objects (red).

Vertical shaded regions indicate the four analysis windows used for statistics (200–300, 300–500, 500–800, 800–1100 ms). **Panel B.** Topographic maps displaying the mean normalized difference between negative vs. neutral remembered objects where red represents greater positive effects for negative relative to neutral, and blue the opposite pattern (colour scale at right). All amplitudes are in microvolts (μV).

## 5.4. Discussion

The present study examined how emotional background contexts (negative vs. neutral) influence behavioural memory and the electrophysiological correlates of subsequent recollection for paired neutral faces and objects. Behavioural measures confirmed stimulus-dependent differences: objects produced larger recollection and familiarity estimates than faces, and negative faces showed enhanced familiarity estimates relative to neutral faces. Importantly, all ERP analyses reported here concern trials that were subsequently given remember (R) judgments (i.e., recollection-related trials). ERP analyses at encoding and retrieval revealed distinct temporal and topographic neural correlates for faces and objects and critically showed that emotional context modulates these correlates in different ways.

The behavioural pattern that emerged in the R/K/N data and the derived recollection/familiarity estimates indicates a dissociation between stimulus class and the influence of emotional context. Objects showed generally stronger memory estimates than faces, whereas emotional context selectively influenced face familiarity measures but not recollection estimates. This partial dissociation is consistent with the broader dual-process framework in which familiarity and recollection reflect separable processes (Yonelinas, 2002). It also resonates with recent reports showing that emotional context (or intrinsic emotion) can bias familiarity-based responding under some task conditions while leaving recollection (or source memory) relatively stable (Ventura-Bort et al., 2016). These behavioural results align with research demonstrating that arousal or threat-related signals rapidly bias perceptual and gist-level representations that underlie familiarity, whereas the hippocampally mediated binding processes that support recollection are less consistently modulated by valence per se unless encoding conditions specifically favour item-context binding (Kensinger, 2009; Mather & Sutherland, 2011).

Encoding ERPs prior to later R responses showed that faces compared to objects exhibited larger and earlier amplitudes for subsequently remembered trials overall. Perceptual inspection of faces and objects involve different cognitive processes (Tsao & Livingstone, 2009; Dehaghani et al., 2024). Faces engage specialized mechanisms very early on, when compared with objects. From very early stages faces elicit the N170, that is interpreted as a neural correlate of facial structural encoding (Bentin et al., 1996; Eimer, 2000; Rossion & Jacques, 2011). These operations often manifest as frontal SMEs during elaborative encoding, boosting frontal slow-wave positivity (Paller & Wagner, 2002; Uncapher & Wagner, 2009). By contrast, objects depend more on posterior visuo-perceptual model selection and feature binding, eliciting later SMEs related to posterior parietal systems (Schendan & Kutas, 2003, 2007)This functional difference in processing stimuli demonstrate the broader neurocognitive models in which face perception relies more on "holistic" (i.e., using relatively less part decomposition than most other types of objects) processes (Farah et al., 1998), whereas object processing engages more feature-based and semantic networks (Patterson et al., 2007; Martin et al., 2018; Binder & Desai, 2011).

Critically, both faces and objects showed an encoding emotional effect, in which neutral-encoded were more positive than negative-encoded stimuli across 200–300, 300–500, 500–800 and 800–1100 ms. The grand-average waveforms showed an earlier frontal effect for faces, while for objects that difference was more marked over centro-parietal sites in later windows. This indicates that the presence of emotional contextual scenes elicited an early EPN

(200–300 ms, posterior negativity) followed by a sustained LPP (>300 ms, centro-parietal positivity) indexing prioritized attention to affective content (Olofsson et al., 2008; Hajcak et al., 2010). Under negative contexts, the scene-evoked LPP temporally overlaps SME windows and captures attentional resources (Mather & Sutherland, 2011; Paller & Wagner, 2002; Uncapher & Wagner, 2009) effectively attenuating target-related encoding positivity.

Interestingly, the topographical patterns for these emotional effects (neutral > negative) were different for faces and objects. Faces showed a frontal emotional effect, while objects showed a parietal effect. Because face-related SMEs are earlier and frontal, the emotional attenuation appears earlier/frontally for faces (Paller & Wagner, 2002; Gobbini & Haxby, 2007). Because object-related SMEs are later and parietal, the LPP's posterior dominance yields a later, parietal neutral > negative effect for objects (Schendan & Kutas, 2003; Olofsson et al., 2008).

Retrieval ERPs (remember trials only) also showed divergent dynamics for faces and objects. For faces, emotional differences between negative and neutral remembered trials emerged only in the late epochs (500–800 and 800–1100 ms). The waveforms and topographies indicate that these face emotional differences are late and fronto-central in distribution. Thus, whereas encoding SMEs for faces were present early and sustained (and neutral > negative), retrieval differences for faces attributable to emotional context were delayed, manifesting primarily in late recollection-related windows. This late frontal modulation suggests that emotional context influenced evaluative or monitoring processes during recollection (consistent with frontal late positivities reported in the literature), rather than the parietal recollection ERP correlate (Rugg & Curran, 2007; Weymar et al., 2013).

For objects, direct emotional comparison did not elicit significant differences. Differences between remembered trials and correct rejections appeared later than for faces (from 500–800 ms to 800–1100 ms). Importantly, the object-related retrieval effects showed two distinct components: the typical old/new parietal effect with a more positive remembered ERP waveform and more negative correct rejection trials (in the 500–800 ms time window), and a opposite pattern, in which correct rejection showed more positivity than remembered trials (800–1100 ms).

This reversal in polarity can be explained by the late posterior negativity (LPN) (Sommer et al., 2018). The LPN component is related to mnemonic processes that require highly specific reconstructive processing or continued evaluation of retrieval outcomes (Mecklinger et al., 2016). It is frequently evident in source memory paradigms and evident at parietal sites for studied items (Herron, 2017). This effect has been shown to incorporate both action monitoring and reconstructive episodic memory processes (Herron, 2007; Johansson & Mecklinger, 2003), and has been characterised as a correlate of reconstructive source memory processes involved in both episodic and semantic memory (Mecklinger et al., 2016).

In our memory task, since we specifically probed participants to answer R in the RKN task if they could retrieve any specific contextual detail from the encoding episode, they probably had highly specific reconstructive processing of the target item and associated context. It is possible that our lack of direct ERP differences during retrieval for objects is caused by the LPN attenuating the later positivities related to remembered objects. Interestingly, we did not find this reversal in polarity caused by the LPN for faces. Probably due to faces having a lot less remembered trials than objects.

Several limitations deserve mention. First, ERP analyses here were restricted to Remember trials because of low trial counts for “know” responses; consequently, the present conclusions emphasize to neural correlates of recollection rather than familiarity. Second, the directionality of the SMEs (neutral > negative) and its stimulus dependence suggest that task parameters (e.g., the instruction to create an associative story) shape how emotional contexts influence encoding; future experiments that manipulate encoding goals, attention, or arousal parametrically could disentangle these effects. Third, although we drew on key ERP studies in the field, multimodal approaches (fMRI, pupillometry, or eye tracking) could clarify whether the neutral-context SME advantage reflects greater overt attention to item–context binding or differential engagement of hippocampal–cortical networks (Dolcos & Cabeza, 2002; Ventura-Bort et al., 2016). Additionally, due to time constraints, presently we cannot present data on the vividness assessment made during the encoding task. Finally, replication with larger samples and varied retention intervals would inform whether the pattern generalizes across delays (Kuhn et al., 2022; Ventura-Bort et al., 2016).

### 5.5. Conclusion

This study demonstrates that emotional background contexts modulate memory-related ERPs in stimulus-dependent and temporally specific ways. For subsequently recollected trials, neutral contexts elicited larger positive SMEs at encoding for both faces and objects, with faces showing earlier and more sustained SMEs than objects. At retrieval, emotional modulation manifested differently across stimulus classes: objects exhibited earlier parietal retrieval differences linked to emotional context, whereas faces showed later frontal modulations. Behaviourally, objects produced higher recollection and familiarity overall, and negative context selectively elevated familiarity for faces. Together, these results indicate that emotion–context effects are neither unitary nor uniformly enhancement-oriented; instead, stimulus class, the stage of processing (encoding vs. retrieval), and the specific memory signal (recollection-based ERPs in the present data) jointly determine whether and how emotional context alters memory. The findings refine current ERP models of emotional memory and underscore the need to consider stimulus domain and processing stage when interpreting emotional modulation of episodic memory.

# 6. General Discussion

The present work explores the findings of three experiments that aim to understand the behavioural and electrophysiological effects observed in recognition memory paradigms. The experiments seek to assess the emotional influence present in facial recognition. In the first experiment, to modulate emotional effects, facial expressions of fear and happiness were used. During the first experiment we also assessed source memory for those emotional expressions. In the second experiment, the strategy employed to modulate emotional effects were the use of emotional scenes as background pictures. The rationale behind this decision is that the background pictures would lend their emotional quality to the neutral faces that were presented superimposed into them. Finally, in the third experiment, we also used emotional scenes as background pictures, the difference here was the target stimuli. Both faces and objects were used as target stimuli presented superimposed onto the emotional contextual pictures.

In summary, the results of the first experiment can be divided into two categories, the behavioural and the ERP data. Participant showed higher accuracy in recognizing faces with fearful expressions. This outcome is in line with previous research (Kensinger, 2009; Righi et al., 2012; Grady et al., 2007). Similar effects were observed for words and scenes (Kensinger & Corkin., 2003; Ochsner, 2000).

However, there was no difference for source memory which suggests that the emotional impact of facial expression is merely implicit. This contradicts prior research demonstrating that contextual attributes of negative events are better remembered than those of neutral or positive events (Kensinger et al., 2007; Kensinger & Schacter, 2005; Mather & Nesmith, 2008), including the superior recall of the location of arousing negative stimuli compared to positive and non-arousing stimuli (Mather & Nesmith, 2008). It's important to highlight that these prior studies did not specifically focus on facial expressions as the emotional stimuli.

During encoding, ERP data showed that fearful faces elicited greater amplitudes than happy, this effect was mainly observed in over inferior and left-hemisphere sites on early time windows. This aligns with the idea that the amygdala's influence on perception and attention might modify the encoding of memory, prioritizing significant emotional events for more effective encoding (Phelps, 2004). The specific components modulated by the emotional expressions were the N170 (known to reflect structural face encoding) and the N250 (which is associated with face individuation) (Bentin et al., 1996).

During retrieval, data showed an emotional expression effect in left lateral-frontal electrodes, indicating greater positivity for fearful expressions, an effect observed in both recognition and source memory, and especially during the 300-500 ms time window. This indicates that the memory enhancements would have come from early recognition memory processes rather than recollection-specific processes.

Considering Experiment 2, our behavioural data showed no significant differences in recognition accuracy or reaction time when participants identified faces paired with negative, positive, or neutral contexts. This result aligns with earlier research (Smith et al. 2004; Jaeger et al. 2009). It is possible that, during encoding of emotionally neutral stimuli, it might lose attention allocation due to being overshadowed by emotionally charged scene components, especially when presented together (Mather, 2007; Kensinger et al., 2007; Smith et al., 2004).

In terms of ERP results, Experiment 2 showed that typical old/new pattern (Rugg & Curran, 2007) for neutral hits. That was not true for positive nor negative hits. We also observed an early central negativity for items studied in negative contexts. This emotion-related negativity attenuated the expected old/new positivities for emotionally encoded items, demonstrating that emotional context during encoding qualitatively shapes the neural dynamics of face recognition, with negative contexts engaging an implicit, arousal-weighted reactivation/fluency signal that modulates, but does not strengthen, explicit remembering. This aligns with reports that arousal can elicit early anterior retrieval modulations (Smith et al., 2004; Jaeger et al., 2009)

In Experiment 3, our behavioural data showed two main findings. First, that objects were better retrieved than faces. Second, that in terms of familiarity, negative (vs. neutral) contexts increased memory for faces. These results agree with dual-process accounts in which familiarity and recollection are separable and can be differently modulated (Yonelinas, 2002) and with proposals that arousal or threat signals bias familiarity-based responding while leaving recollection relatively stable unless encoding specifically fosters item–context binding (Kensinger, 2009; Mather & Sutherland, 2011; Ventura-Bort et al., 2016). Additionally, and maybe most importantly, it is consistent with our finding from Experiment 1, in which recognition was greater for faces encoded with emotional expressions, but showed no difference in source memory.

ERP analyses for Experiment 3 had two main findings. First, encoding SMEs were larger for neutral than negative contexts across both stimulus classes. For faces these emotional differences were earlier and sustained. They progressed from frontal to more parietal distributions. For objects the observed emotional differences occurred later and were predominantly parietal. This indicates that the negative contexts elicited an early EPN followed by a sustained LPP indexing prioritized attention to affective content (Olofsson et al., 2008; Hajcak et al., 2010). Under negative contexts, the scene-evoked LPP temporally overlaps SME windows and captures attentional resources (Mather & Sutherland, 2011; Paller & Wagner, 2002; Uncapher & Wagner, 2009) effectively attenuating target-related encoding amplitudes.

Our second main finding was that, during retrieval, faces showed late fronto-central differences between negative and neutral trials, implicating evaluative/monitoring operations rather than the parietal recollection correlate (Rugg & Curran, 2007; Weymar et al., 2013). This result, although later in timing, is spatially consistent with the fearful vs. happy effect found in

Experiment 1. Objects, on the other hand, did not show emotional modulation at retrieval. Instead, we saw a the typical old/new parietal effect and a later polarity reversal indicating LPN influence. This LPN influence suggests that processes related to reconstructive source memory (Mecklinger et al., 2016) was involved for objects, but not for faces.

In conclusion, this doctoral work shows that emotion influences memory encoding and retrieval via distinct neural and cognitive mechanisms that depend on the nature of the emotional stimuli (facial expressions vs. background scenes) and target types (faces vs. objects). Specifically, fearful facial expressions appear to enhance early perceptual encoding and familiarity-based recognition, reflecting amygdala-driven prioritization of socially relevant threat cues, while emotional scenes exert more complex, stimulus-dependent influences that can both facilitate and impair associative binding. But mainly, what these findings show is that emotion provokes modulation over both encoding and retrieval, and that in some cases the way this modulation occurs cannot simply be assessed as an enhancement or diminishment of memory related effects. There are several concomitant processes that complicate and overlap with the typical proposed memory effects. Sometimes these overlaps are observed as attenuations or even polarity reversals of the expected effects. Moreover, the dissociation between behavioural outcomes and ERP modulations underscores how emotional influences may operate implicitly at the neural level, even when not overtly evident in recognition accuracy.

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**Appendix A –** List of codes for the images of faces used on Experiment 1.

| Code | Category | Code | Category | Code | Category |
|---|---|---|---|---|---|
| 004_o_m_f_a | Fear | 120_o_f_h_a | Happy | 057_y_m_n_a | Neutral |
| 005_o_f_f_a | Fear | 121_o_m_h_a | Happy | 058_m_m_n_a | Neutral |
| 006_m_f_f_a | Fear | 122_m_f_h_a | Happy | 059_o_m_n_a | Neutral |
| 007_m_m_f_a | Fear | 123_y_m_h_a | Happy | 060_o_f_n_a | Neutral |
| 008_y_m_f_a | Fear | 124_o_f_h_a | Happy | 061_m_f_n_a | Neutral |
| 010_y_f_f_a | Fear | 125_y_f_h_a | Happy | 062_y_m_n_a | Neutral |
| 011_m_f_f_a | Fear | 126_m_m_h_a | Happy | 063_y_f_n_a | Neutral |
| 012_o_f_f_a | Fear | 127_y_m_h_a | Happy | CFD-BF-001-025-N | Neutral |
| 013_y_m_f_a | Fear | 128_m_f_h_a | Happy | CFD-BF-002-001-N | Neutral |
| 014_m_m_f_a | Fear | 130_o_f_h_a | Happy | CFD-BF-003-003-N | Neutral |
| 015_o_m_f_a | Fear | 131_o_m_h_a | Happy | CFD-BF-004-014-N | Neutral |
| 016_y_m_f_a | Fear | 132_y_f_h_a | Happy | CFD-BF-005-001-N | Neutral |
| 018_o_m_f_a | Fear | 133_o_f_h_a | Happy | CFD-BF-006-017-N | Neutral |
| 019_m_f_f_a | Fear | 134_y_f_h_a | Happy | CFD-BF-007-001-N | Neutral |
| 020_y_f_f_a | Fear | 135_y_m_h_a | Happy | CFD-BF-008-001-N | Neutral |
| 021_o_f_f_a | Fear | 136_m_m_h_a | Happy | CFD-BF-009-002-N | Neutral |
| 022_y_f_f_a | Fear | 137_o_m_h_a | Happy | CFD-BF-010-001-N | Neutral |
| 024_o_f_f_a | Fear | 138_m_f_h_a | Happy | CFD-BF-011-002-N | Neutral |
| 025_y_m_f_a | Fear | 139_m_f_h_a | Happy | CFD-BF-012-001-N | Neutral |
| 026_m_m_f_a | Fear | 140_y_f_h_a | Happy | CFD-BF-013-001-N | Neutral |
| 027_o_m_f_a | Fear | 141_o_m_h_a | Happy | CFD-BF-014-002-N | Neutral |
| 028_y_f_f_a | Fear | 142_m_m_h_a | Happy | CFD-BF-015-004-N | Neutral |
| 029_m_f_f_a | Fear | 143_o_f_h_a | Happy | CFD-BF-016-017-N | Neutral |
| 030_o_f_f_a | Fear | 144_y_m_h_a | Happy | CFD-BM-001-014-N | Neutral |
| 031_y_m_f_a | Fear | 146_o_m_h_a | Happy | CFD-BM-002-013-N | Neutral |
| 032_m_m_f_a | Fear | 147_y_m_h_a | Happy | CFD-BM-003-003-N | Neutral |
| 033_o_m_f_a | Fear | 148_o_f_h_a | Happy | CFD-BM-009-002-N | Neutral |
| 034_y_f_f_a | Fear | 149_m_m_h_a | Happy | CFD-BM-010-003-N | Neutral |
| 035_m_f_f_a | Fear | 150_y_f_h_a | Happy | CFD-BM-011-016-N | Neutral |
| 036_o_f_f_a | Fear | 151_o_m_h_a | Happy | CFD-BM-013-002-N | Neutral |
| 037_y_m_f_a | Fear | 152_y_f_h_a | Happy | CFD-BM-015-015-N | Neutral |
| 038_m_m_f_a | Fear | 153_y_m_h_a | Happy | CFD-BM-016-036-N | Neutral |
| 039_o_m_f_a | Fear | CFD-BF-027-006-HO | Happy | CFD-BM-017-021-N | Neutral |
| 040_y_f_f_a | Fear | CFD-BF-028-006-HO | Happy | CFD-BM-018-001-N | Neutral |
| 041_y_m_f_a | Fear | CFD-BF-029-005-HO | Happy | CFD-BM-019-002-N | Neutral |
| 042_o_m_f_a | Fear | CFD-BF-030-007-HO | Happy | CFD-WF-001-003-N | Neutral |
| 043_m_f_f_a | Fear | CFD-BF-031-051-HO | Happy | CFD-WF-002-004-N | Neutral |
| 044_o_f_f_a | Fear | CFD-BF-032-043-HO | Happy | CFD-WF-003-003-N | Neutral |
| 045_m_m_f_a | Fear | CFD-BF-033-031-HO | Happy | CFD-WF-005-010-N | Neutral |
| 046_o_m_f_a | Fear | CFD-BF-034-005-HO | Happy | CFD-WF-006-002-N | Neutral |
| 047_o_f_f_a | Fear | CFD-BF-035-027-HO | Happy | CFD-WF-007-001-N | Neutral |
| 048_y_f_f_a | Fear | CFD-BF-036-030-HO | Happy | CFD-WF-008-002-N | Neutral |
| 049_y_m_f_a | Fear | CFD-BF-037-026-HO | Happy | CFD-WF-009-001-N | Neutral |
| 050_m_f_f_a | Fear | CFD-BF-038-004-HO | Happy | CFD-WF-010-004-N | Neutral |
| 051_m_m_f_a | Fear | CFD-BF-039-033-HO | Happy | CFD-WF-011-002-N | Neutral |
| 052_m_f_f_a | Fear | CFD-BF-040-043-HO | Happy | CFD-WF-012-002-N | Neutral |
| 053_o_m_f_a | Fear | CFD-BF-041-004-HO | Happy | CFD-WF-013-003-N | Neutral |
| 054_y_f_f_a | Fear | CFD-BF-042-028-HO | Happy | CFD-WM-004-010-N | Neutral |
| 055_o_f_f_a | Fear | CFD-BM-028-028-HO | Happy | CFD-WM-006-002-N | Neutral |
| 056_m_m_f_a | Fear | CFD-BM-029-029-HO | Happy | CFD-WM-009-002-N | Neutral |

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|---|---|---|---|---|---|
| 057_y_m_f_a | Fear | CFD-BM-030-004-HO | Happy | CFD-WM-010-001-N | Neutral |
| 058_m_m_f_a | Fear | CFD-BM-031-004-HO | Happy | CFD-WM-011-002-N | Neutral |
| 059_o_m_f_a | Fear | CFD-BM-032-007-HO | Happy | CFD-WM-012-001-N | Neutral |
| 060_o_f_f_a | Fear | CFD-BM-033-029-HO | Happy | CFD-WM-013-001-N | Neutral |
| 061_m_f_f_a | Fear | CFD-BM-034-033-HO | Happy | CFD-WM-014-002-N | Neutral |
| 062_y_m_f_a | Fear | CFD-BM-036-004-HO | Happy | CFD-WM-015-002-N | Neutral |
| 063_y_f_f_a | Fear | CFD-BM-037-036-HO | Happy | CFD-WM-017-002-N | Neutral |
| CFD-BF-001-009-F | Fear | CFD-BM-038-007-HO | Happy | 094_m_m_n_a | Neutral |
| CFD-BF-002-022-F | Fear | CFD-BM-039-034-HO | Happy | 096_o_f_n_a | Neutral |
| CFD-BF-003-020-F | Fear | CFD-BM-040-030-HO | Happy | 097_m_f_n_a | Neutral |
| CFD-BF-004-002-F | Fear | CFD-WF-020-023-HO | Happy | 098_y_f_n_a | Neutral |
| CFD-BF-005-022-F | Fear | CFD-WF-021-016-HO | Happy | 099_y_m_n_a | Neutral |
| CFD-BF-006-018-F | Fear | CFD-WF-022-019-HO | Happy | 100_o_f_n_a | Neutral |
| CFD-BF-007-024-F | Fear | CFD-WF-023-020-HO | Happy | 101_y_f_n_a | Neutral |
| CFD-BF-008-018-F | Fear | CFD-WF-024-006-HO | Happy | 102_o_m_n_a | Neutral |
| CFD-BF-009-019-F | Fear | CFD-WF-025-006-HO | Happy | 103_m_f_n_a | Neutral |
| CFD-BF-010-015-F | Fear | CFD-WF-026-017-HO | Happy | 104_m_m_n_a | Neutral |
| CFD-BF-011-021-F | Fear | CFD-WF-027-021-HO | Happy | 105_y_m_n_a | Neutral |
| CFD-BF-012-018-F | Fear | CFD-WF-028-024-HO | Happy | 106_y_f_n_a | Neutral |
| CFD-BF-013-026-F | Fear | CFD-WF-029-021-HO | Happy | 107_o_m_n_a | Neutral |
| CFD-BF-014-021-F | Fear | CFD-WF-030-003-HO | Happy | 108_m_m_n_a | Neutral |
| CFD-BF-015-025-F | Fear | CFD-WF-031-005-HO | Happy | 109_y_m_n_a | Neutral |
| CFD-BF-016-021-F | Fear | CFD-WM-024-003-HO | Happy | 110_o_f_n_a | Neutral |
| CFD-BM-001-007-F | Fear | CFD-WM-025-019-HO | Happy | 111_m_f_n_a | Neutral |
| CFD-BM-002-002-F | Fear | CFD-WM-026-006-HO | Happy | 112_o_f_n_a | Neutral |
| CFD-BM-003-031-F | Fear | CFD-WM-028-007-HO | Happy | 113_m_f_n_a | Neutral |
| CFD-BM-009-009-F | Fear | CFD-WM-029-029-HO | Happy | 114_y_m_n_a | Neutral |
| CFD-BM-010-015-F | Fear | CFD-WM-031-004-HO | Happy | 115_y_f_n_a | Neutral |
| CFD-BM-011-013-F | Fear | CFD-WM-032-004-HO | Happy | 116_m_m_n_a | Neutral |
| CFD-BM-013-019-F | Fear | CFD-WM-033-007-HO | Happy | 117_m_f_n_a | Neutral |
| CFD-BM-015-014-F | Fear | CFD-WM-034-035-HO | Happy | 118_o_m_n_a | Neutral |
| CFD-BM-016-030-F | Fear | CFD-WM-035-033-HO | Happy | 119_y_m_n_a | Neutral |
| CFD-BM-017-064-F | Fear | 004_o_m_n_a | Neutral | 120_o_f_n_a | Neutral |
| CFD-BM-018-040-F | Fear | 005_o_f_n_a | Neutral | 121_o_m_n_a | Neutral |
| CFD-BM-019-049-F | Fear | 006_m_f_n_a | Neutral | 122_m_f_n_a | Neutral |
| CFD-WF-001-027-F | Fear | 007_m_m_n_a | Neutral | 123_y_m_n_a | Neutral |
| CFD-WF-002-025-F | Fear | 008_y_m_n_a | Neutral | 124_o_f_n_a | Neutral |
| CFD-WF-003-025-F | Fear | 010_y_f_n_a | Neutral | 125_y_f_n_a | Neutral |
| CFD-WF-005-027-F | Fear | 011_m_f_n_a | Neutral | 126_m_m_n_a | Neutral |
| CFD-WF-006-011-F | Fear | 012_o_f_n_a | Neutral | 127_y_m_n_a | Neutral |
| CFD-WF-007-026-F | Fear | 013_y_m_n_a | Neutral | 128_m_f_n_a | Neutral |
| CFD-WF-008-016-F | Fear | 014_m_m_n_a | Neutral | 130_o_f_n_a | Neutral |
| CFD-WF-009-015-F | Fear | 015_o_m_n_a | Neutral | 131_o_m_n_a | Neutral |
| CFD-WF-010-013-F | Fear | 016_y_m_n_a | Neutral | 132_y_f_n_a | Neutral |
| CFD-WF-011-016-F | Fear | 018_o_m_n_a | Neutral | 133_o_f_n_a | Neutral |
| CFD-WF-012-017-F | Fear | 019_m_f_n_a | Neutral | 134_y_f_n_a | Neutral |
| CFD-WF-013-019-F | Fear | 020_y_f_n_a | Neutral | 135_y_m_n_a | Neutral |
| CFD-WM-004-002-F | Fear | 021_o_f_n_a | Neutral | 136_m_m_n_a | Neutral |
| CFD-WM-006-039-F | Fear | 022_y_f_n_a | Neutral | 137_o_m_n_a | Neutral |
| CFD-WM-009-014-F | Fear | 024_o_f_n_a | Neutral | 138_m_f_n_a | Neutral |
| CFD-WM-010-020-F | Fear | 025_y_m_n_a | Neutral | 139_m_f_n_a | Neutral |
| CFD-WM-011-019-F | Fear | 026_m_m_n_a | Neutral | 140_y_f_n_a | Neutral |
| CFD-WM-012-026-F | Fear | 027_o_m_n_a | Neutral | 141_o_m_n_a | Neutral |

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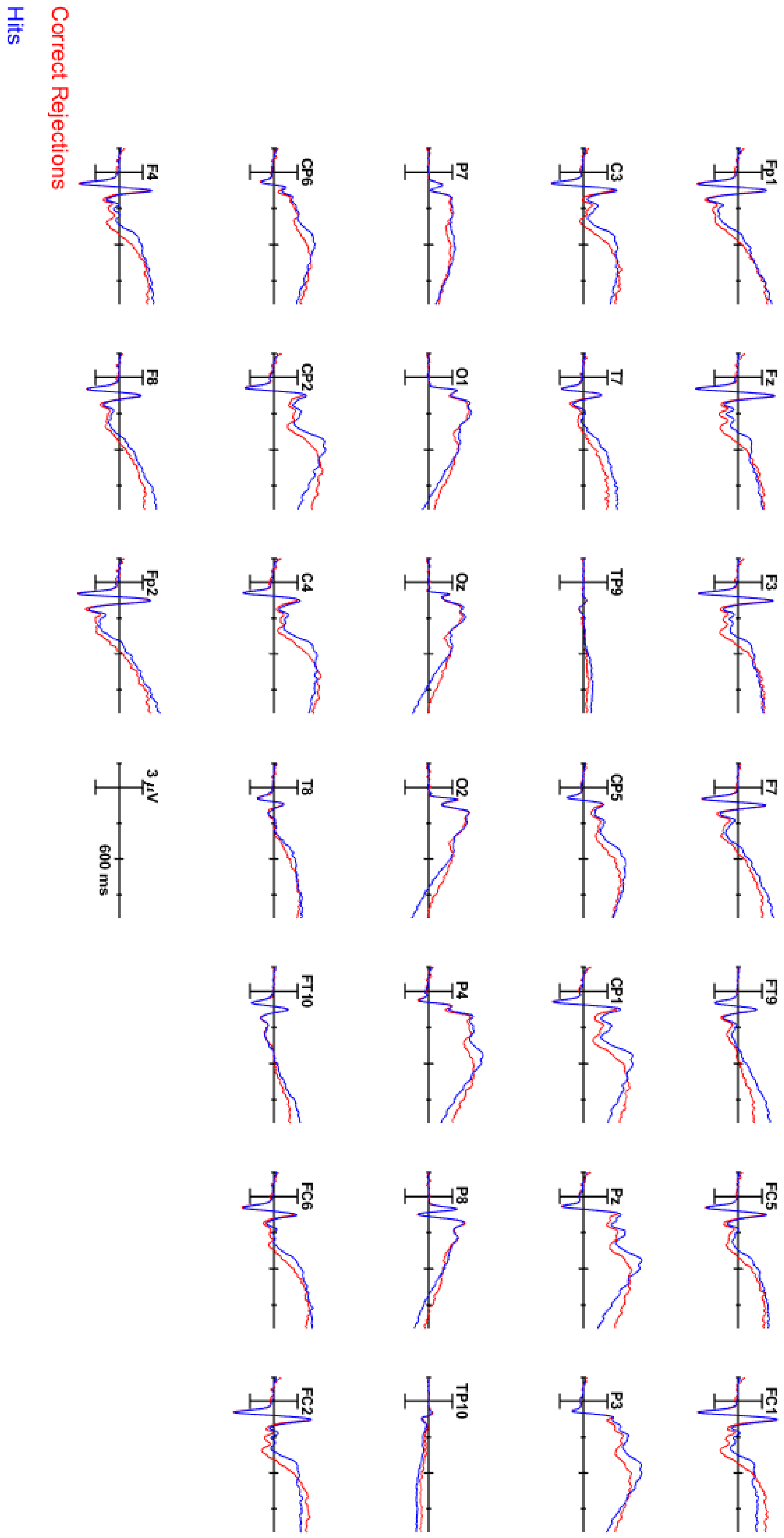
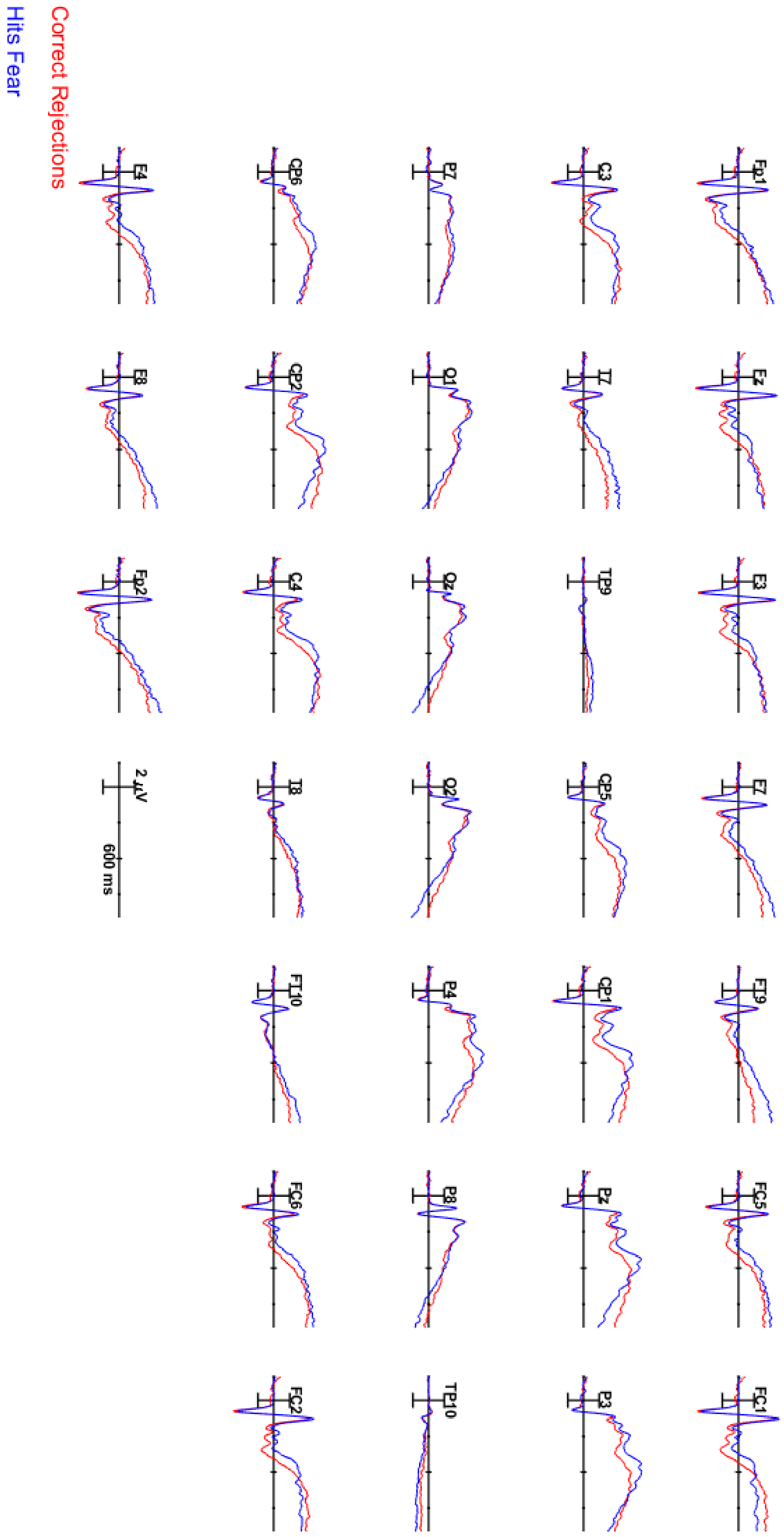
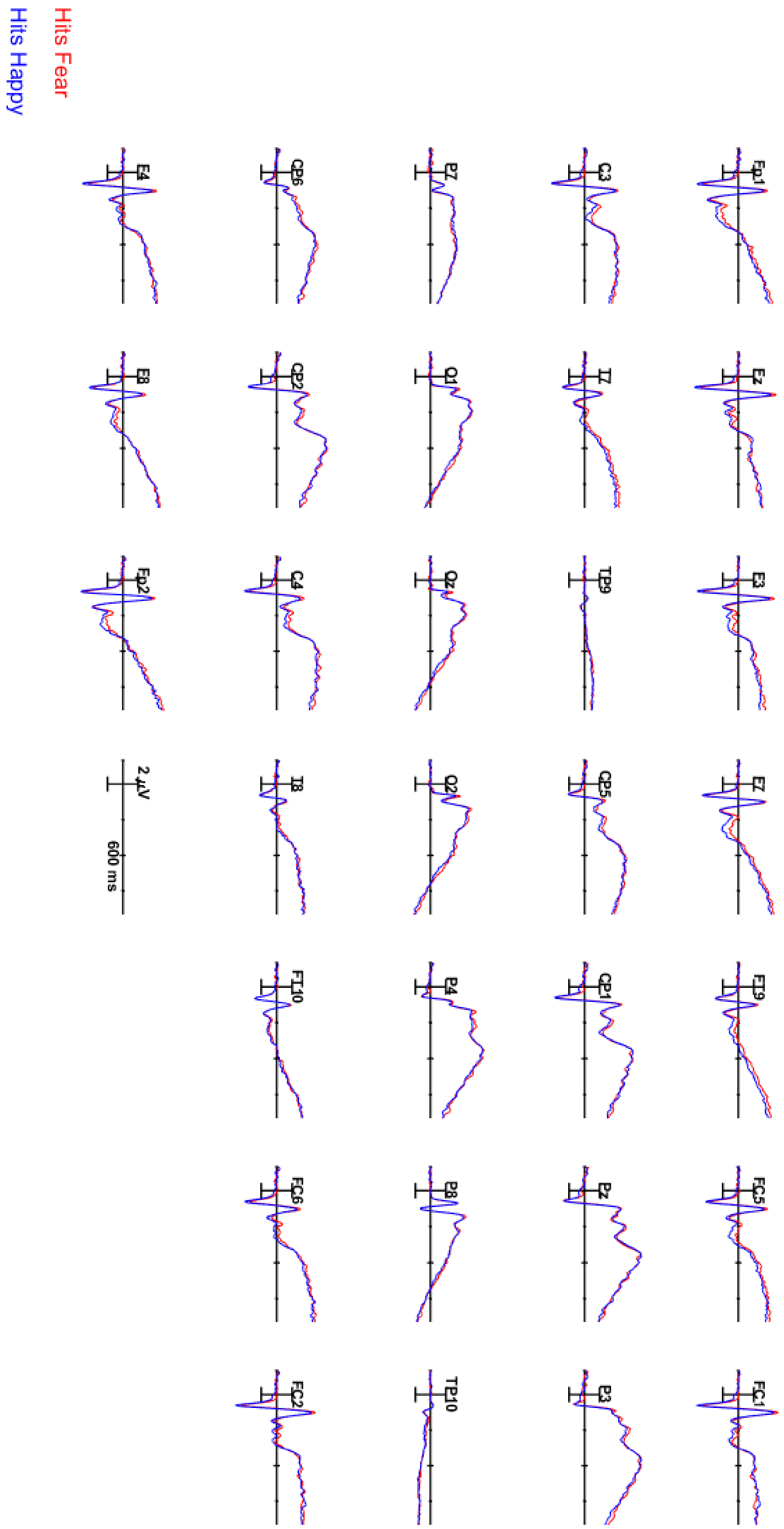
|---|---|---|---|---|---|
| CFD-WM-013-019-F | Fear | 028_y_f_n_a | Neutral | 142_m_m_n_a | Neutral |
| CFD-WM-014-024-F | Fear | 029_m_f_n_a | Neutral | 143_o_f_n_a | Neutral |
| CFD-WM-015-023-F | Fear | 030_o_f_n_a | Neutral | 144_y_m_n_a | Neutral |
| CFD-WM-017-019-F | Fear | 031_y_m_n_a | Neutral | 146_o_m_n_a | Neutral |
| 094_m_m_h_a | Happy | 032_m_m_n_a | Neutral | 147_y_m_n_a | Neutral |
| 096_o_f_h_a | Happy | 033_o_m_n_a | Neutral | 148_o_f_n_a | Neutral |
| 097_m_f_h_a | Happy | 034_y_f_n_a | Neutral | 149_m_m_n_a | Neutral |
| 098_y_f_h_a | Happy | 035_m_f_n_a | Neutral | 150_y_f_n_a | Neutral |
| 099_y_m_h_a | Happy | 036_o_f_n_a | Neutral | 151_o_m_n_a | Neutral |
| 100_o_f_h_a | Happy | 037_y_m_n_a | Neutral | 152_y_f_n_a | Neutral |
| 101_y_f_h_a | Happy | 038_m_m_n_a | Neutral | 153_y_m_n_a | Neutral |
| 102_o_m_h_a | Happy | 039_o_m_n_a | Neutral | CFD-BF-027-002-N | Neutral |
| 103_m_f_h_a | Happy | 040_y_f_n_a | Neutral | CFD-BF-028-001-N | Neutral |
| 104_m_m_h_a | Happy | 041_y_m_n_a | Neutral | CFD-BF-029-031-N | Neutral |
| 105_y_m_h_a | Happy | 042_o_m_n_a | Neutral | CFD-BF-030-002-N | Neutral |
| 106_y_f_h_a | Happy | 043_m_f_n_a | Neutral | CFD-BF-031-002-N | Neutral |
| 107_o_m_h_a | Happy | 044_o_f_n_a | Neutral | CFD-BF-032-038-N | Neutral |
| 108_m_m_h_a | Happy | 045_m_m_n_a | Neutral | CFD-BF-033-028-N | Neutral |
| 109_y_m_h_a | Happy | 046_o_m_n_a | Neutral | CFD-BF-034-002-N | Neutral |
| 110_o_f_h_a | Happy | 047_o_f_n_a | Neutral | CFD-BF-035-001-N | Neutral |
| 111_m_f_h_a | Happy | 048_y_f_n_a | Neutral | CFD-BF-036-027-N | Neutral |
| 112_o_f_h_a | Happy | 049_y_m_n_a | Neutral | CFD-BF-037-022-N | Neutral |
| 113_m_f_h_a | Happy | 050_m_f_n_a | Neutral | CFD-BF-038-037-N | Neutral |
| 114_y_m_h_a | Happy | 051_m_m_n_a | Neutral | CFD-BF-039-031-N | Neutral |
| 115_y_f_h_a | Happy | 052_m_f_n_a | Neutral | CFD-BF-040-003-N | Neutral |
| 116_m_m_h_a | Happy | 053_o_m_n_a | Neutral | CFD-BF-041-001-N | Neutral |
| 117_m_f_h_a | Happy | 054_y_f_n_a | Neutral | CFD-BF-042-026-N | Neutral |
| 118_o_m_h_a | Happy | 055_o_f_n_a | Neutral | CFD-BM-028-002-N | Neutral |
| 119_y_m_h_a | Happy | 056_m_m_n_a | Neutral | CFD-BM-029-024-N | Neutral |
| CFD-BM-030-003-N | Neutral | CFD-WM-024-015-N | Neutral | 076_o_m_n_a | New |
| CFD-BM-031-003-N | Neutral | CFD-WM-025-002-N | Neutral | 077_m_m_n_a | New |
| CFD-BM-032-024-N | Neutral | CFD-WM-026-001-N | Neutral | 079_o_f_n_a | New |
| CFD-BM-033-003-N | Neutral | CFD-WM-028-003-N | Neutral | 080_m_f_n_a | New |
| CFD-BM-034-031-N | Neutral | CFD-WM-029-023-N | Neutral | 081_y_m_n_a | New |
| CFD-BM-036-003-N | Neutral | CFD-WM-031-003-N | Neutral | 082_m_m_n_a | New |
| CFD-BM-037-033-N | Neutral | CFD-WM-032-001-N | Neutral | 083_o_m_n_a | New |
| CFD-BM-038-001-N | Neutral | CFD-WM-033-025-N | Neutral | 084_m_f_n_a | New |
| CFD-BM-039-029-N | Neutral | CFD-WM-034-030-N | Neutral | 085_y_f_n_a | New |
| CFD-BM-040-002-N | Neutral | CFD-WM-035-032-N | Neutral | 086_o_f_n_a | New |
| CFD-WF-020-002-N | Neutral | 064_m_f_n_a | New | 087_m_m_n_a | New |
| CFD-WF-021-002-N | Neutral | 065_o_m_n_a | New | 088_o_f_n_a | New |
| CFD-WF-022-017-N | Neutral | 066_y_m_n_a | New | 089_y_m_n_a | New |
| CFD-WF-023-003-N | Neutral | 067_o_f_n_a | New | 090_y_f_n_a | New |
| CFD-WF-024-003-N | Neutral | 068_m_m_n_a | New | 091_o_m_n_a | New |
| CFD-WF-025-019-N | Neutral | 069_y_f_n_a | New | 092_m_m_n_a | New |
| CFD-WF-026-002-N | Neutral | 070_m_m_n_a | New | 154_o_f_n_a | New |
| CFD-WF-027-003-N | Neutral | 071_y_f_n_a | New | 155_m_m_n_a | New |
| CFD-WF-028-023-N | Neutral | 072_y_m_n_a | New | 156_m_f_n_a | New |
| CFD-WF-029-002-N | Neutral | 073_m_f_n_a | New | 157_m_f_n_a | New |
| CFD-WF-030-002-N | Neutral | 074_o_m_n_a | New | 158_o_f_n_a | New |
| CFD-WF-031-027-N | Neutral | 075_o_f_n_a | New | 159_m_m_n_a | New |
| 160_y_m_n_a | New | CFD-BF-017-003-N | New | CFD-BM-043-071-N | New |
| 161_o_m_n_a | New | CFD-BF-018-039-N | New | CFD-BM-044-001-N | New |

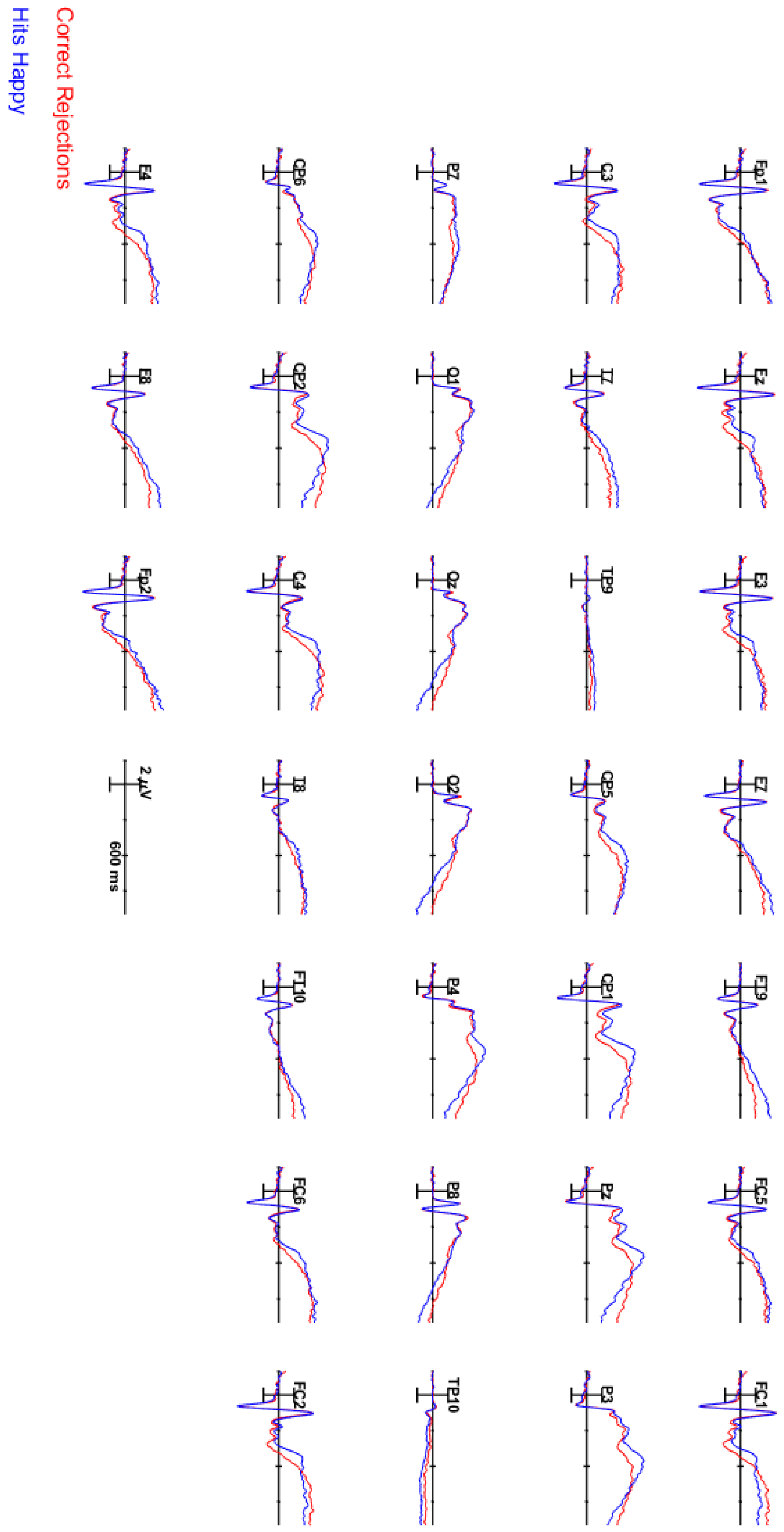
| | | | | | |
|---|---|---|---|---|---|
| 162_y_f_n_a | New | CFD-BF-019-001-N | New | CFD-BM-045-004-N | New |
| 163_y_f_n_a | New | CFD-BF-020-002-N | New | CFD-BM-046-006-N | New |
| 164_o_f_n_a | New | CFD-BF-021-013-N | New | CFD-WF-014-002-N | New |
| 165_m_m_n_a | New | CFD-BF-023-010-N | New | CFD-WF-015-006-N | New |
| 166_o_m_n_a | New | CFD-BF-024-002-N | New | CFD-WF-016-015-N | New |
| 167_y_m_n_a | New | CFD-BF-025-002-N | New | CFD-WF-017-003-N | New |
| 168_m_f_n_a | New | CFD-BF-043-003-N | New | CFD-WF-018-017-N | New |
| 169_m_m_n_a | New | CFD-BF-044-034-N | New | CFD-WF-019-005-N | New |
| 170_y_m_n_a | New | CFD-BF-045-003-N | New | CFD-WF-033-002-N | New |
| 171_y_f_n_a | New | CFD-BF-047-003-N | New | CFD-WF-034-006-N | New |
| 172_o_m_n_a | New | CFD-BF-048-002-N | New | CFD-WF-035-024-N | New |
| 173_y_f_n_a | New | CFD-BF-049-032-N | New | CFD-WF-036-023-N | New |
| 174_o_f_n_a | New | CFD-BF-050-003-N | New | CFD-WF-037-029-N | New |
| 175_y_m_n_a | New | CFD-BF-051-035-N | New | CFD-WF-038-021-N | New |
| 176_o_m_n_a | New | CFD-BM-020-001-N | New | CFD-WM-019-003-N | New |
| 177_y_f_n_a | New | CFD-BM-021-021-N | New | CFD-WM-020-001-N | New |
| 178_m_m_n_a | New | CFD-BM-022-022-N | New | CFD-WM-022-001-N | New |
| 179_m_m_n_a | New | CFD-BM-023-029-N | New | CFD-WM-023-001-N | New |
| 180_m_f_n_a | New | CFD-BM-024-001-N | New | CFD-WM-036-031-N | New |
| 182_y_f_n_a | New | CFD-BM-041-035-N | New | CFD-WM-037-025-N | New |
| | | | | CFD-WM-038-003-N | New |
| | | | | CFD-WM-039-018-N | New |

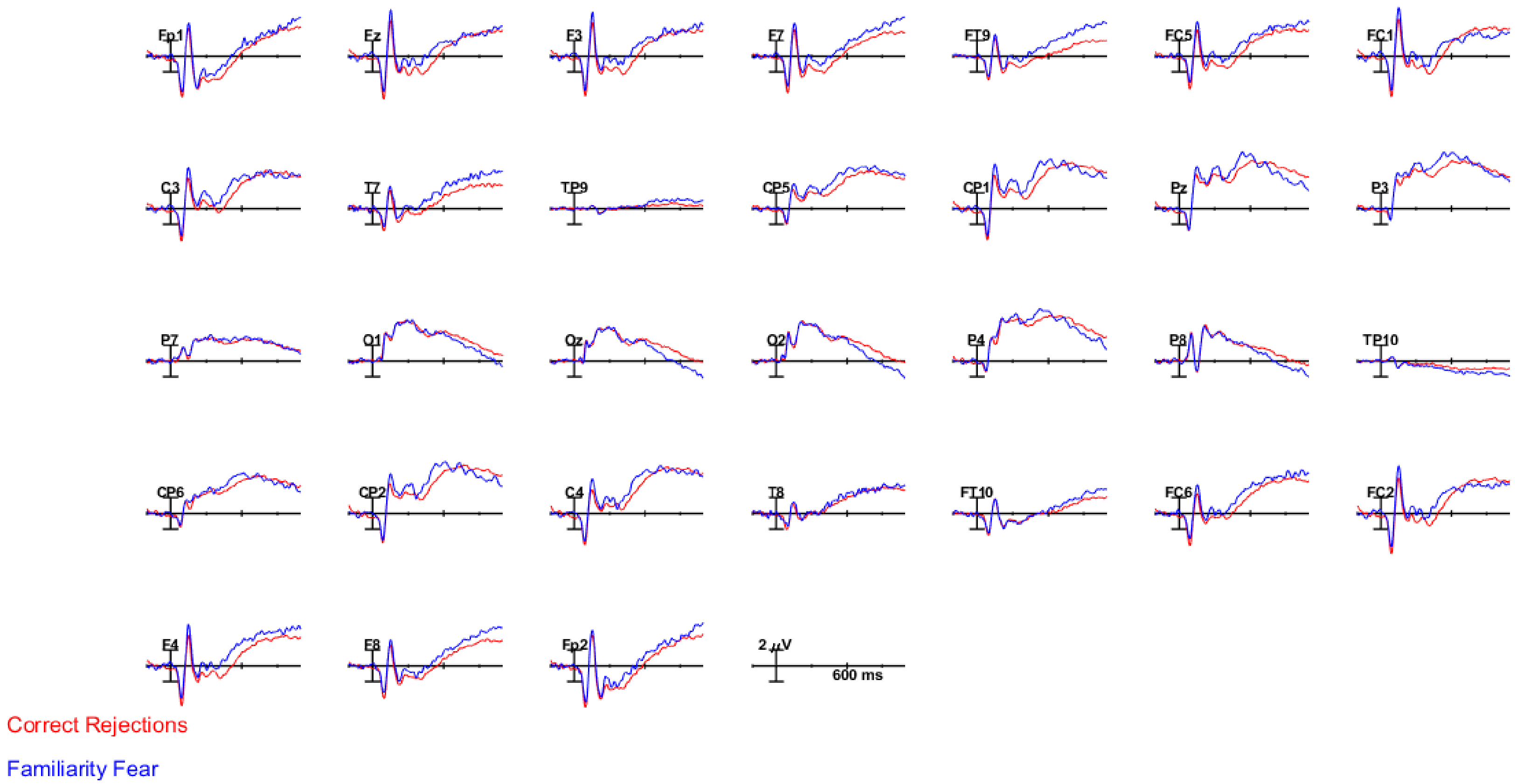
**Appendix B** – ERPs of all electrodes utilized for analysis on Experiment 1.

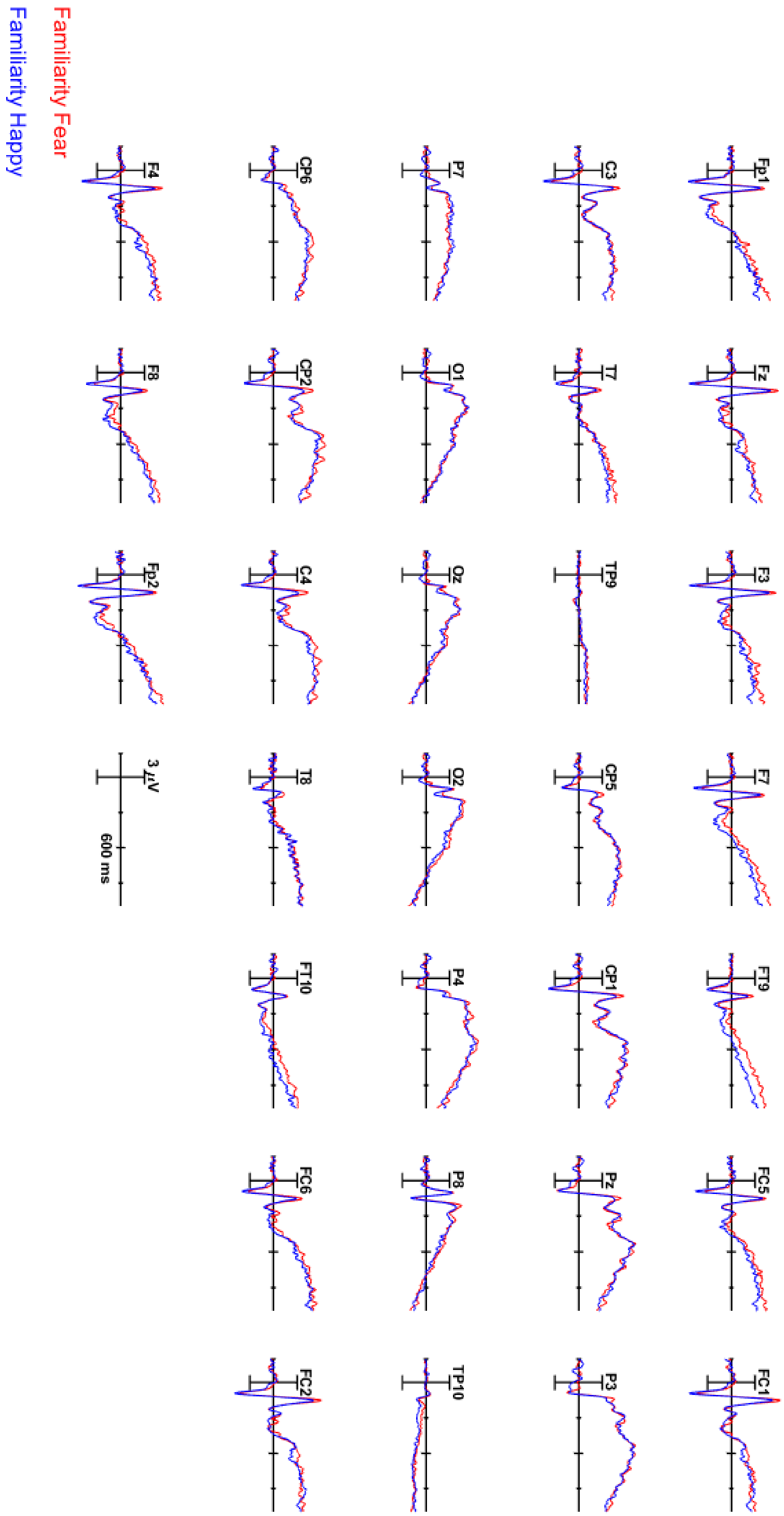


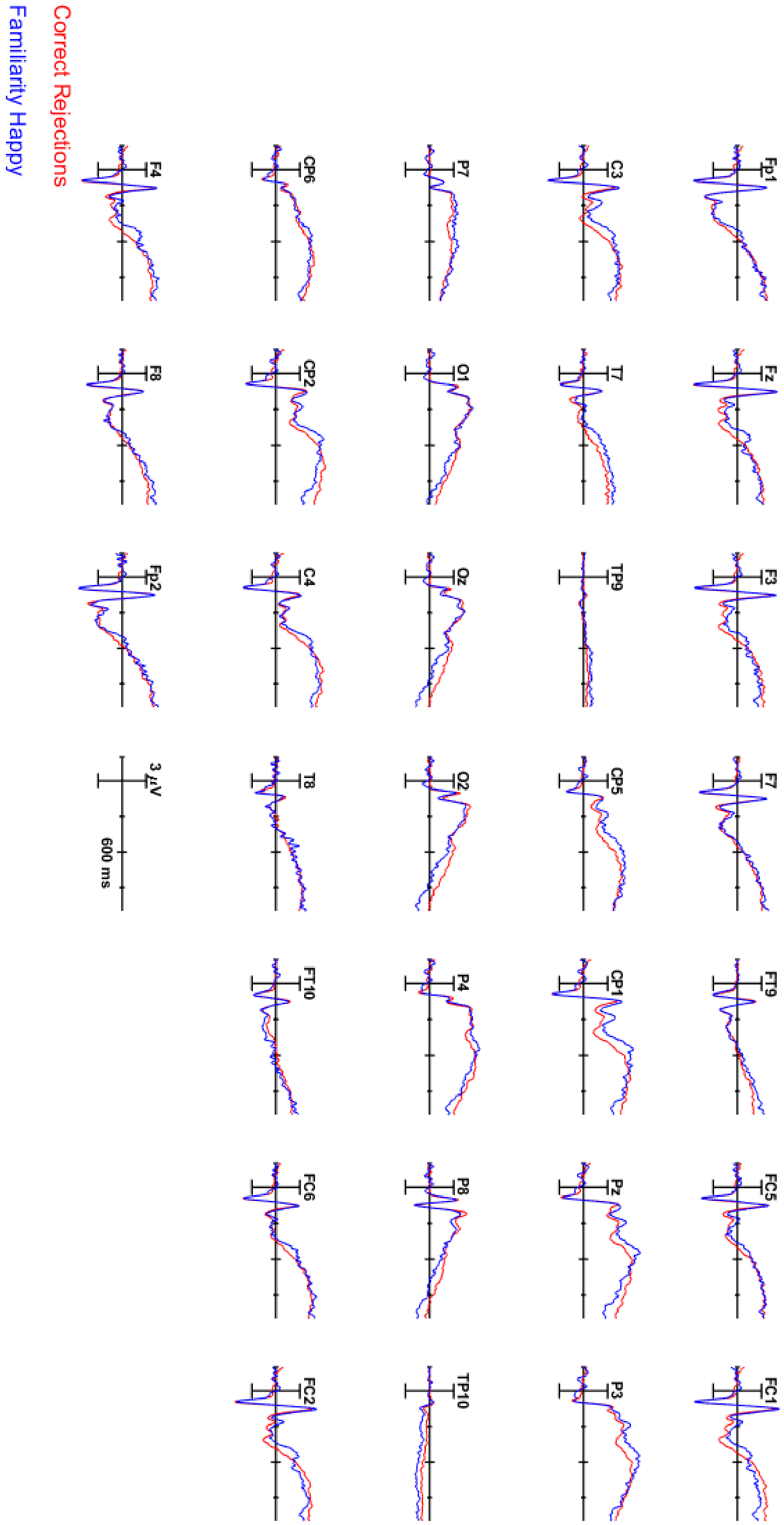

Correct Rejections
Hits Fear
Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms

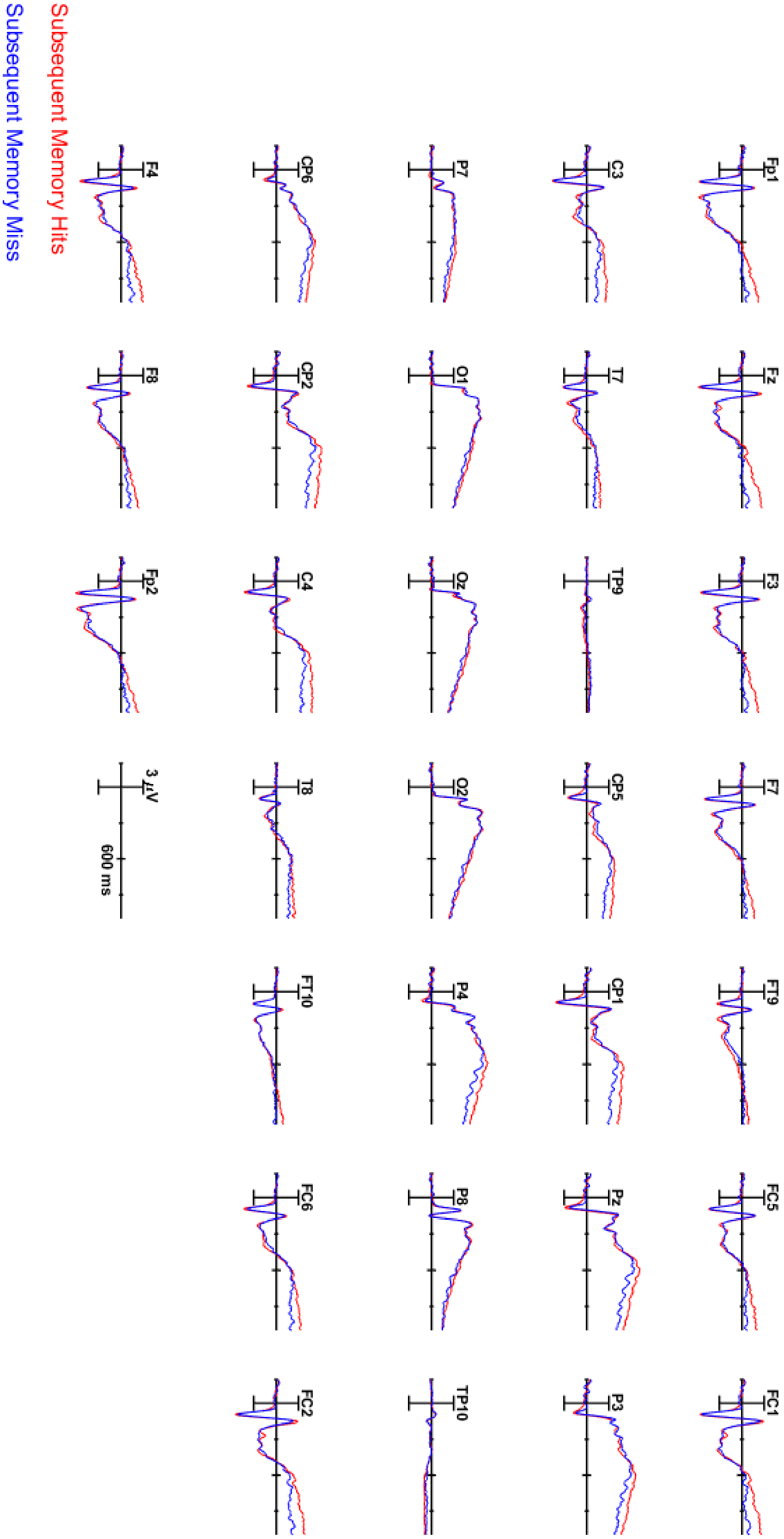

Hits Fear
Hits Happy
Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms

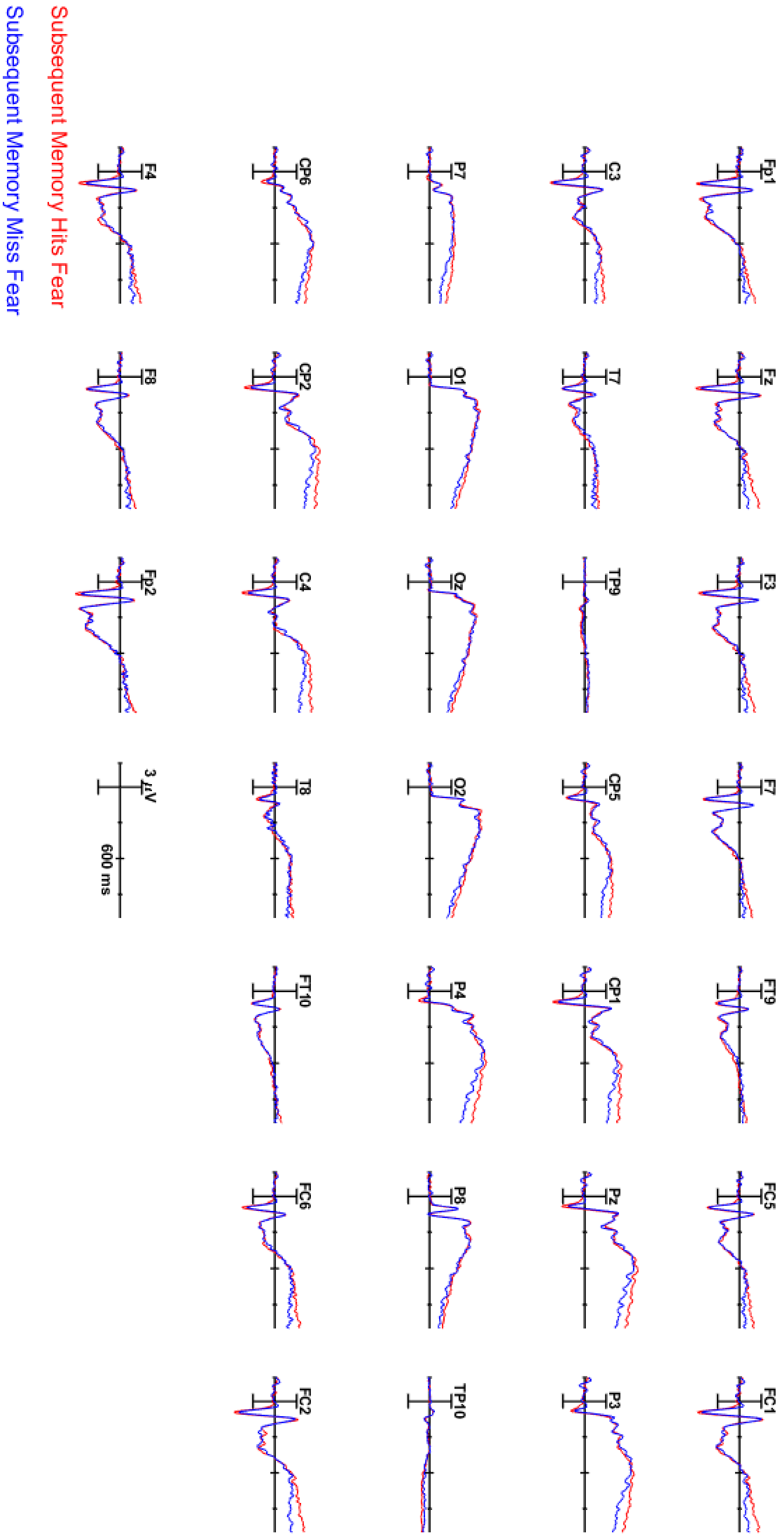

Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms
Correct Rejections
Hits Happy

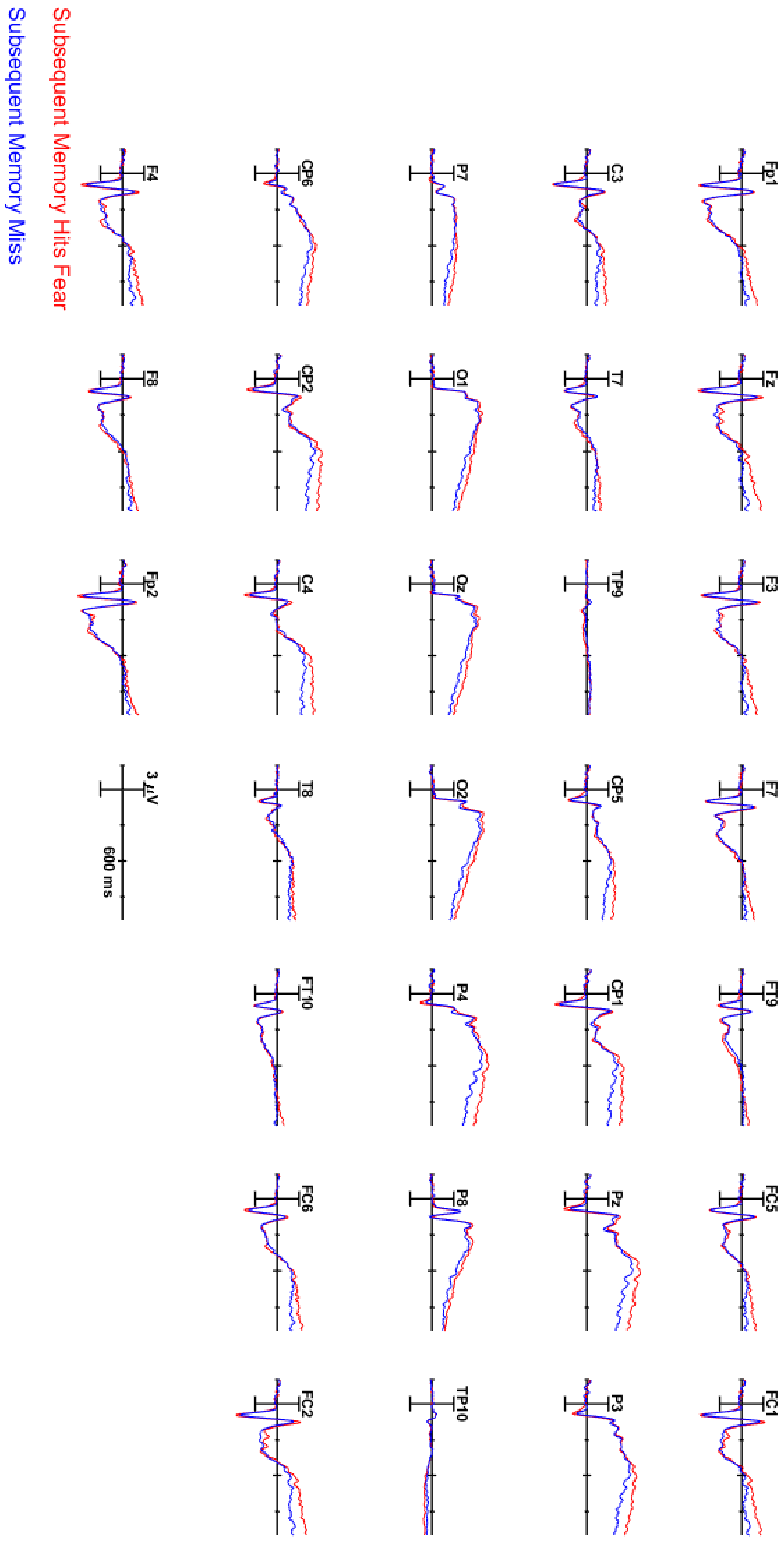

Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms
Correct Rejections
Familiarity Fear

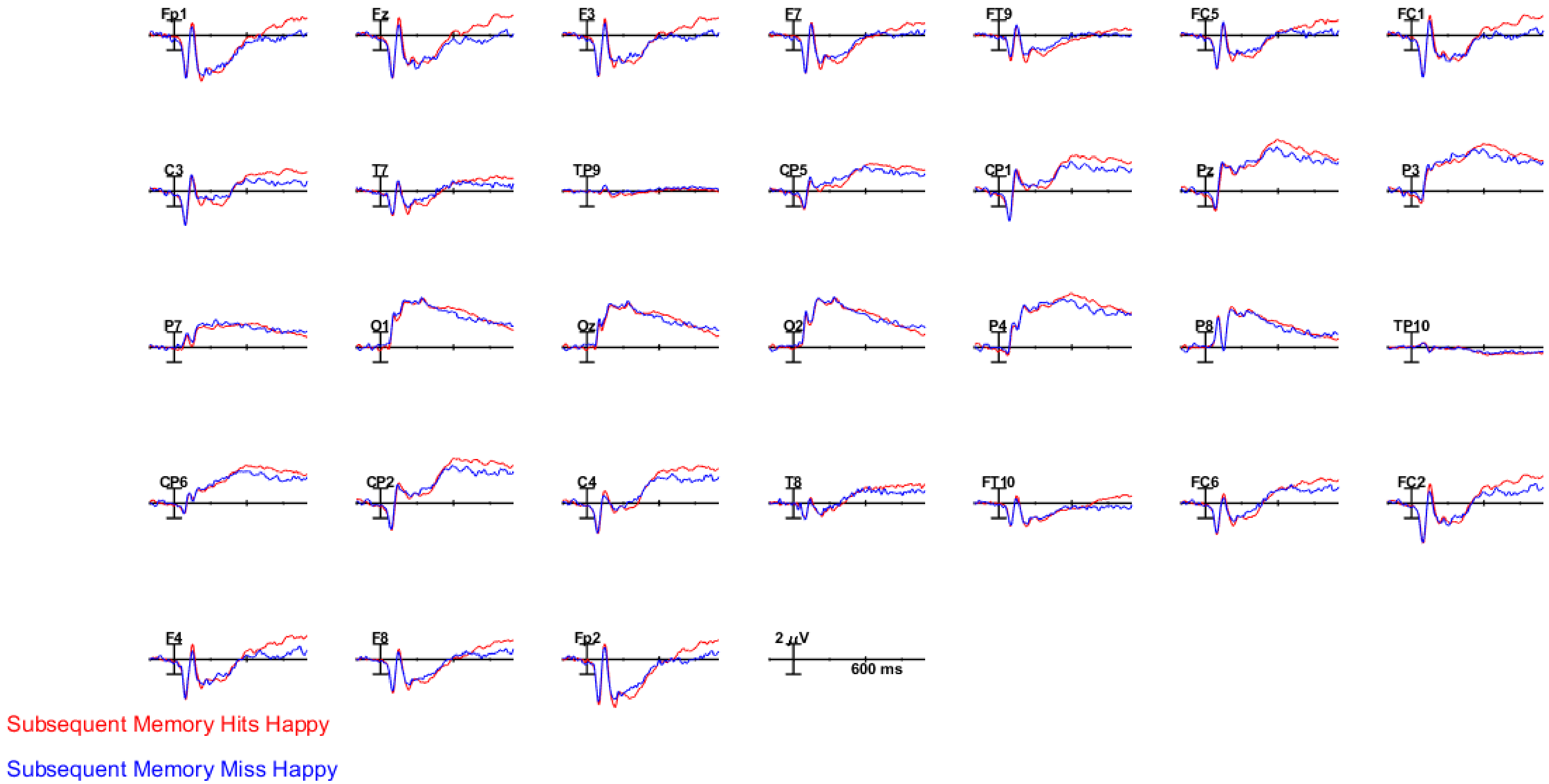

Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 µV
600 ms
Familiarity Fear
Familiarity Happy

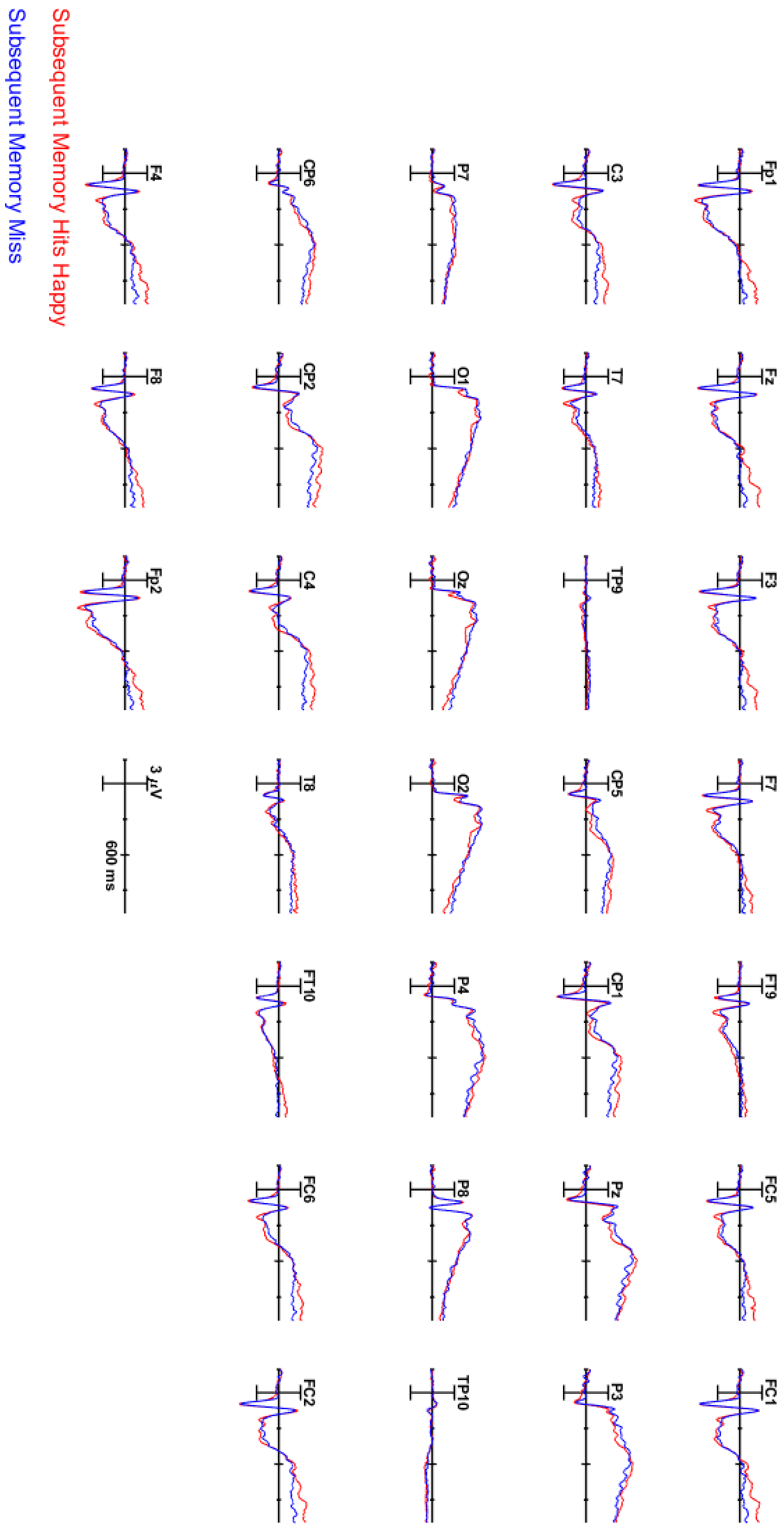

Correct Rejections
Familiarity Happy
Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 µV
600 ms

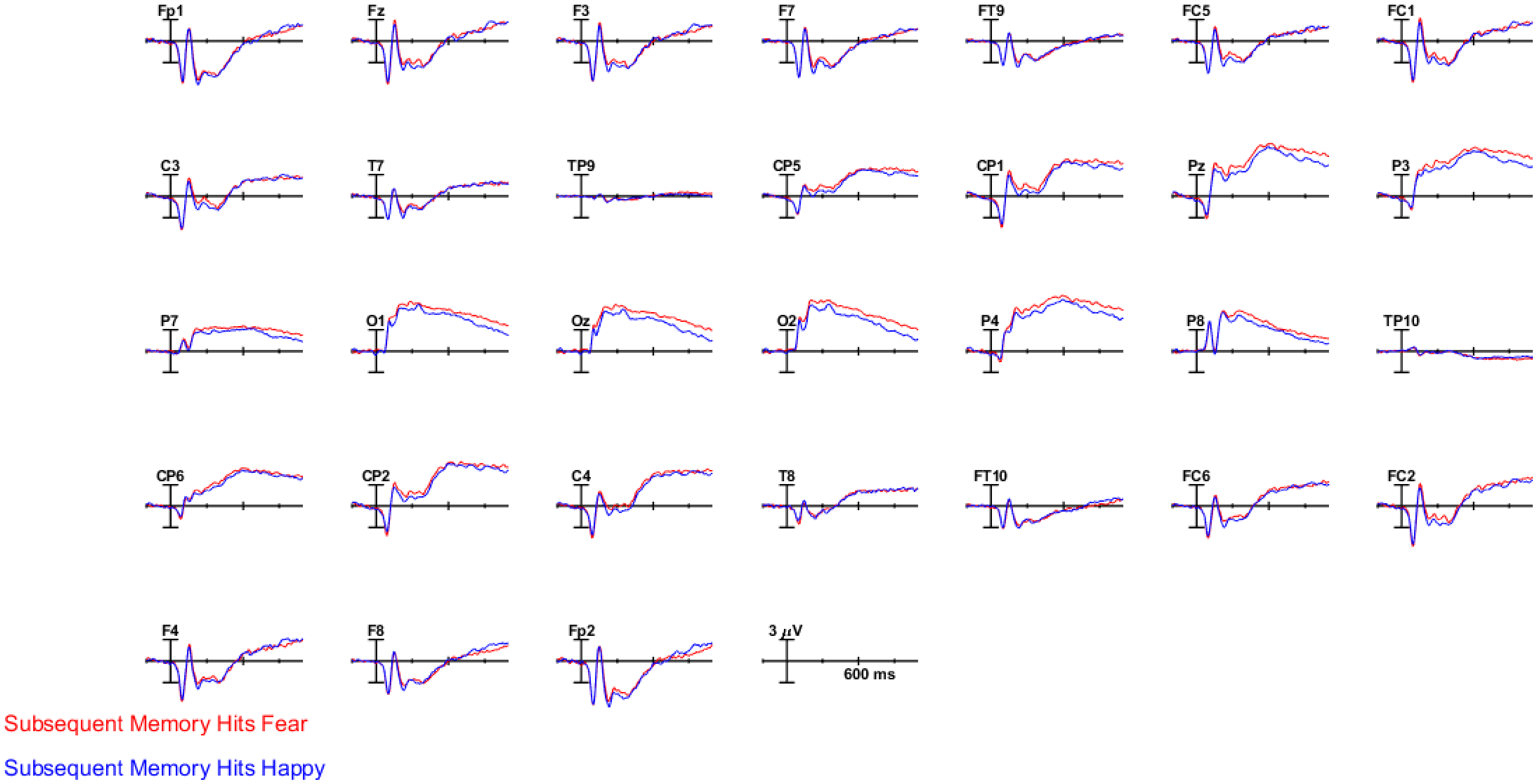

Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 µV
600 ms
Subsequent Memory Hits
Subsequent Memory Miss

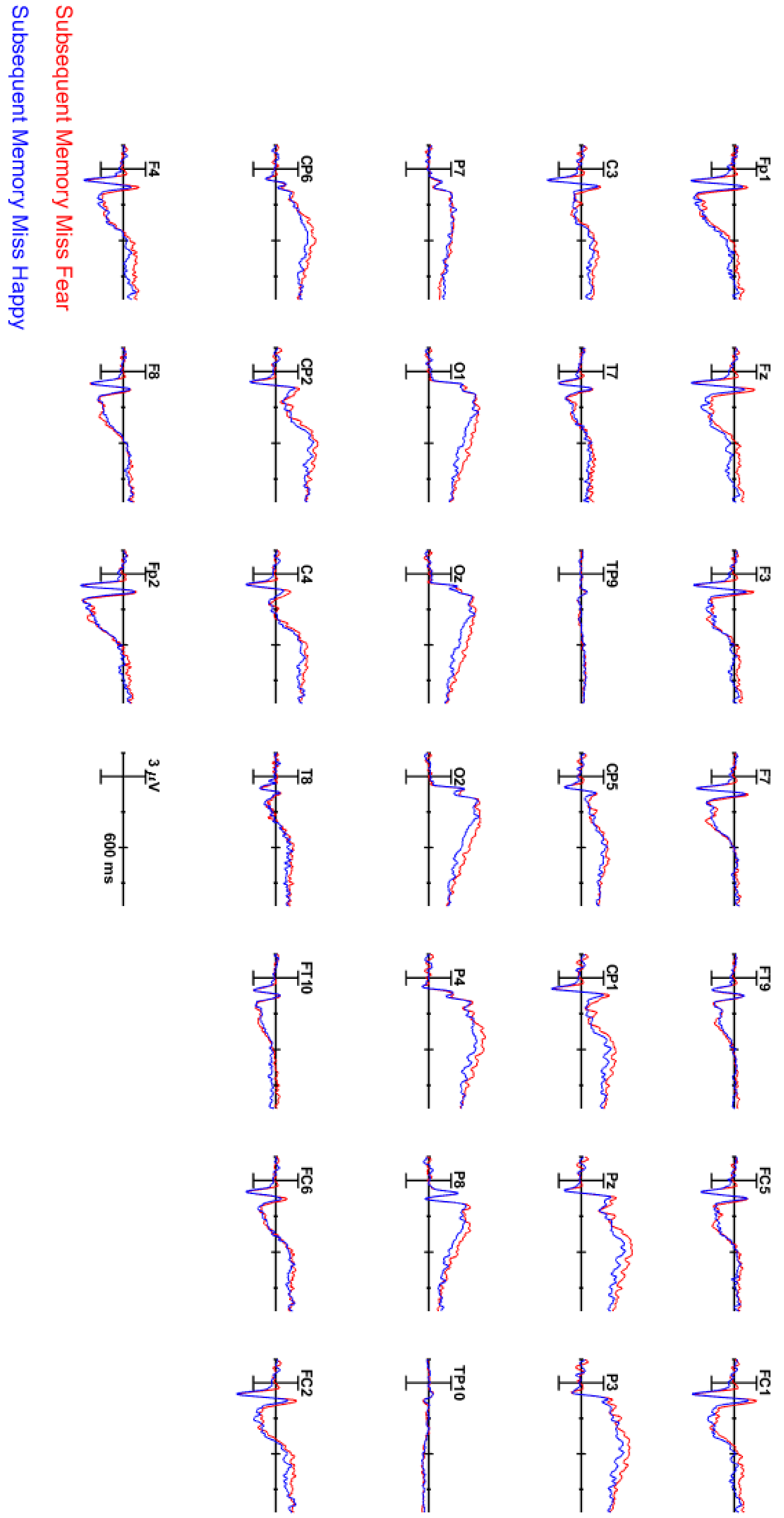

Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 μV
600 ms
Subsequent Memory Hits Fear
Subsequent Memory Miss Fear

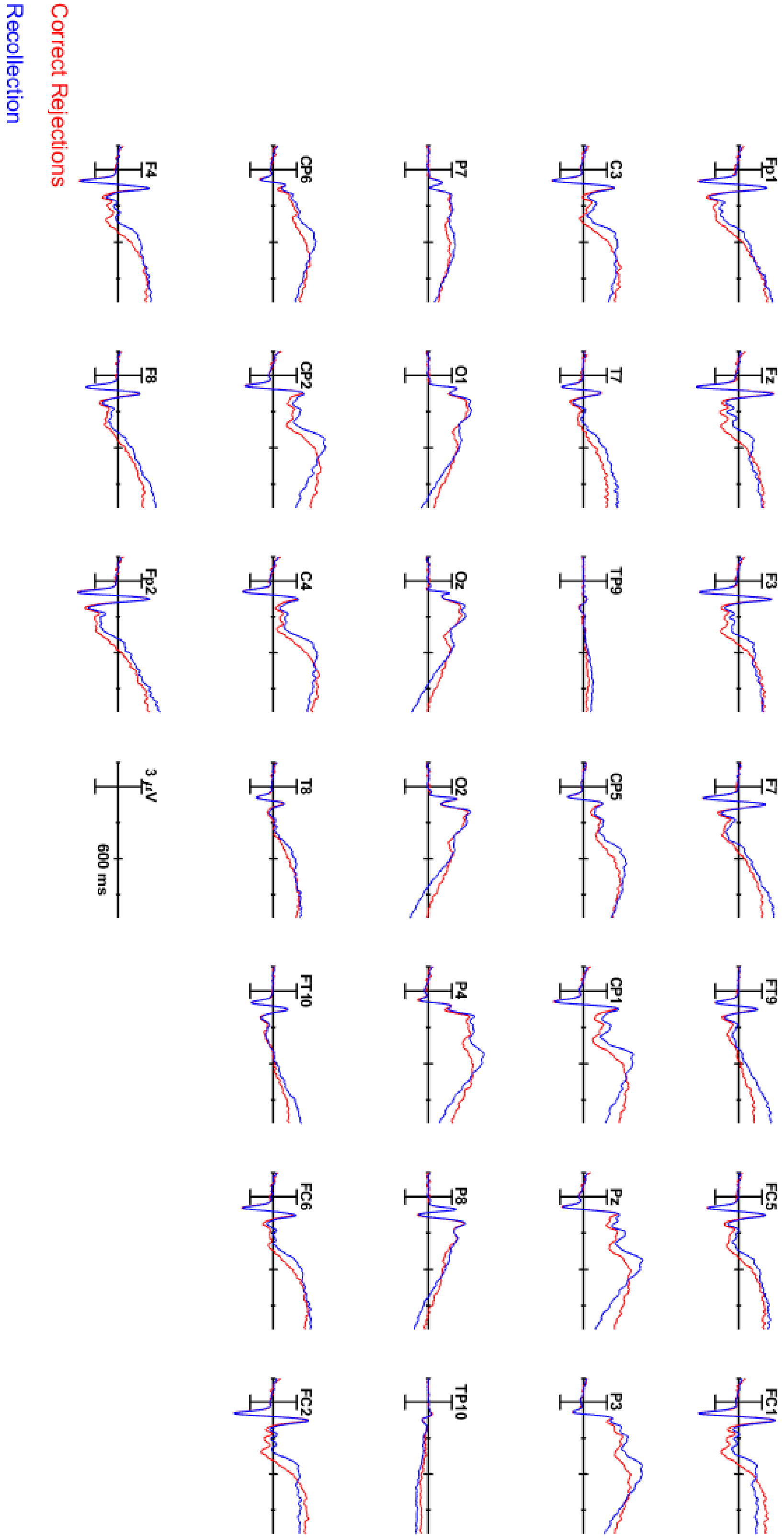

Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 μV
600 ms
Subsequent Memory Hits Fear
Subsequent Memory Miss

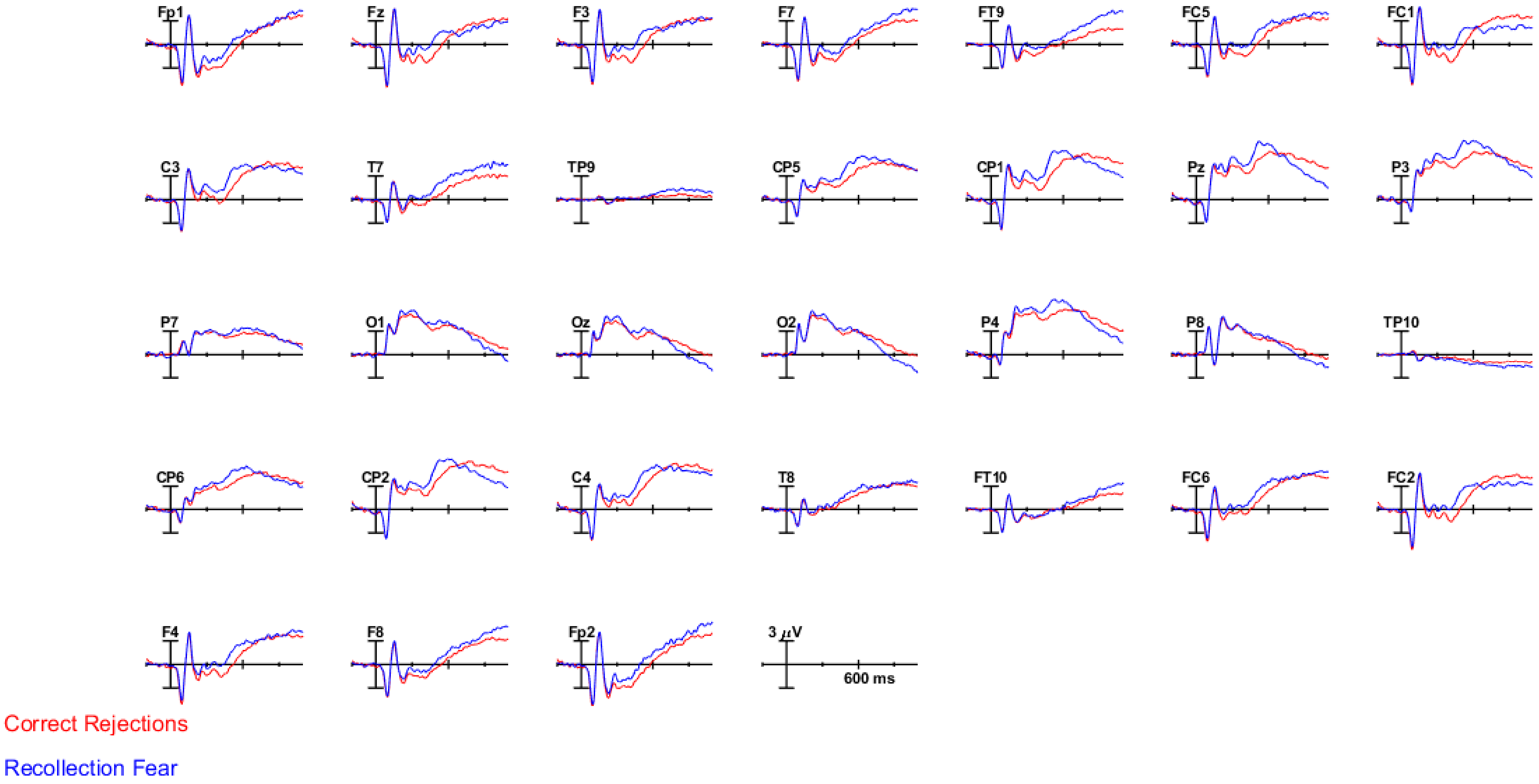

Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms
Subsequent Memory Hits Happy
Subsequent Memory Miss Happy

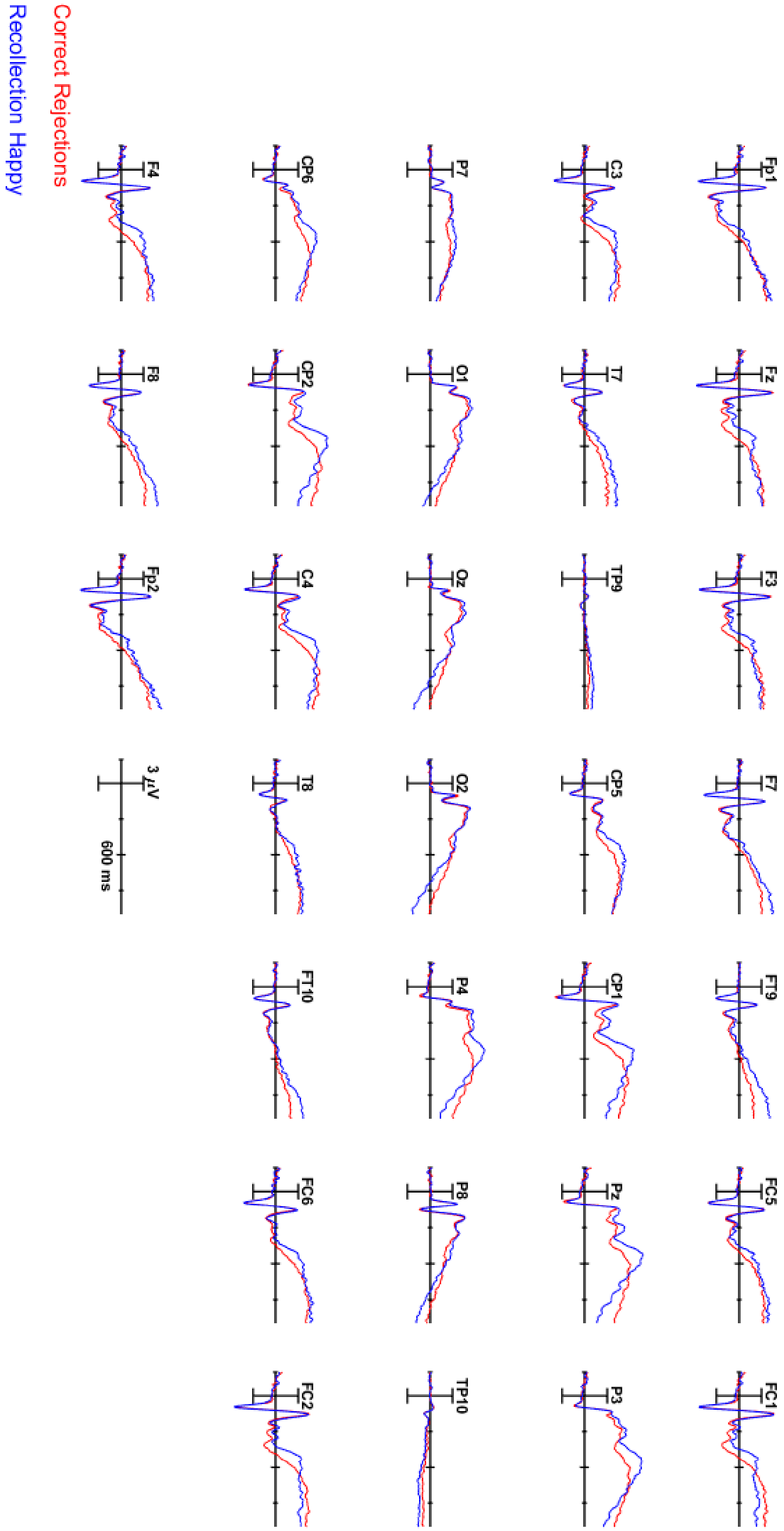

Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 µV
600 ms
Subsequent Memory Hits Happy
Subsequent Memory Miss

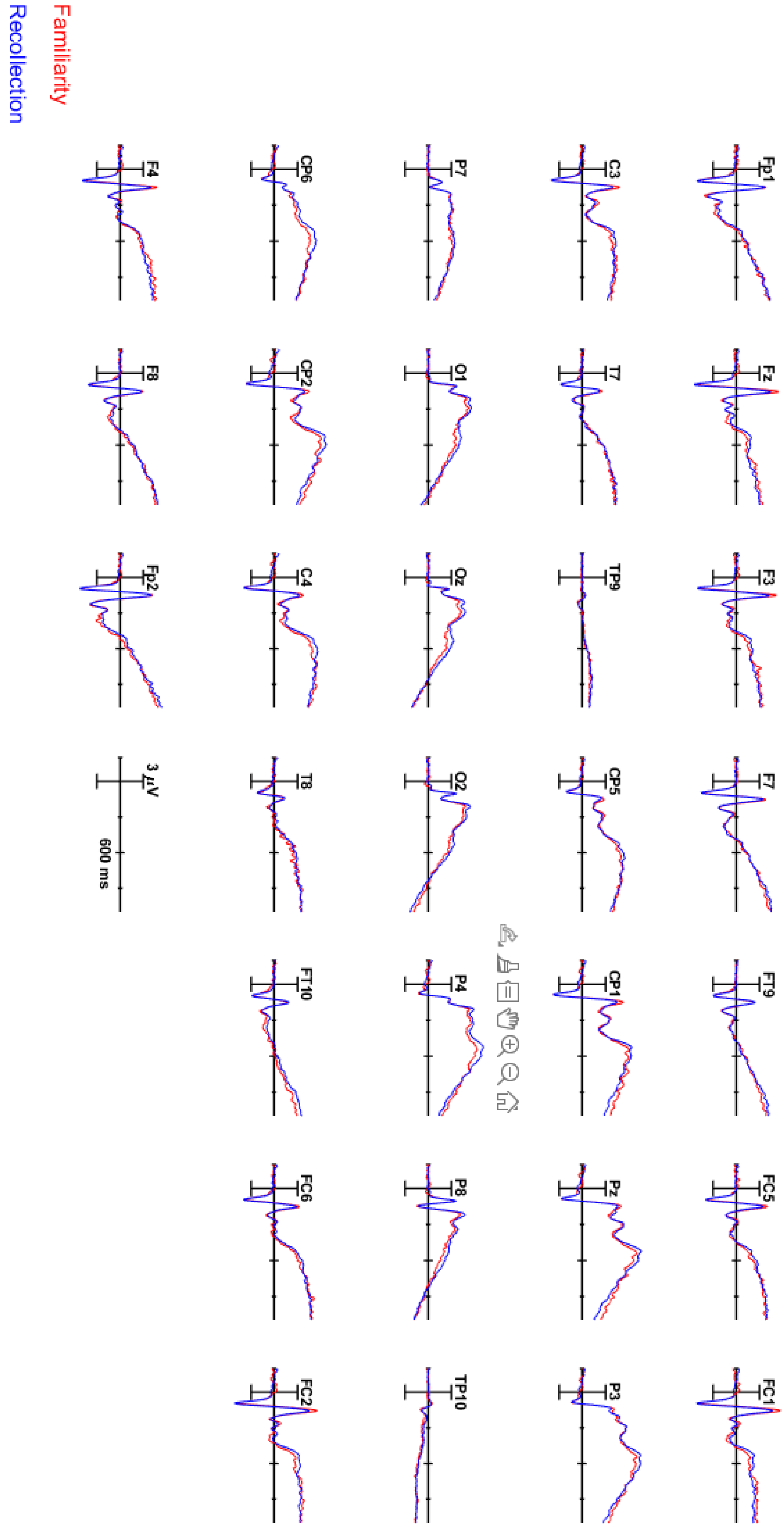

Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 µV
600 ms
Subsequent Memory Hits Fear
Subsequent Memory Hits Happy


Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 µV
600 ms
Subsequent Memory Miss Fear
Subsequent Memory Miss Happy


Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 µV
600 ms
Correct Rejections
Recollection


Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 μV
600 ms
Correct Rejections
Recollection Fear


Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 µV
600 ms
Correct Rejections
Recollection Happy


Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
3 µV
600 ms
Familiarity
Recollection

**Appendix C –** List of codes for the contextual images used on Experiment 2.

| **Code** | **Category** |
|---|---|
| 1275.jpg | Neg |
| 2130.jpg | Neg |
| 2720.jpg | Neg |
| 3280.jpg | Neg |
| 7234.jpg | Neg |
| 7700.jpg | Neg |
| 8231.jpg | Neg |
| 9001.jpg | Neg |
| 9010.jpg | Neg |
| 9042.jpg | Neg |
| 9220.jpg | Neg |
| 9390.jpg | Neg |
| 9561.jpg | Neg |
| Animals_017_v.jpg | Neg |
| Animals_018_h.jpg | Neg |
| Animals_029_v.jpg | Neg |
| Animals_057_h.jpg | Neg |
| Animals_064_v.jpg | Neg |
| Animals_067_h.jpg | Neg |
| Faces_011_h.jpg | Neg |
| Faces_150_h.jpg | Neg |
| Faces_151_v.jpg | Neg |
| Faces_173_v.jpg | Neg |
| Faces_176_h.jpg | Neg |
| Faces_285_h.jpg | Neg |
| Faces_294_h.jpg | Neg |
| Faces_302_h.jpg | Neg |
| Faces_303_h.jpg | Neg |
| Landscapes_004_h.jpg | Neg |
| Landscapes_010_h.jpg | Neg |
| Landscapes_014_h.jpg | Neg |
| Landscapes_017_h.jpg | Neg |
| Landscapes_029_v.jpg | Neg |
| Objects_006_h.jpg | Neg |
| Objects_011_h.jpg | Neg |
| Objects_110_v.jpg | Neg |
| Objects_111_h.jpg | Neg |
| Objects_125_h.jpg | Neg |
| Objects_144_h.jpg | Neg |
| Objects_154_h.jpg | Neg |
| Objects_157_h.jpg | Neg |
| Objects_218_h.jpg | Neg |
| People_010_h.jpg | Neg |
| People_012_h.jpg | Neg |
| People_082_h.jpg | Neg |
| People_085_h.jpg | Neg |
| People_090_v.jpg | Neg |
| People_094_h.jpg | Neg |
| People_118_h.jpg | Neg |
| People_119_h.jpg | Neg |
| People_120_h.jpg | Neg |
| People_121_h.jpg | Neg |
| People_125_h.jpg | Neg |
| People_136_h.jpg | Neg |
| People_142_h.jpg | Neg |
| People_143_h.jpg | Neg |
| People_145_h.jpg | Neg |
| People_147_h.jpg | Neg |
| People_197_h.jpg | Neg |
| People_245_v.jpg | Neg |
| 1616.jpg | Neu |
| 2020.jpg | Neu |
| 2381.jpg | Neu |
| 2485.jpg | Neu |
| 2487.jpg | Neu |
| 2514.jpg | Neu |
| 2580.jpg | Neu |
| 2600.jpg | Neu |
| 2880.jpg | Neu |
| 4100.jpg | Neu |
| 4605.jpg | Neu |
| 5530.jpg | Neu |
| 5740.jpg | Neu |
| 6571.jpg | Neu |
| 7002.jpg | Neu |
| 7006.jpg | Neu |
| 7009.jpg | Neu |
| 7025.jpg | Neu |
| 7031.jpg | Neu |
| 7035.jpg | Neu |
| 7100.jpg | Neu |
| 7110.jpg | Neu |
| 7150.jpg | Neu |
| 7170.jpg | Neu |
| 7175.jpg | Neu |
| 7183.jpg | Neu |
| 7185.jpg | Neu |
| 7187.jpg | Neu |
| 7205.jpg | Neu |
| 7217.jpg | Neu |
| 7224.jpg | Neu |
| 7235.jpg | Neu |

| Code | Category |
|---|---|
| 7490.jpg | Neu |
| 7705.jpg | Neu |
| 8465.jpg | Neu |
| Acorns 3 | Neu |
| Bark 5 | Neu |
| Barrels 1 | Neu |
| Bottle 1 | Neu |
| Cups 1 | Neu |
| Fence 2 | Neu |
| Fire hydrant | Neu |
| Keyboard 3 | Neu |
| Landscapes_016_h.jpg | Neu |
| Landscapes_037_v.jpg | Neu |
| Landscapes_046_h.jpg | Neu |
| Landscapes_072_h.jpg | Neu |
| Objects_214_h.jpg | Neu |
| Objects_220_h.jpg | Neu |
| Office supplies | Neu |
| Office supplies | Neu |
| Paper 3 | Neu |
| Paper 5 | Neu |
| People_138_h.jpg | Neu |
| Rocks 2 | Neu |
| Sidewalk 1 | Neu |
| Socks 1 | Neu |
| Timber 4 | Neu |
| Yarn 3 | Neu |
| Yarn 4 | Neu |
| 1650.jpg | Pos |
| 4302.jpg | Pos |
| 4533.jpg | Pos |
| 4659.jpg | Pos |
| 4664.jpg | Pos |
| 4666.jpg | Pos |
| 4670.jpg | Pos |
| 4672.jpg | Pos |
| 4680.jpg | Pos |
| 4681.jpg | Pos |
| 4683.jpg | Pos |
| 5270.jpg | Pos |
| 5450.jpg | Pos |
| 5460.jpg | Pos |
| 5629.jpg | Pos |
| 7289.jpg | Pos |
| 7350.jpg | Pos |
| 7351.jpg | Pos |
| 7475.jpg | Pos |
| 8034.jpg | Pos |
| 8040.jpg | Pos |
| 8180.jpg | Pos |
| 8260.jpg | Pos |
| 8300.jpg | Pos |
| 8340.jpg | Pos |
| 8400.jpg | Pos |
| 8502.jpg | Pos |
| 8503.jpg | Pos |
| 9156.jpg | Pos |
| Animals_002_v.jpg | Pos |
| Animals_165_h.jpg | Pos |
| Animals_175_h.jpg | Pos |
| Animals_179_h.jpg | Pos |
| Faces_132_h.jpg | Pos |
| Faces_134_h.jpg | Pos |
| Faces_234_h.jpg | Pos |
| Faces_261_v.jpg | Pos |
| Faces_321_h.jpg | Pos |
| Faces_322_v.jpg | Pos |
| Faces_342_h.jpg | Pos |
| Faces_347_h.jpg | Pos |
| Faces_352_h.jpg | Pos |
| Faces_361_v.jpg | Pos |
| Objects_037_h.jpg | Pos |
| Objects_069_h.jpg | Pos |
| Objects_078_h.jpg | Pos |
| Objects_081_h.jpg | Pos |
| Objects_171_h.jpg | Pos |
| Objects_291_h.jpg | Pos |
| People_029_h.jpg | Pos |
| People_130_h.jpg | Pos |
| People_160_h.jpg | Pos |
| People_171_v.jpg | Pos |
| People_175_h.jpg | Pos |
| People_178_h.jpg | Pos |
| People_180_h.jpg | Pos |
| People_183_h.jpg | Pos |
| People_189_h.jpg | Pos |
| People_193_h.jpg | Pos |
| People_196_h.jpg | Pos |

## **Appendix D –** List of codes for the images of faces used on Experiment 2.

CFD-AF-212-097-N
CFD-AF-213-126-N
CFD-AF-214-139-N
CFD-AF-215-70-N
CFD-AF-216-106-N
CFD-AF-217-155-N
CFD-AF-218-157-N
CFD-AF-219-106-N
CFD-AF-220-107-N
CFD-AF-221-147-N
CFD-AF-222-134-N
CFD-AF-223-183-N
CFD-AM-214-168-N
CFD-AM-215-120-N
CFD-AM-216-114-N
CFD-AM-217-085-N
CFD-AM-218-085-N
CFD-AM-219-101-N
CFD-AM-220-134-N
CFD-AM-221-184-N
CFD-AM-223-138-N
CFD-AM-224-126-N
CFD-AM-225-102-N
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CFD-BF-036-027-N
CFD-BF-037-022-N
CFD-BF-038-037-N
CFD-BF-039-031-N
CFD-BF-040-003-N
CFD-BF-041-001-N
CFD-BF-042-026-N
CFD-BF-043-003-N
CFD-BF-044-034-N
CFD-BF-045-003-N
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CFD-WF-202-056-N
CFD-WF-203-229-N
CFD-WF-204-038-N
CFD-WF-205-006-N
CFD-WF-206-147-N
CFD-WF-207-014-N
CFD-WF-208-068-N
CFD-WF-209-052-N
CFD-WF-210-086-N
CFD-WF-211-001-N
CFD-WF-212-050-N
CFD-WF-213-031-N
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CFD-WF-218-087-N
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CFD-WM-036-031-N
CFD-WM-037-025-N
CFD-WM-038-003-N
CFD-WM-039-018-N
CFD-WM-040-022-N
CFD-WM-041-021-N
CFD-WM-200-034-N
CFD-WM-201-063-N
CFD-WM-202-107-N
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CFD-WM-211-054-N
CFD-WM-212-097-N
CFD-WM-213-076-N
CFD-WM-214-026-N
CFD-WM-215-041-N
CFD-WM-216-061-N
CFD-WM-217-070-N
CFD-LF-208-127-N
CFD-LF-218-072-N
CFD-LF-220-120-N
CFD-LF-224-176-N
CFD-BM-016-036-N
CFD-LF-210-220-N
CFD-BM-019-002-N
CFD-BM-023-029-N
CFD-BM-018-001-N
CFD-BM-027-001-N
CFD-BM-024-001-N
CFD-BM-020-001-N
CFD-LF-204-133-N
CFD-LF-223-064-N
CFD-LM-217-162-N
CFD-LM-219-295-N
CFD-LM-214-165-N
CFD-LM-212-143-N
CFD-LM-218-183-N
CFD-BM-025-035-N
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CFD-LF-203-066-N
CFD-BM-021-021-N
CFD-LF-200-058-N
CFD-LF-201-035-N
CFD-BM-022-022-N
CFD-LM-223-175-N
CFD-WM-002-009-N
CFD-WF-028-023-N
CFD-WF-005-010-N
CFD-WF-008-002-N
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CFD-BF-050-003-N
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CFD-BM-034-031-N
CFD-BM-036-003-N
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CFD-BM-041-035-N
CFD-BM-043-071-N
CFD-BM-044-001-N
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CFD-BM-202-063-N
CFD-BM-203-001-N
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CFD-BM-205-001-N
CFD-BM-206-114-N
CFD-BM-207-024-N
CFD-LF-225-164-N
CFD-LF-226-174-N
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CFD-LF-228-125-N
CFD-LF-229-164-N
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CFD-LF-232-199-N
CFD-LF-233-277-N
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CFD-LF-235-219-N
CFD-LF-236-221-N
CFD-LF-237-190-N
CFD-LF-238-154-N
CFD-LF-239-148-N
CFD-LF-240-199-N

CFD-BF-047-003-N
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CFD-BF-050-003-N
CFD-BF-051-035-N
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CFD-BM-030-003-N
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CFD-BM-039-029-N
CFD-BM-040-002-N
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CFD-BM-046-006-N
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CFD-BM-201-077-N
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CFD-BM-205-001-N
CFD-BM-206-114-N
CFD-BM-207-024-N
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CFD-LF-226-174-N
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CFD-LF-239-148-N
CFD-LF-240-199-N
CFD-LF-241-188-N
CFD-WM-218-074-N
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CFD-AM-204-122-N
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CFD-AM-205-153-N
CFD-BF-020-002-N
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CFD-AF-205-155-N
CFD-AM-201-076-N
CFD-AF-202-122-N
CFD-AF-201-060-N
CFD-AF-208-003-N
CFD-AM-206-086-N
CFD-BF-015-004-N
CFD-BM-001-014-N
CFD-BF-003-003-N
CFD-AM-207-108-N
CFD-AM-209-048-N
CFD-AM-210-035-N
CFD-BF-016-017-N
CFD-BM-002-013-N
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CFD-BF-018-039-N
CFD-BF-025-002-N
CFD-BF-014-002-N
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CFD-BF-024-002-N
CFD-AM-208-143-N
CFD-BM-012-018-N
CFD-BM-009-002-N
CFD-BF-010-001-N
CFD-AM-213-056-N
CFD-WF-022-017-N
CFD-WF-015-006-N
CFD-WM-028-003-N
CFD-WF-019-005-N
CFD-WM-009-002-N
CFD-WM-020-001-N
CFD-WF-016-015-N
CFD-WM-015-002-N
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CFD-WM-016-001-N
CFD-WM-021-001-N
CFD-WF-001-003-N
CFD-WF-009-001-N
CFD-LM-224-162-N
CFD-WF-010-004-N
CFD-WM-025-002-N
CFD-WM-031-003-N
CFD-WF-002-004-N
CFD-WM-029-023-N
CFD-WM-024-015-N
CFD-WF-012-002-N
CFD-WM-023-001-N
CFD-LM-226-175-N
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CFD-WF-017-003-N
CFD-WM-004-010-N
CFD-WF-027-003-N
CFD-WM-011-002-N
CFD-LM-227-103-N
CFD-WF-013-003-N
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CFD-WM-006-002-N
CFD-WM-026-001-N
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CFD-LM-244-068-N
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CFD-LM-247-095-N
CFD-LM-248-089-N
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CFD-LM-251-073-N
CFD-LM-252-076-N
CFD-LM-253-075-N
CFD-WM-257-161-N
CFD-WM-258-125-N
CFD-WF-030-002-N
CFD-WF-031-027-N
CFD-WF-033-002-N
CFD-WF-034-006-N
CFD-WF-035-024-N
CFD-WF-036-023-N
CFD-WF-037-029-N
CFD-WF-038-021-N
CFD-WF-039-025-N
CFD-WF-200-099-N

CFD-LF-242-121-N
CFD-LF-243-175-N
CFD-LF-244-096-N
CFD-LF-245-166-N
CFD-LF-246-129-N
CFD-LF-247-051-N
CFD-LF-248-160-N
CFD-LF-249-132-N
CFD-LM-228-188-N
CFD-LM-229-187-N
CFD-LM-230-202-N
CFD-LM-231-214-N
CFD-LM-232-204-N
CFD-LM-233-171-N
CFD-LM-234-176-N
CFD-LM-235-231-N
CFD-LM-236-163-N
CFD-LM-237-264-N
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CFD-LM-251-073-N
CFD-LM-252-076-N
CFD-LM-253-075-N
CFD-WM-257-161-N
CFD-WM-258-125-N
CFD-WF-030-002-N
CFD-WF-031-027-N
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CFD-WF-034-006-N
CFD-WF-035-024-N
CFD-WF-036-023-N
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CFD-WF-039-025-N
CFD-WF-200-099-N
CFD-BF-011-002-N
CFD-BM-011-016-N
CFD-BF-013-001-N
CFD-AF-204-067-N
CFD-BF-001-025-N
CFD-BM-004-002-N
CFD-BF-021-013-N
CFD-AF-209-006-N
CFD-AF-207-023-N
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CFD-BF-006-017-N
CFD-BF-007-001-N
CFD-AM-211-052-N
CFD-BM-013-002-N
CFD-LF-206-078-N
CFD-LM-222-239-N
CFD-LM-202-072-N
CFD-LM-204-001-N
CFD-LM-216-082-N
CFD-LM-209-111-N
CFD-LM-210-156-N
CFD-LM-206-204-N
CFD-LM-221-216-N
CFD-LM-208-110-N
CFD-LM-211-128-N
CFD-LM-201-057-N
CFD-LM-215-247-N
CFD-LM-213-061-N
CFD-LM-207-004-N
CFD-LF-212-066-N
CFD-LM-203-026-N
CFD-LF-207-198-N
CFD-LF-216-121-N
CFD-LF-221-002-N
CFD-LF-219-223-N
CFD-BM-017-021-N
CFD-LF-214-090-N
CFD-LM-200-045-N
CFD-LF-222-147-N
CFD-LF-211-003-N
CFD-LF-215-157-N
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CFD-LF-217-082-N
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CFD-WF-207-014-N
CFD-WF-208-068-N
CFD-WF-209-052-N
CFD-WF-210-086-N
CFD-WF-211-001-N
CFD-WF-212-050-N
CFD-WF-213-031-N
CFD-WF-214-122-N
CFD-WF-215-145-N
CFD-WF-216-079-N
CFD-WF-217-085-N
CFD-WF-218-087-N
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CFD-WM-036-031-N
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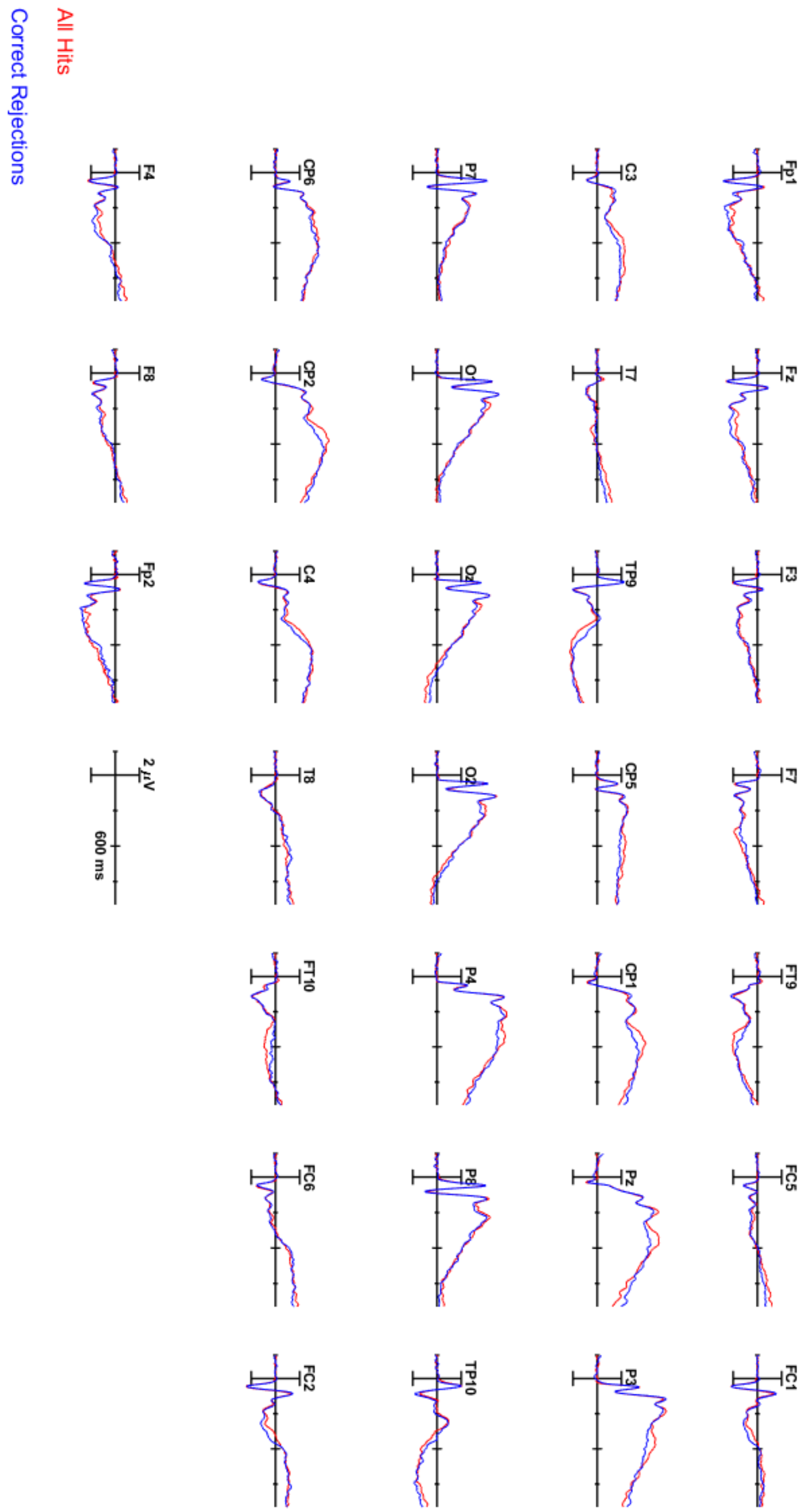
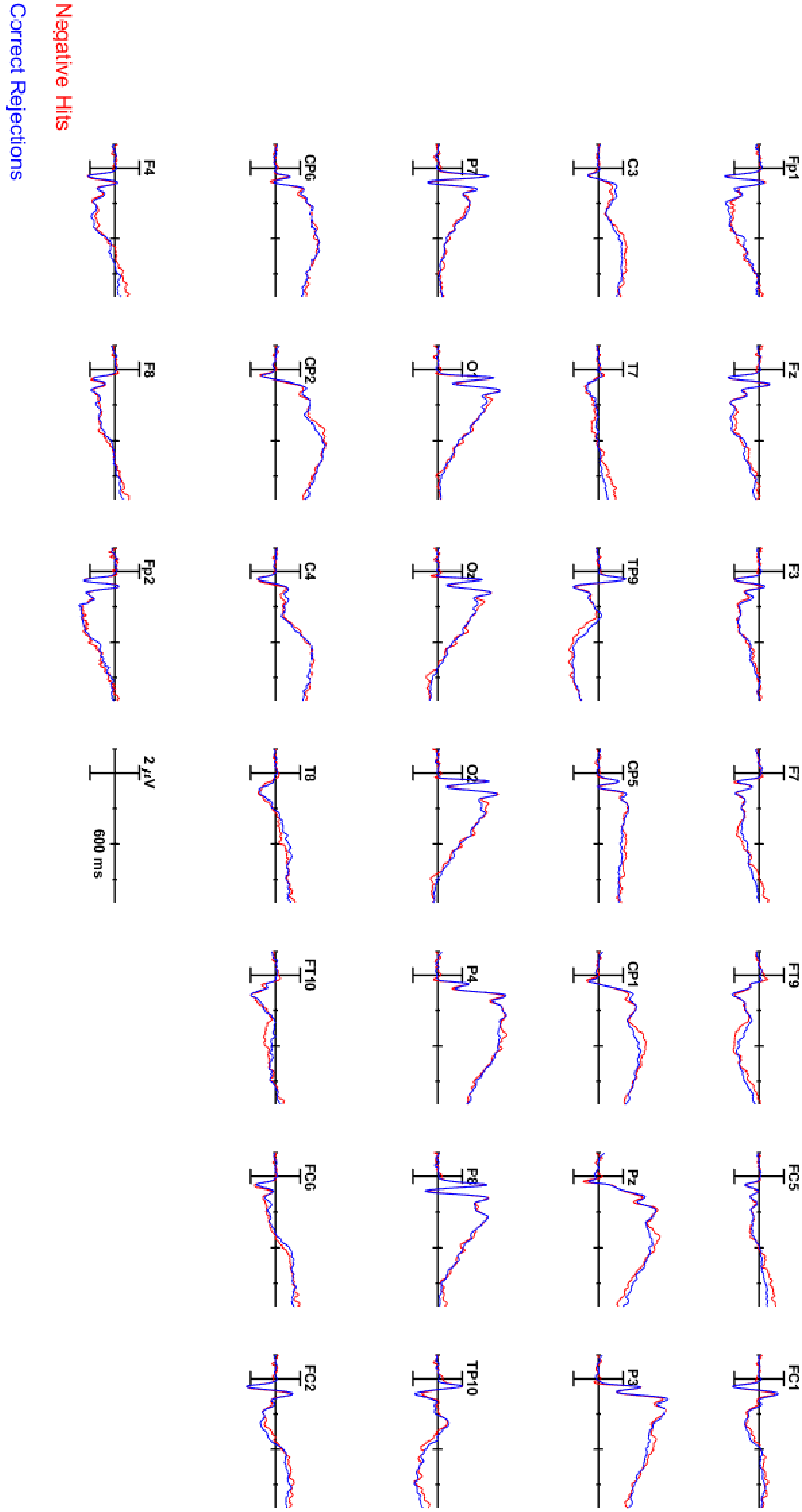
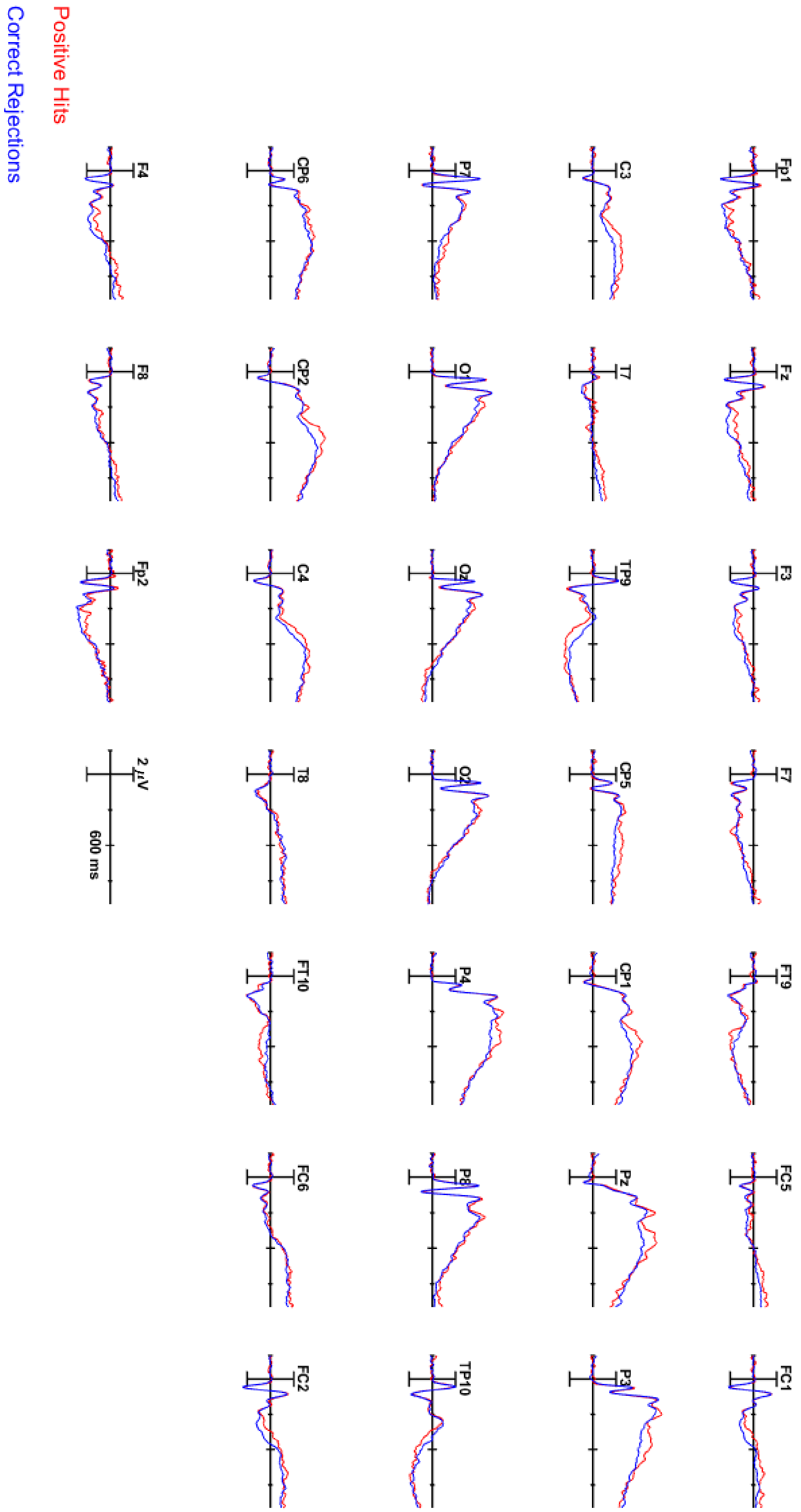
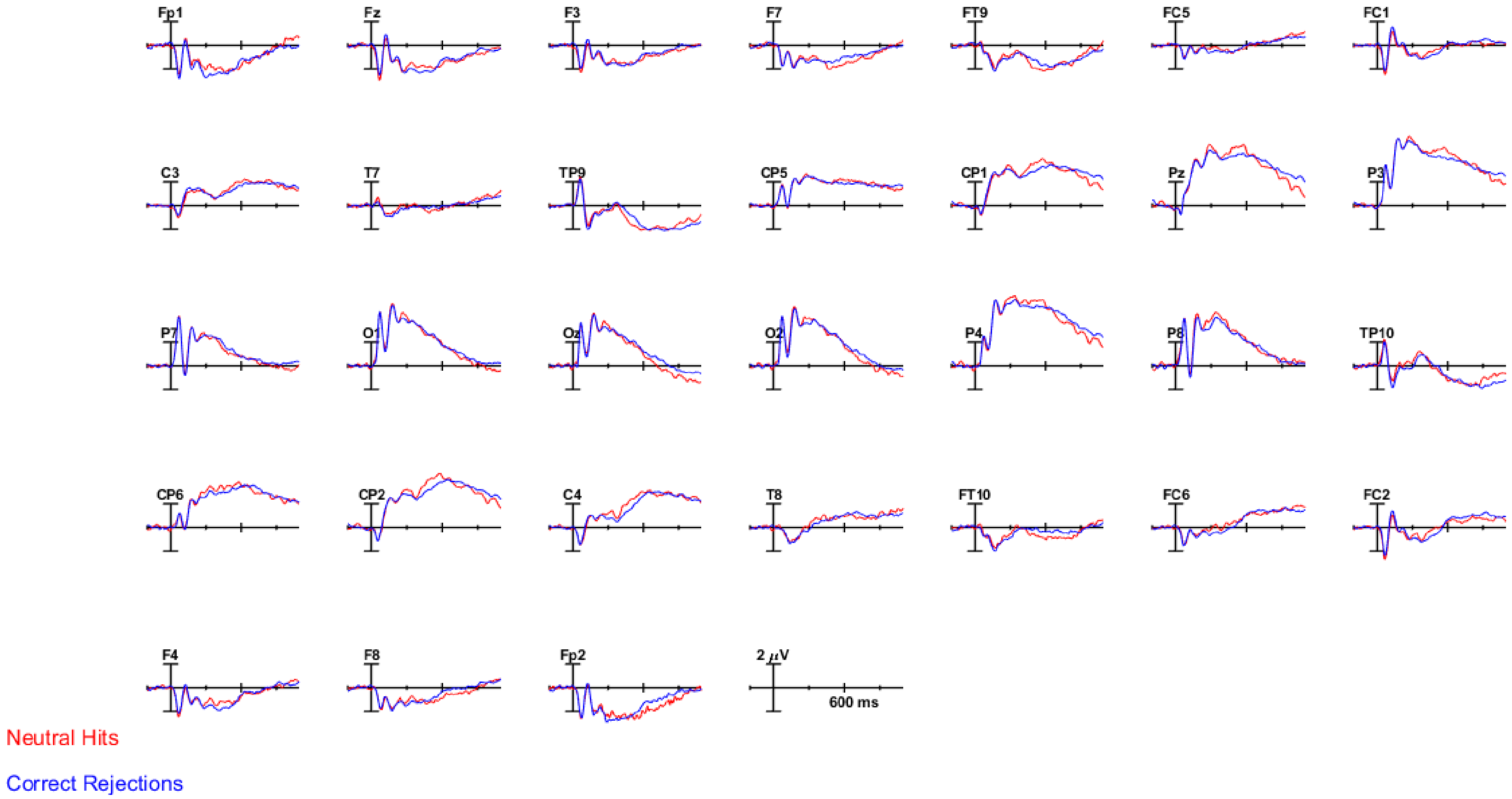
CFD-WM-038-003-N
CFD-WM-039-018-N
CFD-WM-040-022-N
CFD-WM-041-021-N
CFD-WM-200-034-N
CFD-WM-201-063-N
CFD-WM-202-107-N
CFD-WM-203-023-N
CFD-WM-204-031-N
CFD-WM-205-007-N
CFD-WM-206-045-N
CFD-WM-207-048-N
CFD-WM-208-068-N
CFD-WM-209-038-N
CFD-WM-210-057-N
CFD-WM-211-054-N
CFD-WM-212-097-N
CFD-WM-213-076-N
CFD-WM-214-026-N
CFD-WM-215-041-N
CFD-WM-216-061-N
CFD-WM-217-070-N
CFD-WM-218-074-N

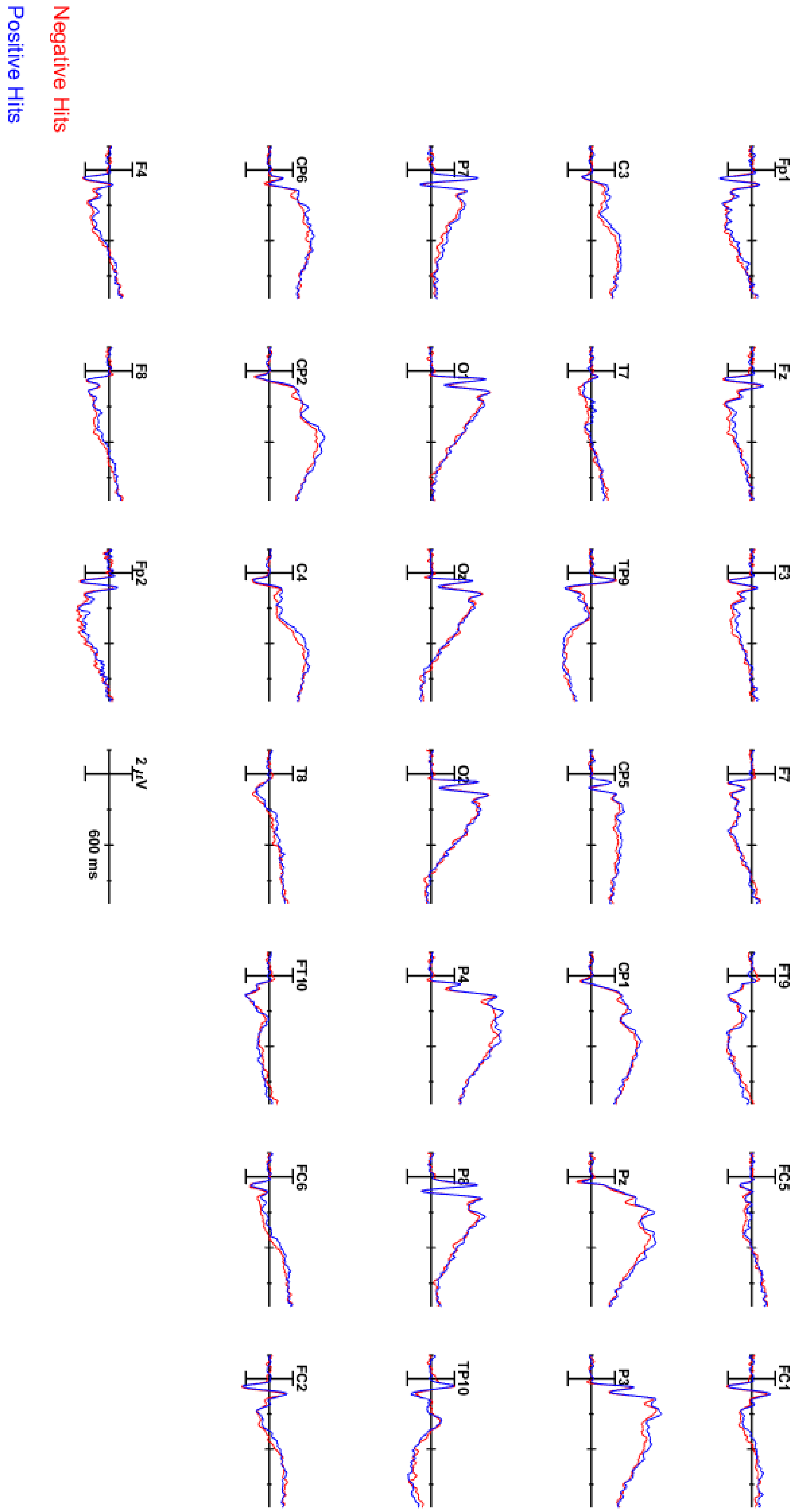
**Appendix E** – ERPs of all electrodes utilized for analysis on Experiment 2.

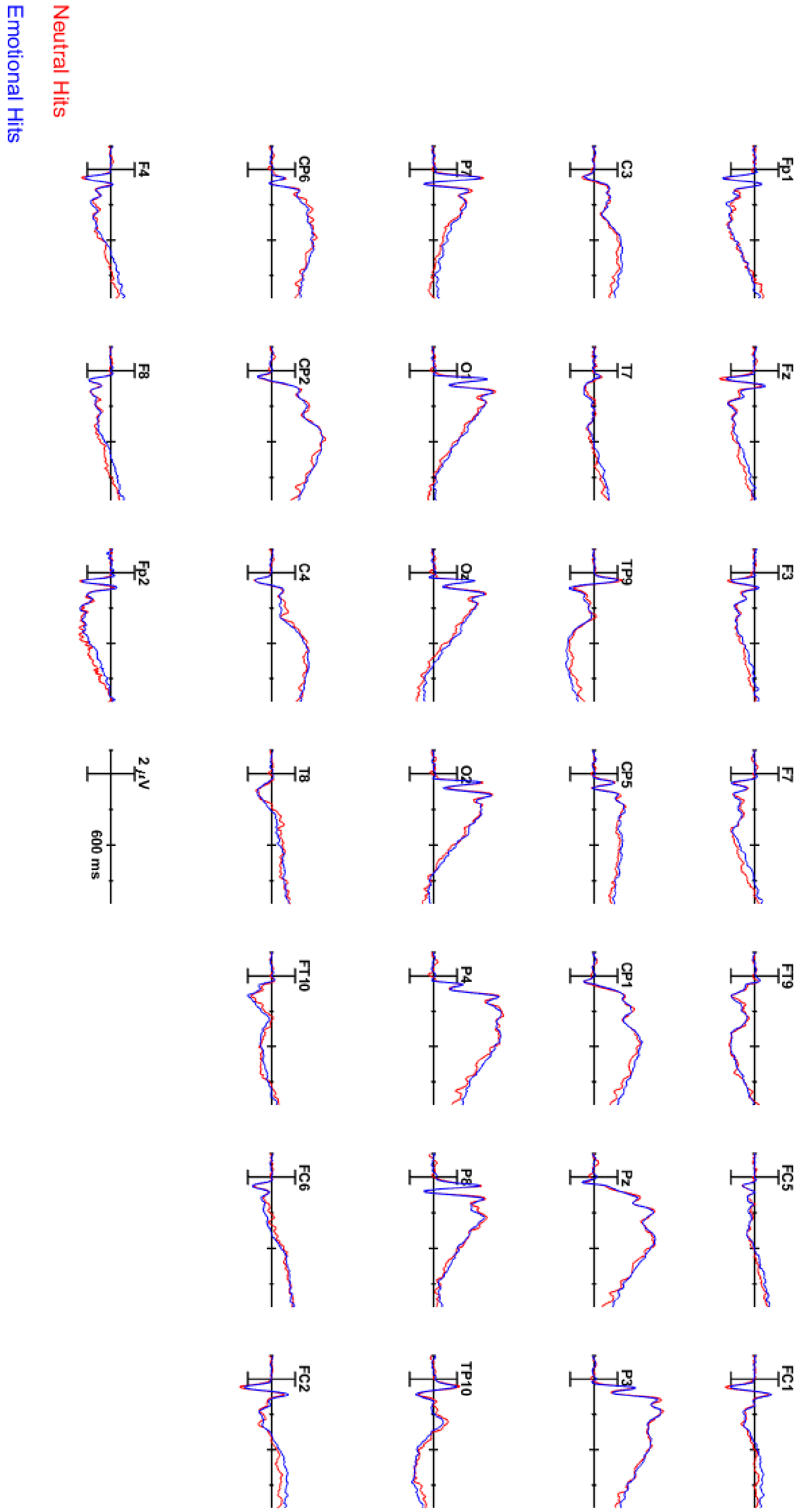


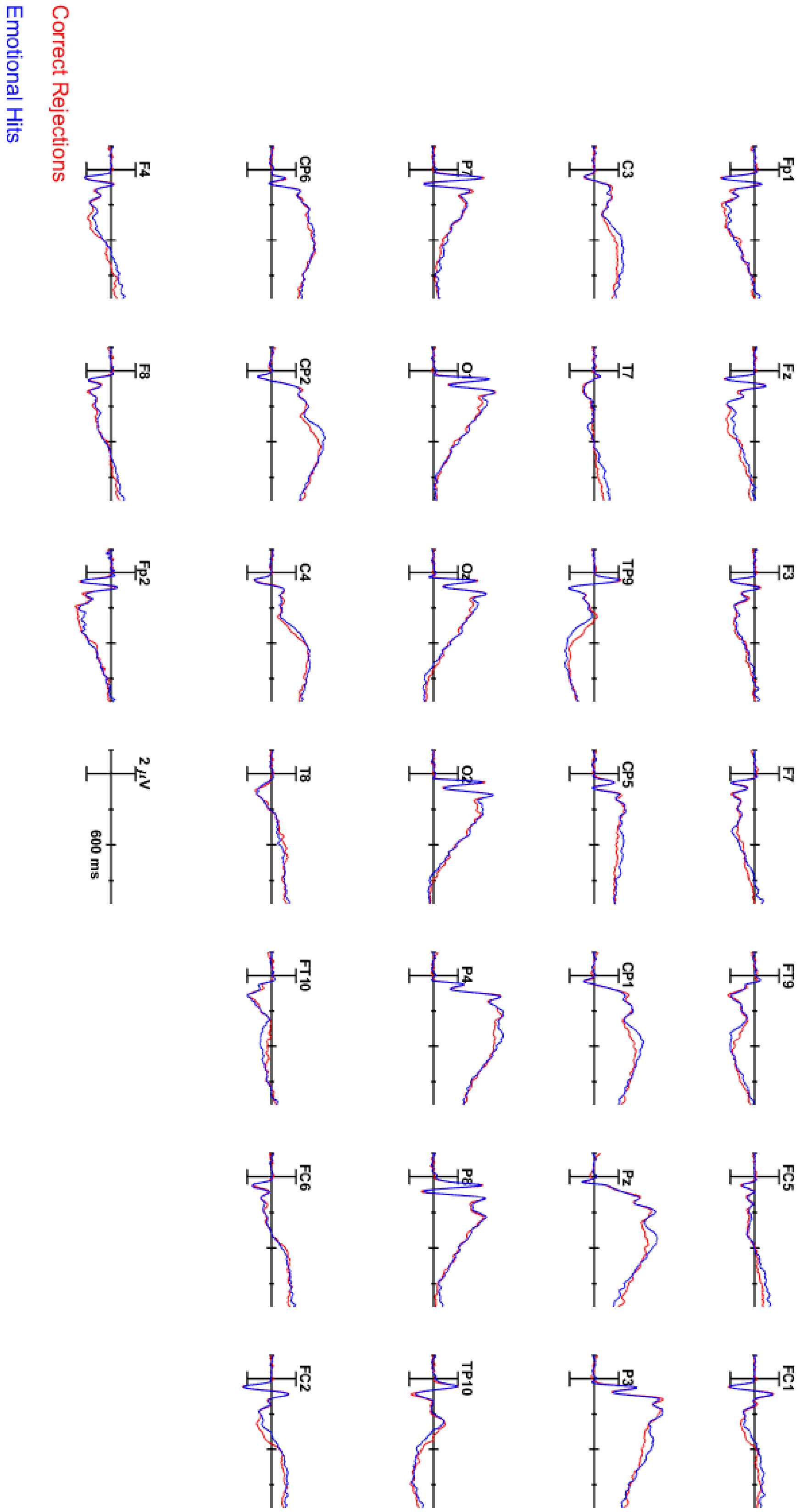

Negative Hits
Correct Rejections
Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms


Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms
Positive Hits
Correct Rejections


Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 μV
600 ms
Neutral Hits
Correct Rejections


Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms
Negative Hits
Positive Hits


Neutral Hits
Emotional Hits
Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms


Correct Rejections
Emotional Hits
Fp1
Fz
F3
F7
FT9
FC5
FC1
C3
T7
TP9
CP5
CP1
Pz
P3
P7
O1
Oz
O2
P4
P8
TP10
CP6
CP2
C4
T8
FT10
FC6
FC2
F4
F8
Fp2
2 µV
600 ms

**Appendix F –** List of codes for the contextual images used on Experiment 3.

| **Code** | **Category** | **Code** | **Category** |
|---|---|---|---|
| 3168.jpg | Neg | 9320.jpg | Neg |
| 3064.jpg | Neg | 3500.jpg | Neg |
| 3266.jpg | Neg | 9830.jpg | Neg |
| 3261.jpg | Neg | 3030.jpg | Neg |
| 3301.jpg | Neg | 3080.jpg | Neg |
| 9090.jpg | Neg | 3550_2.jpg | Neg |
| 3062.jpg | Neg | People_198_h.jpg | Neg |
| 2730.jpg | Neg | People_237_h.jpg | Neg |
| 6260.jpg | Neg | 9050.jpg | Neg |
| 2800.jpg | Neg | 6570.jpg | Neg |
| 6360.jpg | Neg | 6821.jpg | Neg |
| 3010.jpg | Neg | 9600.jpg | Neg |
| 3051.jpg | Neg | Faces_367_h.jpg | Neg |
| 9910.jpg | Neg | 3180.jpg | Neg |
| 9921.jpg | Neg | 9415.jpg | Neg |
| 3350.jpg | Neg | 6370.jpg | Neg |
| 3170.jpg | Neg | Animals_074_h.jpg | Neg |
| 6300.jpg | Neg | 2750.jpg | Neg |
| 9340.jpg | Neg | 6838.jpg | Neg |
| 3010.jpg | Neg | Faces_371_v.jpg | Neg |
| 3015.jpg | Neg | People_038_h.jpg | Neg |
| 3000.jpg | Neg | 2753.jpg | Neg |
| 6212.jpg | Neg | 6242.jpg | Neg |
| 9007.jpg | Neg | 9421.jpg | Neg |
| 9040.jpg | Neg | 9920.jpg | Neg |
| 3120.jpg | Neg | 9181.jpg | Neg |
| People_238_h.jpg | Neg | Faces_364_v.jpg | Neg |
| 3400.jpg | Neg | 3530.jpg | Neg |
| 3071.jpg | Neg | 6540.jpg | Neg |
| 6510.jpg | Neg | 6830.jpg | Neg |
| 9330.jpg | Neg | 9230.jpg | Neg |
| 9253.jpg | Neg | 9046.jpg | Neg |
| 9400.jpg | Neg | 6213.jpg | Neg |
| 3550.jpg | Neg | 9571.jpg | Neg |
| 9560.jpg | Neg | 9280.jpg | Neg |
| 2352_2.jpg | Neg | People_226_h.jpg | Neg |
| 3150.jpg | Neg | 6940.jpg | Neg |
| 9265.jpg | Neg | People_240_h.jpg | Neg |
| 6313.jpg | Neg | 3230.jpg | Neg |
| 6560.jpg | Neg | People_218_v.jpg | Neg |
| 6350.jpg | Neg | 3061.jpg | Neg |
| 6550.jpg | Neg | 9911.jpg | Neg |
| 3110.jpg | Neg | Faces_143_v.jpg | Neg |
| 6571.jpg | Neg | People_208_h.jpg | Neg |
| 6831.jpg | Neg | Animals_056_h.jpg | Neg |
| 9252.jpg | Neg | People_227_h.jpg | Neg |
| 6250.jpg | Neg | People_201_v.jpg | Neg |
| 9405.jpg | Neg | People_211_v.jpg | Neg |
| 9290.jpg | Neg | People_221_h.jpg | Neg |

| Code | Category | Code | Category |
|---|---|---|---|
| 3130.jpg | Neg | 9008.jpg | Neg |
| 6200.jpg | Neg | 2722.jpg | Neg |
| 9433.jpg | Neg | Faces_159_h.jpg | Neg |
| 2205.jpg | Neg | 7224.jpg | Neu |
| 2710.jpg | Neg | 7235.jpg | Neu |
| 9611.jpg | Neg | 7490.jpg | Neu |
| 2141.jpg | Neg | 7491.jpg | Neu |
| 9584.jpg | Neg | 7496.jpg | Neu |
| People_246_h.jpg | Neg | 7500.jpg | Neu |
| Faces_365_v.jpg | Neg | 7550.jpg | Neu |
| People_220_h.jpg | Neg | 7560.jpg | Neu |
| 1280.jpg | Neg | 7950.jpg | Neu |
| 9570.jpg | Neg | Animals_030_h.jpg | Neu |
| 1111.jpg | Neg | Animals_069_h.jpg | Neu |
| 1201.jpg | Neg | Animals_133_h.jpg | Neu |
| Animals_077_h.jpg | Neg | Animals_200_v.jpg | Neu |
| Objects_125_h.jpg | Neg | Faces_006_h.jpg | Neu |
| 9160.jpg | Neg | Faces_023_h.jpg | Neu |
| 2053.jpg | Neg | Faces_167_v.jpg | Neu |
| Landscapes_077_v.jpg | Neu | Faces_171_v.jpg | Neu |
| 1303.jpg | Neu | Faces_190_h.jpg | Neu |
| 1390.jpg | Neu | Faces_198_h.jpg | Neu |
| 2190.jpg | Neu | Faces_215_v.jpg | Neu |
| 2215.jpg | Neu | Faces_216_h.jpg | Neu |
| 2280.jpg | Neu | Faces_218_h.jpg | Neu |
| 2312.jpg | Neu | Faces_220_h.jpg | Neu |
| 2372.jpg | Neu | Faces_289_h.jpg | Neu |
| 2385.jpg | Neu | Faces_305_h.jpg | Neu |
| 2495.jpg | Neu | Faces_312_h.jpg | Neu |
| 2518.jpg | Neu | Faces_320_v.jpg | Neu |
| 2570.jpg | Neu | Landscapes_016_h.jpg | Neu |
| 5532.jpg | Neu | Landscapes_020_h.jpg | Neu |
| 5535.jpg | Neu | Landscapes_024_v.jpg | Neu |
| 5920.jpg | Neu | Landscapes_044_h.jpg | Neu |
| 6150.jpg | Neu | Landscapes_061_h.jpg | Neu |
| 7000.jpg | Neu | Landscapes_067_h.jpg | Neu |
| 7004.jpg | Neu | Landscapes_076_h.jpg | Neu |
| 7006.jpg | Neu | Landscapes_079_v.jpg | Neu |
| 7020.jpg | Neu | Landscapes_159_h.jpg | Neu |
| 7025.jpg | Neu | Landscapes_170_h.jpg | Neu |
| 7031.jpg | Neu | Objects_009_h.jpg | Neu |
| 7034.jpg | Neu | Objects_014_h.jpg | Neu |
| 7035.jpg | Neu | Objects_035_h.jpg | Neu |
| 7100.jpg | Neu | Objects_045_h.jpg | Neu |
| 7130.jpg | Neu | Objects_050_h.jpg | Neu |
| 7150.jpg | Neu | Objects_057_h.jpg | Neu |
| 7175.jpg | Neu | Objects_060_h.jpg | Neu |
| 7180.jpg | Neu | Objects_067_h.jpg | Neu |
| 7182.jpg | Neu | Objects_071_h.jpg | Neu |
| 7184.jpg | Neu | Objects_089_h.jpg | Neu |
| 7185.jpg | Neu | Objects_108_v.jpg | Neu |
| 7190.jpg | Neu | Objects_112_h.jpg | Neu |

| **Code** | **Category** | **Code** | **Category** |
|---|---|---|---|
| 7205.jpg | Neu | Objects_115_h.jpg | Neu |
| 7211.jpg | Neu | Objects_119_h.jpg | Neu |
| 7217.jpg | Neu | Objects_130_h.jpg | Neu |
| Objects_131_h.jpg | Neu | Objects_238_h.jpg | Neu |
| Objects_147_v.jpg | Neu | Objects_239_v.jpg | Neu |
| Objects_179_h.jpg | Neu | Objects_244_h.jpg | Neu |
| Objects_187_h.jpg | Neu | Objects_246_h.jpg | Neu |
| Objects_189_h.jpg | Neu | Objects_251_v.jpg | Neu |
| Objects_194_h.jpg | Neu | Objects_274_h.jpg | Neu |
| Objects_196_h.jpg | Neu | Objects_280_v.jpg | Neu |
| Objects_197_v.jpg | Neu | Objects_298_h.jpg | Neu |
| Objects_204_h.jpg | Neu | Objects_299_h.jpg | Neu |
| Objects_208_h.jpg | Neu | Objects_307_v.jpg | Neu |
| Objects_210_h.jpg | Neu | Objects_308_h.jpg | Neu |
| Objects_211_h.jpg | Neu | Objects_311_h.jpg | Neu |
| Objects_213_h.jpg | Neu | Objects_314_h.jpg | Neu |
| Objects_222_h.jpg | Neu | People_066_v.jpg | Neu |
| Objects_224_h.jpg | Neu | People_078_v.jpg | Neu |
| Objects_226_h.jpg | Neu | People_164_h.jpg | Neu |

## **Appendix G –** List of codes for the images of faces used on Experiment 3.

CFD-AF-218-157-N.jpg
CFD-AF-219-106-N.jpg
CFD-AF-220-107-N.jpg
CFD-AF-221-147-N.jpg
CFD-AF-222-134-N.jpg
CFD-AF-223-183-N.jpg
CFD-AM-214-168-N.jpg
CFD-AM-215-120-N.jpg
CFD-AM-216-114-N.jpg
CFD-AM-217-085-N.jpg
CFD-AM-218-085-N.jpg
CFD-AM-219-101-N.jpg
CFD-AM-220-134-N.jpg
CFD-AM-221-184-N.jpg
CFD-AM-223-138-N.jpg
CFD-AM-224-126-N.jpg
CFD-AM-225-102-N.jpg
CFD-AM-226-234-N.jpg
CFD-AM-227-184-N.jpg
CFD-BF-027-002-N.jpg
CFD-BF-028-001-N.jpg
CFD-BF-029-031-N.jpg
CFD-BF-030-002-N.jpg
CFD-BF-031-002-N.jpg
CFD-BF-032-038-N.jpg
CFD-BF-033-028-N.jpg
CFD-BF-034-002-N.jpg
CFD-BF-035-001-N.jpg
CFD-BF-036-027-N.jpg
CFD-BF-037-022-N.jpg
CFD-BF-038-037-N.jpg
CFD-BF-039-031-N.jpg
CFD-BF-040-003-N.jpg
CFD-BF-041-001-N.jpg
CFD-BF-042-026-N.jpg
CFD-BM-029-024-N.jpg
CFD-BM-030-003-N.jpg
CFD-BM-031-003-N.jpg
CFD-BM-032-024-N.jpg
CFD-BM-033-003-N.jpg
CFD-BM-034-031-N.jpg
CFD-BM-036-003-N.jpg
CFD-BM-037-033-N.jpg
CFD-BM-038-001-N.jpg
CFD-BM-039-029-N.jpg
CFD-BM-040-002-N.jpg
CFD-BM-041-035-N.jpg
CFD-LF-234-139-N.jpg
CFD-LF-235-219-N.jpg
CFD-LF-236-221-N.jpg
CFD-LF-237-190-N.jpg
CFD-LF-238-154-N.jpg
CFD-LF-239-148-N.jpg
CFD-LF-240-199-N.jpg
CFD-LF-241-188-N.jpg
CFD-LF-242-121-N.jpg
CFD-LM-227-103-N.jpg
CFD-LM-228-188-N.jpg
CFD-LM-229-187-N.jpg
CFD-LM-230-202-N.jpg
CFD-LM-231-214-N.jpg
CFD-LM-232-204-N.jpg
CFD-LM-233-171-N.jpg
CFD-LM-234-176-N.jpg
CFD-LM-235-231-N.jpg
CFD-LM-236-163-N.jpg
CFD-LM-237-264-N.jpg
CFD-LM-238-129-N.jpg
CFD-LM-239-075-N.jpg
CFD-LM-240-013-N.jpg
CFD-LM-241-125-N.jpg
CFD-LM-242-002-N.jpg
CFD-LM-243-075-N.jpg
CFD-LM-244-068-N.jpg
CFD-WF-030-002-N.jpg
CFD-WF-031-027-N.jpg
CFD-WF-033-002-N.jpg
CFD-WF-034-006-N.jpg
CFD-WF-035-024-N.jpg
CFD-WF-036-023-N.jpg
CFD-WF-037-029-N.jpg
CFD-WF-038-021-N.jpg
CFD-WF-039-025-N.jpg
CFD-WF-200-099-N.jpg
CFD-WF-201-156-N.jpg
CFD-WF-202-056-N.jpg
CFD-WF-203-229-N.jpg
CFD-WF-204-038-N.jpg
CFD-WF-205-006-N.jpg
CFD-WF-206-147-N.jpg
CFD-WF-207-014-N.jpg
CFD-WF-208-068-N.jpg
CFD-WM-035-032-N.jpg
CFD-WM-036-031-N.jpg
CFD-AF-212-097-N.jpg
CFD-AF-213-126-N.jpg
CFD-AF-214-139-N.jpg
CFD-AF-215-70-N.jpg
CFD-AF-216-106-N.jpg
CFD-AF-217-155-N.jpg
CFD-AM-201-076-N.jpg
CFD-AM-202-079-N.jpg
CFD-AM-203-086-N.jpg
CFD-AM-204-122-N.jpg
CFD-AM-205-153-N.jpg
CFD-AM-206-086-N.jpg
CFD-AM-207-108-N.jpg
CFD-AM-208-143-N.jpg
CFD-AM-209-048-N.jpg
CFD-AM-210-035-N.jpg
CFD-AM-211-052-N.jpg
CFD-AM-212-050-N.jpg
CFD-AM-213-056-N.jpg
CFD-BF-001-025-N.jpg
CFD-BF-002-001-N.jpg
CFD-BF-003-003-N.jpg
CFD-BF-004-014-N.jpg
CFD-BF-005-001-N.jpg
CFD-BF-006-017-N.jpg
CFD-BF-007-001-N.jpg
CFD-BF-008-001-N.jpg
CFD-BF-009-002-N.jpg
CFD-BF-010-001-N.jpg
CFD-BF-011-002-N.jpg
CFD-BF-012-001-N.jpg
CFD-BF-013-001-N.jpg
CFD-BF-014-002-N.jpg
CFD-BF-015-004-N.jpg
CFD-BF-016-017-N.jpg
CFD-BM-001-014-N.jpg
CFD-BM-002-013-N.jpg
CFD-BM-003-003-N.jpg
CFD-BM-004-002-N.jpg
CFD-BM-005-003-N.jpg
CFD-BM-009-002-N.jpg
CFD-BM-010-003-N.jpg
CFD-BM-011-016-N.jpg
CFD-BM-012-018-N.jpg
CFD-BM-013-002-N.jpg
CFD-BM-015-015-N.jpg
CFD-BM-016-036-N.jpg
CFD-LF-209-072-N.jpg
CFD-LF-210-220-N.jpg
CFD-LF-211-003-N.jpg
CFD-LF-212-066-N.jpg
CFD-LF-213-079-N.jpg
CFD-LF-214-090-N.jpg
CFD-LF-215-157-N.jpg
CFD-LF-216-121-N.jpg
CFD-LF-217-082-N.jpg
CFD-LM-200-045-N.jpg
CFD-LM-201-057-N.jpg
CFD-LM-202-072-N.jpg
CFD-LM-203-026-N.jpg
CFD-LM-204-001-N.jpg
CFD-LM-206-204-N.jpg
CFD-LM-207-004-N.jpg
CFD-LM-208-110-N.jpg
CFD-LM-209-111-N.jpg
CFD-LM-210-156-N.jpg
CFD-LM-211-128-N.jpg
CFD-LM-212-143-N.jpg
CFD-LM-213-061-N.jpg
CFD-LM-214-165-N.jpg
CFD-LM-215-247-N.jpg
CFD-LM-216-082-N.jpg
CFD-LM-217-162-N.jpg
CFD-LM-218-183-N.jpg
CFD-WF-001-003-N.jpg
CFD-WF-002-004-N.jpg
CFD-WF-003-003-N.jpg
CFD-WF-005-010-N.jpg
CFD-WF-006-002-N.jpg
CFD-WF-007-001-N.jpg
CFD-WF-008-002-N.jpg
CFD-WF-009-001-N.jpg
CFD-WF-010-004-N.jpg
CFD-WF-011-002-N.jpg
CFD-WF-012-002-N.jpg
CFD-WF-013-003-N.jpg
CFD-WF-014-002-N.jpg
CFD-WF-015-006-N.jpg
CFD-WF-016-015-N.jpg
CFD-WF-017-003-N.jpg
CFD-WF-018-017-N.jpg
CFD-WF-019-005-N.jpg
CFD-WM-001-014-N.jpg
CFD-WM-002-009-N.jpg

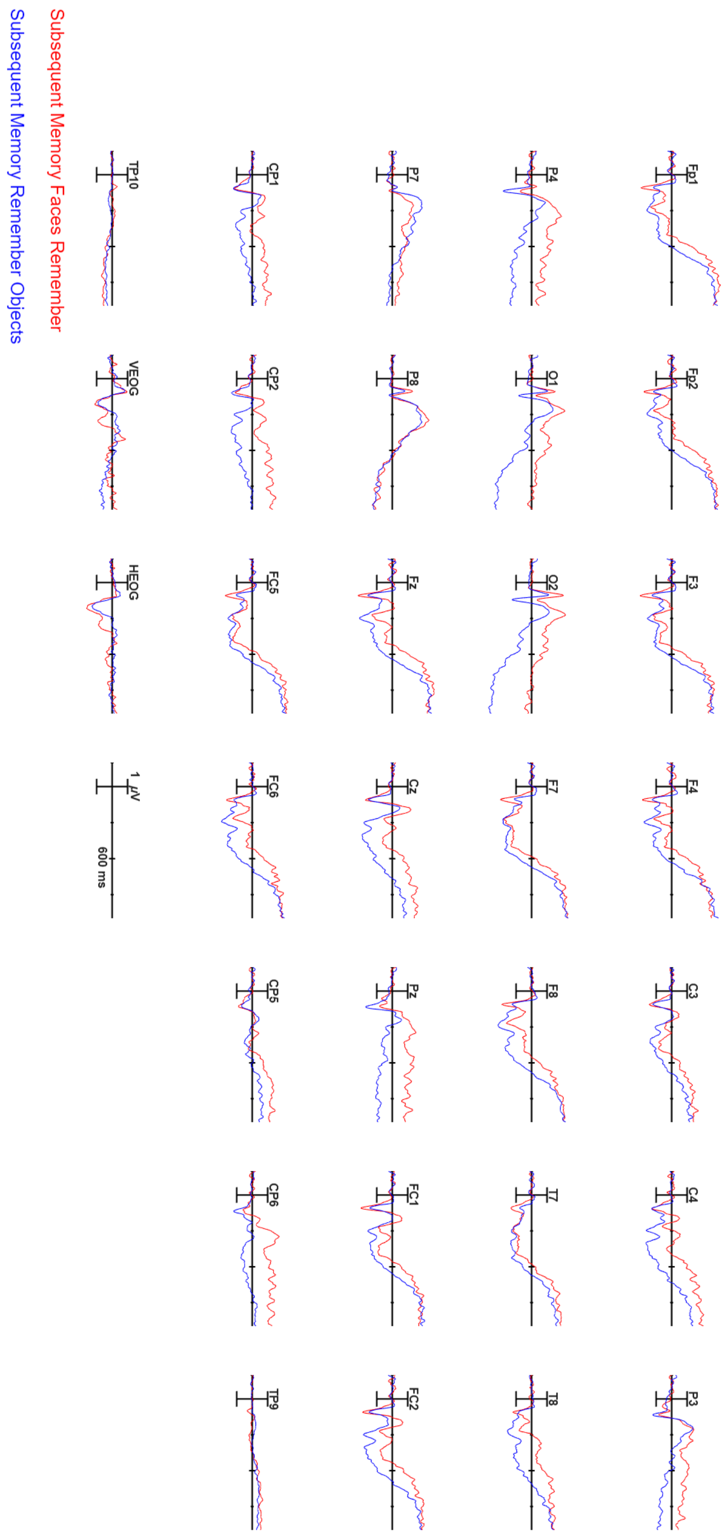
CFD-BM-043-071-N.jpg
CFD-BM-044-001-N.jpg
CFD-BM-045-004-N.jpg
CFD-BM-046-006-N.jpg
CFD-LF-225-164-N.jpg
CFD-LF-226-174-N.jpg
CFD-LF-227-054-N.jpg
CFD-LF-228-125-N.jpg
CFD-LF-229-164-N.jpg
CFD-LF-230-203-N.jpg
CFD-LF-231-260-N.jpg
CFD-LF-232-199-N.jpg
CFD-LF-233-277-N.jpg
CFD-WM-037-025-N.jpg
CFD-WM-038-003-N.jpg
CFD-WM-039-018-N.jpg
CFD-WM-040-022-N.jpg
CFD-WM-041-021-N.jpg
CFD-WM-200-034-N.jpg
CFD-WM-201-063-N.jpg
CFD-WM-202-107-N.jpg
CFD-WM-203-023-N.jpg
CFD-WM-204-031-N.jpg
CFD-WM-205-007-N.jpg
CFD-WM-206-045-N.jpg
CFD-WM-207-048-N.jpg
CFD-BM-017-021-N.jpg
CFD-BM-018-001-N.jpg
CFD-BM-019-002-N.jpg
CFD-BM-020-001-N.jpg
CFD-LF-200-058-N.jpg
CFD-LF-201-035-N.jpg
CFD-LF-202-065-N.jpg
CFD-LF-203-066-N.jpg
CFD-LF-204-133-N.jpg
CFD-LF-205-100-N.jpg
CFD-LF-206-078-N.jpg
CFD-LF-207-198-N.jpg
CFD-LF-208-127-N.jpg
CFD-WM-003-002-N.jpg
CFD-WM-004-010-N.jpg
CFD-WM-006-002-N.jpg
CFD-WM-009-002-N.jpg
CFD-WM-010-001-N.jpg
CFD-WM-011-002-N.jpg
CFD-WM-012-001-N.jpg
CFD-WM-013-001-N.jpg
CFD-WM-014-002-N.jpg
CFD-WM-015-002-N.jpg
CFD-WM-016-001-N.jpg
CFD-WM-017-002-N.jpg
CFD-WM-018-002-N.jpg

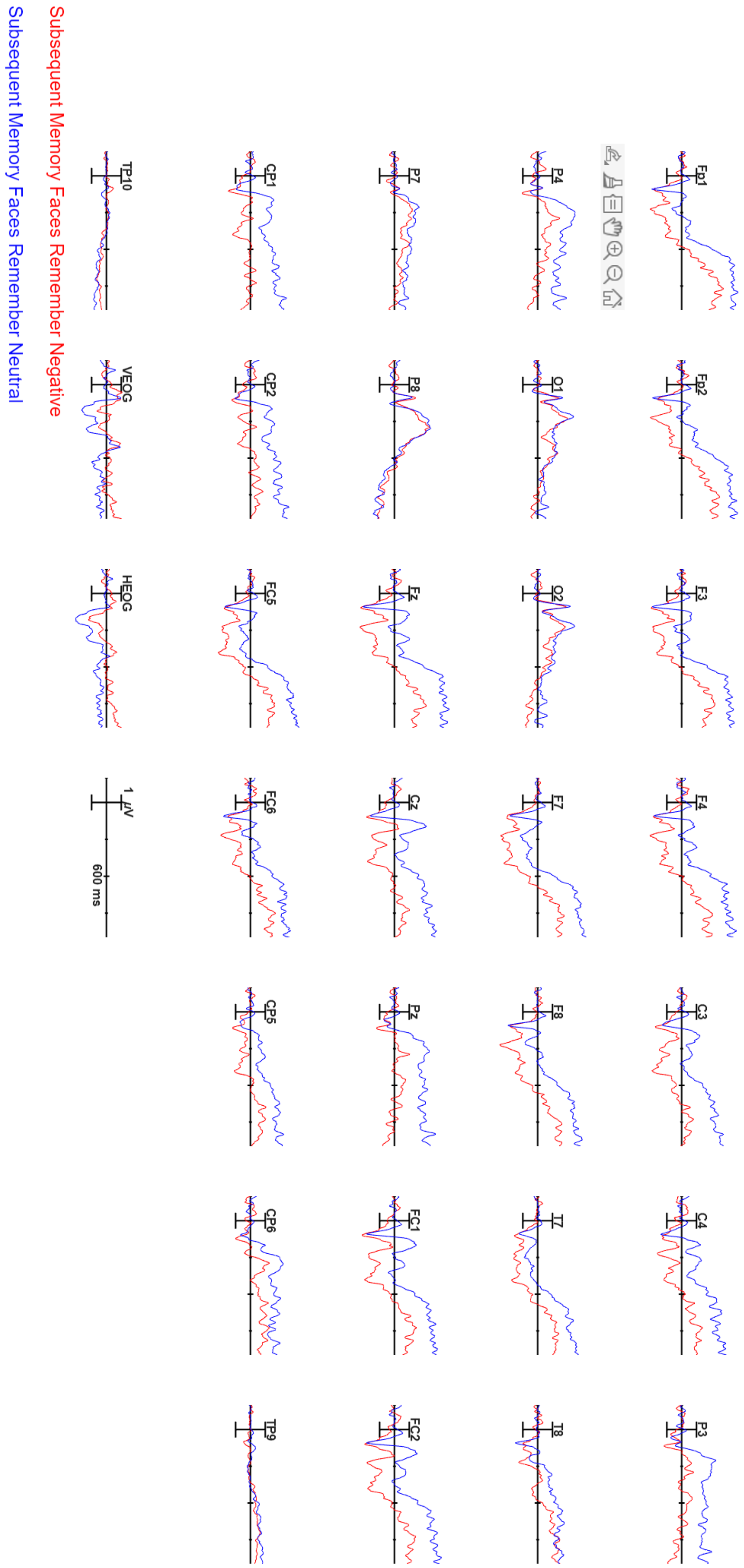
**Appendix H –** List of codes for the images of objects used on Experiment 3.

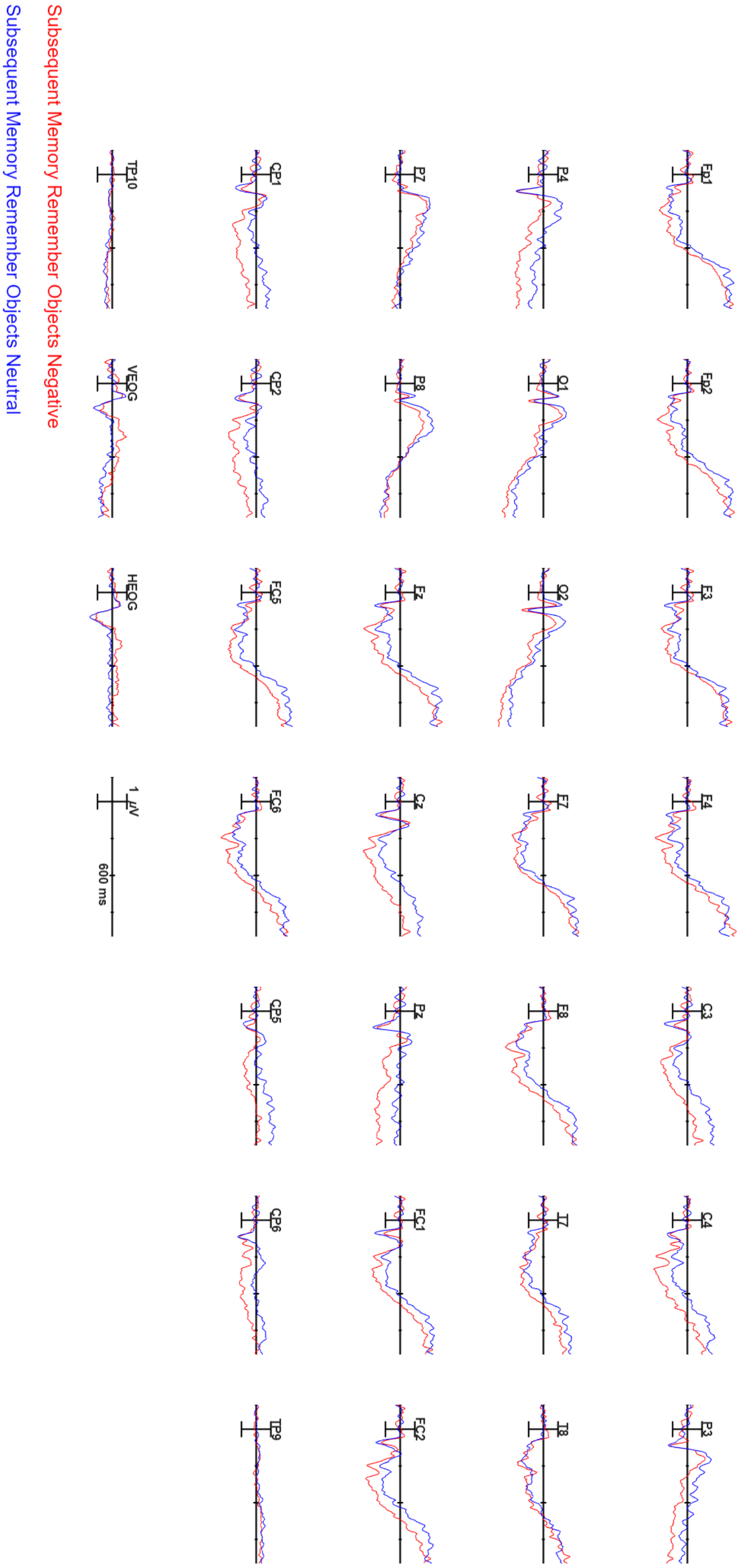
handblender.jpg
hardhat02.jpg
cremebrulee.jpg
candelabra.jpg
plantpot.jpg
firstaidkit.jpg
shower.jpg
cardinal.jpg
donut.jpg
jarofcapers.jpg
safetyglasses.jpg
machinegun.jpg
porsche.jpg
chiliflake.jpg
horseshoe.jpg
waterfountain.jpg
atm.jpg
harmonica.jpg
redonion.jpg
chainsaw.jpg
carlighter02.jpg
dandelion.jpg
communitymailbox.jpg
ostrich.jpg
spicerack.jpg
busshelter.jpg
waterbottleholder.jpg
papershredder.jpg
fence.jpg
acorn.jpg
soccerball.jpg
diploma.jpg
speedball.jpg
exitsign.jpg
clownfish.jpg
pin.jpg
panda.jpg
swordfish.jpg
rawchicken.jpg
badger.jpg
flowerwreath.jpg
hedgetrimmer.jpg
bowlingball.jpg
donotwalksign.jpg
trailerhitchball.jpg
gardenutilityvehicle.jpg
siamesecat.jpg
backfloat.jpg
chipmunk.jpg
blackolive.jpg
pipewrench.jpg
butterfly.jpg
dumpster.jpg
gamecontroller.jpg
sledgehammer.jpg
battleship.jpg
worldmap.jpg
bridge.jpg
stovetop.jpg
coffeemaker.jpg
satellitedish.jpg
fortunecookie.jpg
jetski.jpg
totempole.jpg
bull.jpg
coffeemachine.jpg
americangoldfinch.jpg
lip.jpg
tower.jpg
spaghetti.jpg
drumstick.jpg
chimney.jpg
codedoorlock.jpg
mirror.jpg
lunchbag.jpg
stroller.jpg
servingspoon.jpg
lighthouse.jpg
garbagebin.jpg
rainstick.jpg
donotentersign.jpg
chimpanzee.jpg
duck.jpg
aquarium.jpg
wheat.jpg
flamingo.jpg
kneepad.jpg
puma.jpg
shovel01.jpg
laundrybasket.jpg
stuffedpuffin.jpg
toad.jpg
8ball.jpg
bolt01a.jpg
daisy.jpg
killerwhale.jpg
tree.jpg
birdhouse.jpg
grizzly.jpg
road.jpg
militaryhat.jpg
bassethound.jpg
pricesign.jpg
tambourine.jpg
musket.jpg
horseshoecrab.jpg
waterheater.jpg
railwaycrossingsign.jpg
wheelbarrow.jpg
lychee.jpg
smokedsalmon.jpg
cockroach.jpg
paperairplane.jpg
shoulder.jpg
boat.jpg
hedgeshears.jpg
hippopotamus.jpg
balalaika.jpg
grasshopper.jpg
wagonwheel.jpg
megaphone.jpg
diaperbag.jpg
clover.jpg
gardengnome.jpg
badmintonracket.jpg
hockeygoaliemask.jpg
podium.jpg
christmaswreath.jpg
cello.jpg
fireplace.jpg
golfbag.jpg
ceilingfan.jpg
candydispenser.jpg
hand.jpg
bulletbelt.jpg
taxisign.jpg
palmier.jpg
toynutcracker.jpg
marble.jpg
kangaroo.jpg
chime.jpg
anchor.jpg
pokerchips.jpg
pavedsidewalk.jpg
maraca01.jpg
nose.jpg
walldeco.jpg
car.jpg
candycane.jpg
lawnmower.jpg
cheetah.jpg
icescraper.jpg
crown.jpg
securitycamera.jpg
toysoldier.jpg
bikewheel.jpg
faucet.jpg
campfire.jpg
ellipticalmachine.jpg
exercisemachine.jpg
chessknight.jpg
hockeygoaliepad.jpg
flag.jpg
saltshaker.jpg
ducttape.jpg
slug.jpg
toasteroven.jpg
menwashroomsign.jpg
doublebass.jpg
sportsjersey.jpg
icecube.jpg
triangle.jpg
dolphin.jpg
shelves.jpg
sword.jpg
nightstand.jpg

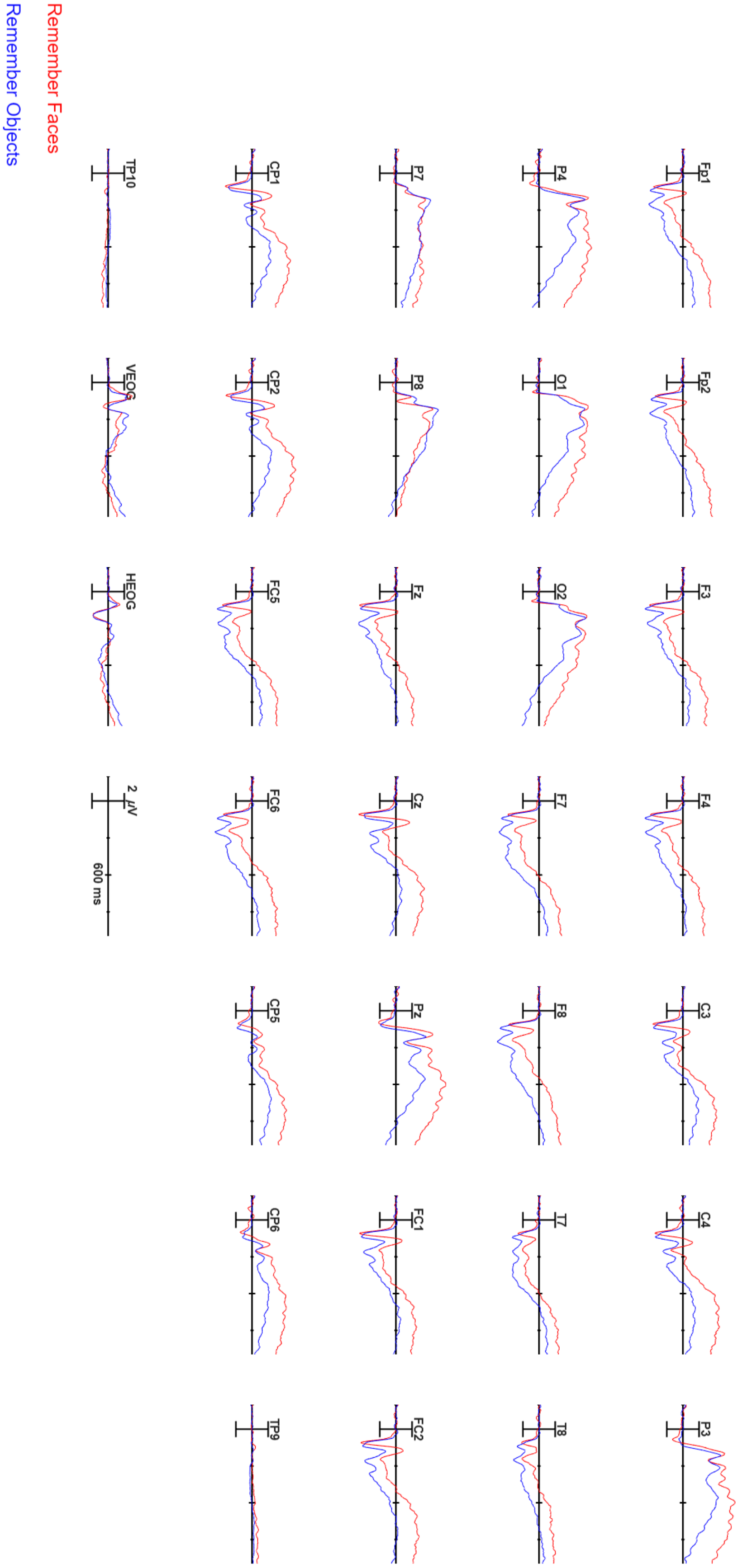
hibiscusflower.jpg
linedpaper.jpg
morningstar.jpg
rockingchair.jpg
visor.jpg
sandbarshark.jpg
hen.jpg
squid.jpg
wafflemaker.jpg
birdseed.jpg
heatpump.jpg
dalmatian.jpg
proboscismonkey.jpg
locker.jpg
gasburner.jpg
pitchfork.jpg
napkin.jpg
gymnasticring.jpg
chameleon.jpg
canoepaddle.jpg
parrot.jpg
pirateflag.jpg
golfball.jpg
icemaker.jpg
cookingpot.jpg
toucan.jpg
trumpet.jpg
bulldozer.jpg
bridgestick.jpg
cementtruck.jpg
lectern.jpg
scooter.jpg
parkbench02.jpg
tuba.jpg
painting.jpg
kiwi.jpg
ballofstring.jpg
chainmail.jpg
holdfast.jpg
cinderblock.jpg
outdoorfireplace.jpg
dumpling.jpg
frenchfries.jpg
cowbell.jpg
nyala.jpg
belugawhale.jpg
toilet.jpg
parkfountain.jpg
spacerover.jpg
pokerset.jpg
treestump.jpg
harpoon.jpg
belltower.jpg
clarinet.jpg
owl.jpg
bumpercar.jpg
powerchair.jpg
banjo.jpg
boatmotor.jpg
paninigrill.jpg
weddingcake.jpg
fingerprint.jpg
zipper.jpg
musicstand.jpg

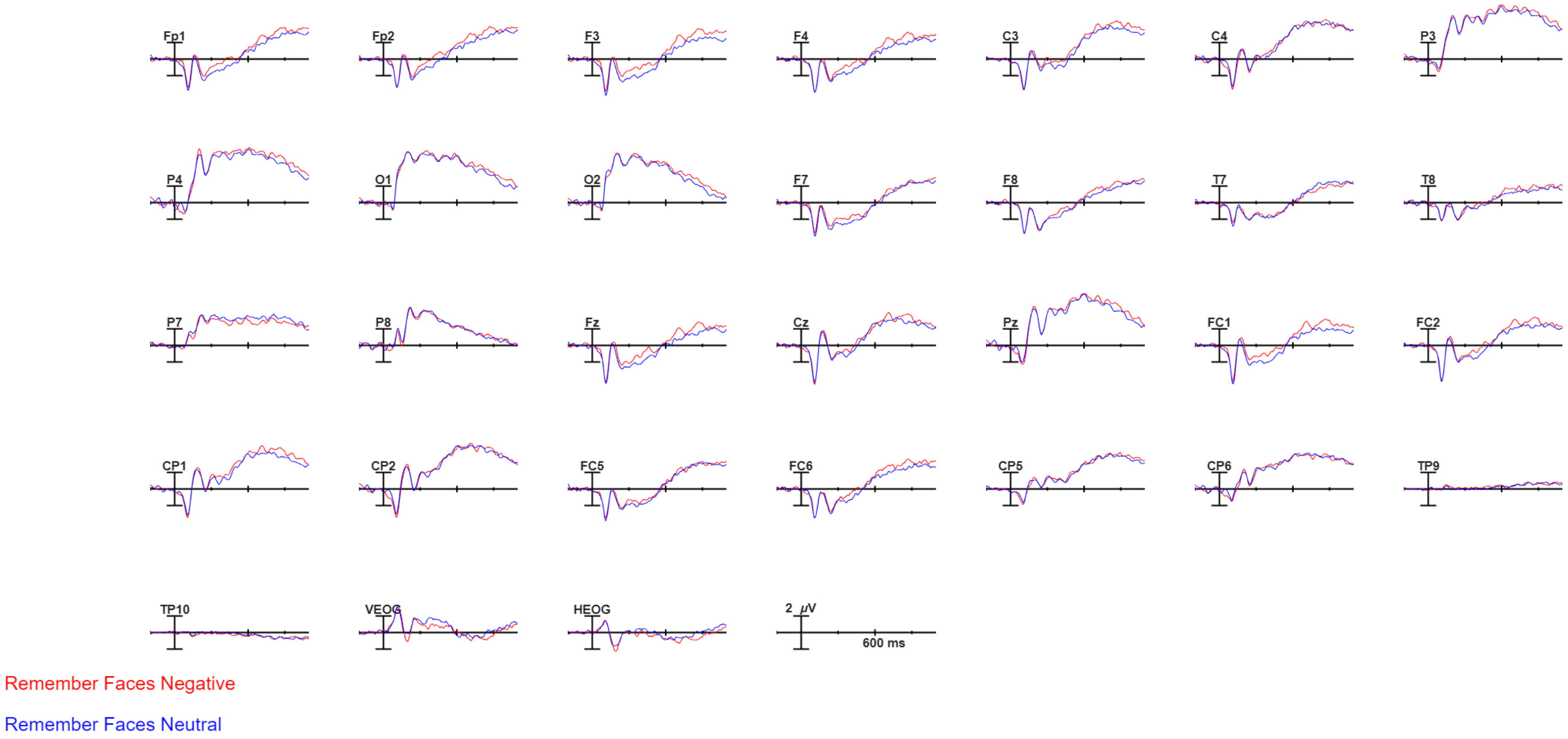
**Appendix J –** ERPs of all electrodes utilized for analysis on Experiment 3.

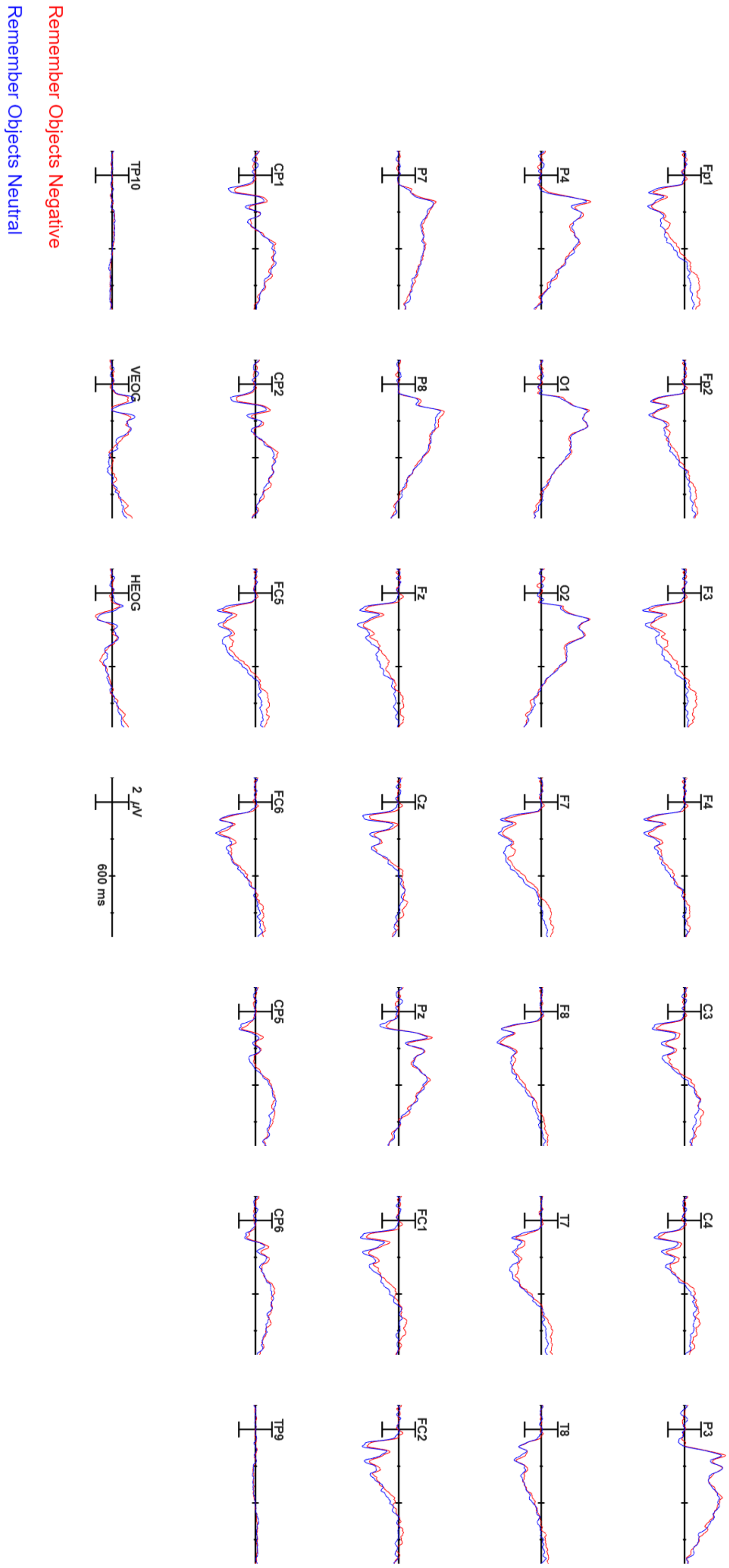


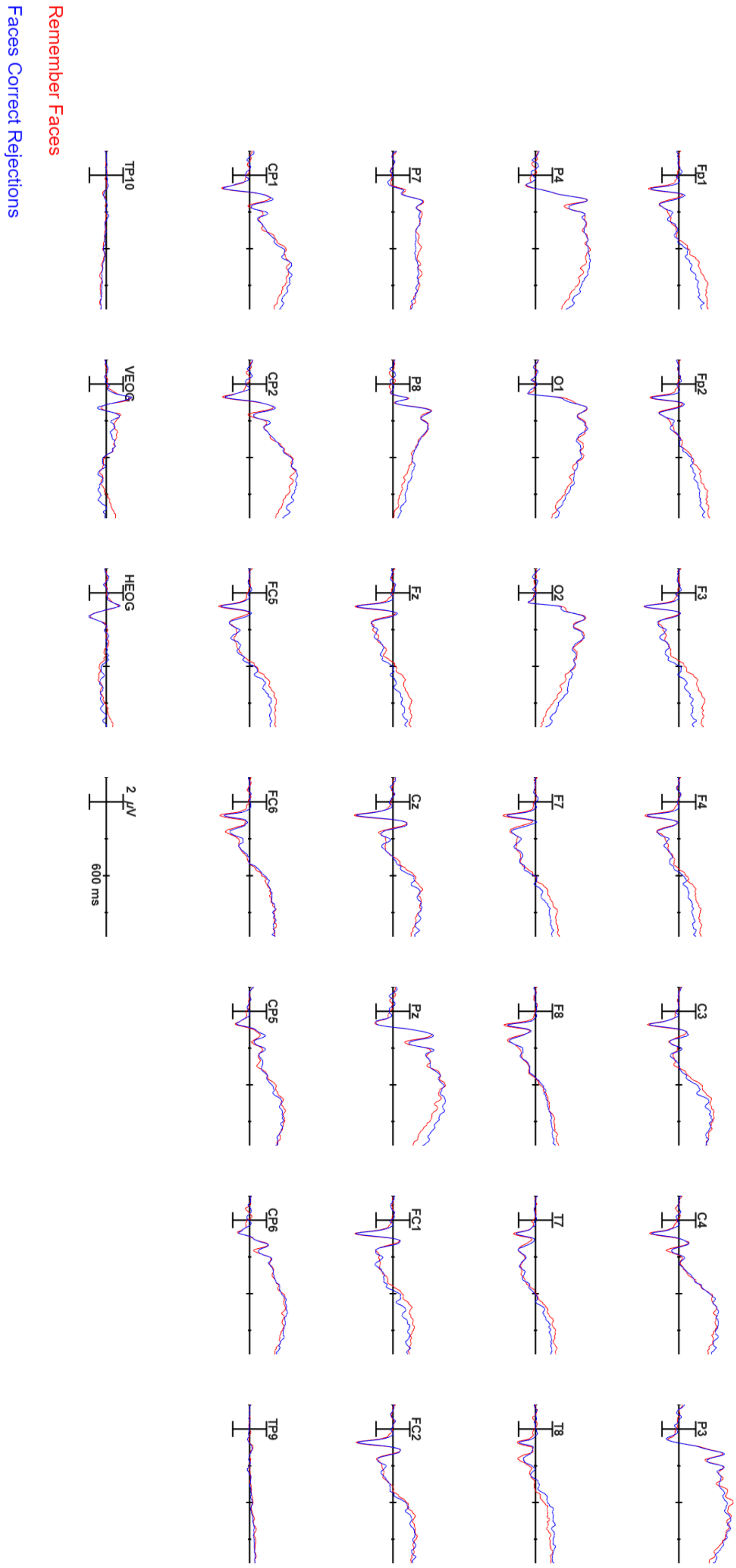

Fp1
Fp2
F3
F4
C3
C4
P3
P4
O1
O2
F7
F8
T7
T8
P7
P8
Fz
Cz
Pz
FC1
FC2
CP1
CP2
FC5
FC6
CP5
CP6
TP9
TP10
VEOG
HEOG
1 µV
600 ms
Subsequent Memory Faces Remember Negative
Subsequent Memory Faces Remember Neutral

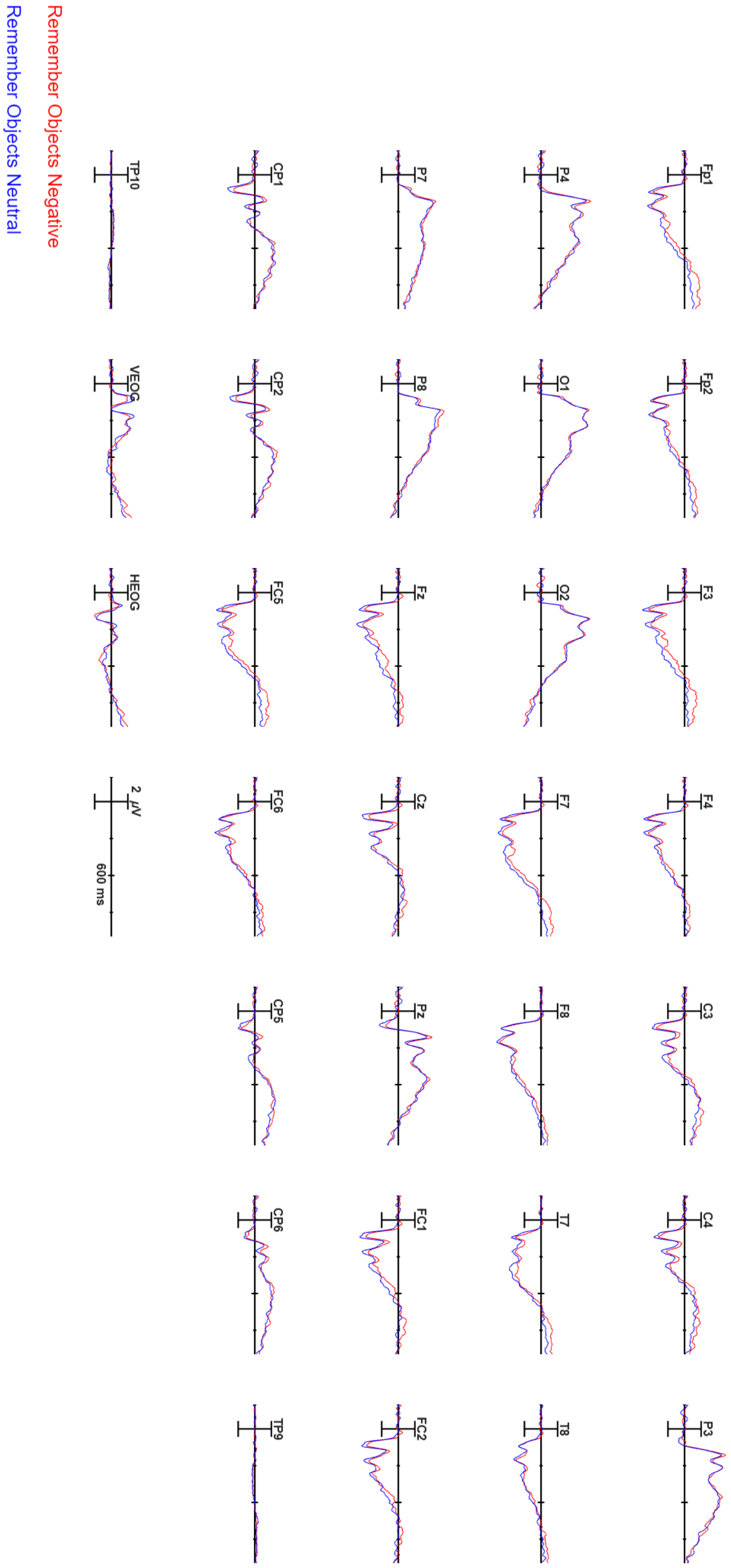

Fp1
Fp2
F3
F4
C3
C4
P3
P4
O1
O2
F7
F8
T7
T8
P7
P8
Fz
Cz
Pz
FC1
FC2
CP1
CP2
FC5
FC6
CP5
CP6
TP9
TP10
VEOG
HEOG
1 µV
600 ms
Subsequent Memory Remember Objects Negative
Subsequent Memory Remember Objects Neutral


Fp1
Fp2
F3
F4
C3
C4
P3
P4
O1
O2
F7
F8
T7
T8
P7
P8
Fz
Cz
Pz
FC1
FC2
CP1
CP2
FC5
FC6
CP5
CP6
TP9
TP10
VEOG
HEOG
2 µV
600 ms
Remember Faces
Remember Objects


Fp1
Fp2
F3
F4
C3
C4
P3
P4
O1
O2
F7
F8
T7
T8
P7
P8
Fz
Cz
Pz
FC1
FC2
CP1
CP2
FC5
FC6
CP5
CP6
TP9
TP10
VEOG
HEOG
2 µV
600 ms
Remember Faces Negative
Remember Faces Neutral


Fp1
Fp2
F3
F4
C3
C4
P3
P4
O1
O2
F7
F8
T7
T8
P7
P8
Fz
Cz
Pz
FC1
FC2
CP1
CP2
FC5
FC6
CP5
CP6
TP9
TP10
VEOG
HEOG
2 µV
600 ms
Remember Objects Negative
Remember Objects Neutral


Fp1
Fp2
F3
F4
C3
C4
P3
P4
O1
O2
F7
F8
T7
T8
P7
P8
Fz
Cz
Pz
FC1
FC2
CP1
CP2
FC5
FC6
CP5
CP6
TP9
TP10
VEOG
HEOG
2 µV
600 ms
Remember Faces
Faces Correct Rejections


Fp1
Fp2
F3
F4
C3
C4
P3
P4
O1
O2
F7
F8
T7
T8
P7
P8
Fz
Cz
Pz
FC1
FC2
CP1
CP2
FC5
FC6
CP5
CP6
TP9
TP10
VEOG
HEOG
2 µV
600 ms
Remember Objects Negative
Remember Objects Neutral