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*Research Highlights

- 1) Facial familiarity and expression interact in the right hemisphere at approximately 170 ms after stimulus onset during switching to familiarity and expression tasks when the unattended dimension was previously attended.
- 2) These interactions gain both hemispheres at around 230 ms.
- 3) The right hemisphere is critical for early identity/expression overlapping.
- 4) Familiarity and expression of faces interact in subjects' accuracy in both directions when selective attention and the relation between stimuli are manipulated.

Perceptual interactions between visual processing of facial familiarity and emotional expression: An event-related potentials study during task-switching

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Abstract

Models of face processing suggest that facial familiarity and expression processes involve independent visual systems. But under some conditions, the two processes interact, as when selective attention is solicited, and/or when a link is established between consecutive stimuli. To assess these assumptions during perceptual face processing, event-related potentials (ERPs) were used while subjects discriminated either familiarity or expression in a task-switching paradigm. Switched trials were designed with competitor priming, the unattended dimension being previously attended. The results indicate interactions appearing in the right hemisphere during the perceptual encoding stage (N170) when subjects processed either familiarity or expression during switched trials. These interactions gain both hemispheres during memory retrieval (P2) and in terms of accuracy. Altogether, these results confirm the critical role of the right hemisphere in perceiving faces and their expressions. Moreover, they suggest that familiarity and expression can interact in both directions.

Models of face processing suggest that extraction of facial identity and emotion involves parallel and independent visual systems [3, 11]. This assumption is supported by studies of brain-damaged patients [24], single-cell recordings [17], neuroimaging [21], and event-related potentials (ERPs) [5]. However, under some conditions, the two processes interact, as shown in healthy subjects during behavioral studies [7, 8, 20], neuroimaging studies [9, 10, 25], and ERP recordings [27].

Behavioral studies of aftereffects show that expression adaptation partially depends on perceptual features important for identity [7], whereas representations of facial identity are independent of variations in expression [8]. Likewise, fMRI studies provide evidence of a functional overlap between identity and expression processing [9, 10, 25]. One explanation of these results is that facial identity serves as a reference from which expressions are more easily derived [6, 9, 10].

Whereas facial identity processing allows recognizing familiar people, the two processes are not strictly identical. Indeed, some prosopagnosic patients show impaired recognition of familiar faces with preserved matching of unfamiliar faces and *vice versa* [29], suggesting that, at least partly, identity and familiarity recruits different neural pathways. Moreover, contrary to identity processing, some have found an expression effect on familiarity categorization and a familiarity effect on expression categorization, especially concerning happy faces [2, 27]. Thus, interactions between facial familiarity and facial expressions can occur in both directions.

Because of their fine temporal resolution, many ERP or magnetoencephalography (MEG) studies have been designed to investigate face processing. Sensitivity to faces emerges as early as 100 ms after stimulus onset during the P1 or M100 occipito-temporal responses [15] indexing a face detection stage. This first stage is followed by the N170 or M170 components 160 ms after stimulus onset, corresponding to discriminations of individual faces (for a recent review, see [18]). Later occipito-temporal ERP components such as the P2 or the N250 are modulated by identity and have been linked respectively to retrieval of a stored representation in memory [14] and to recognition [4, 23]. Likewise, sensitivity to facial expression occurs as early as 100 ms following stimulus onset in the P1 component [1], and in later stages indexed by the N170 [1, 5, 16], the P2 [22] and the N250 [16, 19].

Contrary to expectations, no interaction was described between familiarity and expression for the first perceptual components [5]. This discrepancy may be due to different attentional demands, and to trial-to-trial relations between stimuli, which may enhance overlapping of the two facial dimensions. Indeed, in ERP studies, subjects generally performed the two tasks in separate sessions with randomly counterbalanced stimuli [5], whereas studies finding an interaction between identity (or familiarity) and expression emphasize the role of selective attention and manipulate the link between subsequent faces [2, 7, 9, 20]. For example, Schweinberger et al. [20] used a Garner-type paradigm in which expression was correlated, constant, or orthogonal with identity when the subjects had to recognize faces. Likewise, there is a link between one stimulus and the next in studies using visual adaptation [7, 8], involving interference which cannot be observed with random presentations.

The goal of the present study was to evaluate familiarity and expression discriminations in a task-switching paradigm when occipito-temporal ERPs, reaction times (RTs), and errors are recorded. According to behavioral and neuroimaging studies [7, 8, 9, 10, 20, 25], an interaction between facial dimensions may occur when selective attention and relations between stimuli are manipulated. Thus, task-switching was used because the switch cost (slower and less accurate performance during switched trials) reflects control processes for selective attention [26, 28]. Furthermore, this paradigm allows establishing a link between stimuli at each switched trial, with the facial dimension overtly processed in the previous repeated trial remaining constant (competitor priming [26]). Moreover, to favor perceptual interactions, we used a task-cueing paradigm with a short cue-target interval in which control processes are more reliable to perceptual pathway specific reactive processes than general executive proactive ones [28]. Our main hypothesis is that familiarity and expression interact at both perceptual and behavioral levels during switched trials. More precisely, because familiarity and expression processing may interact in both directions [2, 27], we hypothesize that a familiarity effect is observable during switched expression discriminations, and that an expression effect is observable during switched familiarity discriminations.

Fifteen subjects (8 men, 7 women, mean age: 23 years, range 19 to 29) volunteered in the study, all of them were right-handed with normal or corrected-to-normal vision and had no previous history of neuropsychiatric illness. The stimuli consisted of 20 photographs of well-known celebrities

and 20 unknown faces, half of which had neutral expressions and the other expressed disgust, fear, anger, or sadness. The photographs were selected after a survey among 50 students, by which over 94% of them could recognize the face and the emotional expression. The images were calibrated at different levels of grey with a size of 8 cm x 6 cm and standardized for luminance and contrast with Adobe Photoshop® software. All faces were presented with a full frontal view on a grey background in the middle of a computer screen.

The subjects were seated in a quiet and dark room at a distance of 90 cm from the computer screen, where faces have a size of $5.1^\circ \times 3.8^\circ$ of visual angle. Two tasks were performed alternatively in a switching paradigm in which the nature of the task was given by a specific verbal visual cue ("Familiarity" or "Expression") lasting 50 ms and followed by a blank-screen lasting 250 ms before presentation of each stimulus (cue-target interval of 300 ms). In the familiarity task, the subjects were asked to identify whether the face was known or not. In the emotional expression task, the subjects were asked to identify whether the face expressed an emotion or not. For both tasks, each stimulus lasted 1000 ms and responses were recorded after stimulus onset by pressing right or left sides of a computer mouse with either the right or left hand (randomized between subjects and between tasks). After each response, the screen went blank for a random duration (1000~1500 ms).

The subjects performed 32 blocks of 21 trials. For each block, the first trial was neutral (T), followed by a repeated (R) trial and then by a related switched (S) trial as follows: T; R-S; R-S; etc. Each R-S pair was designed with a competitor priming [26]: the dimension overtly processed in the R trial remaining constant in the next S trial (e.g. R trial performed in the expression task with a fearful face was followed by an S trial performed in the familiarity task with another fearful face irrespective of identity). All R-S pairs were randomly presented. Thus, relations between subsequent stimuli were controlled when performing a repeated trial. The subjects were allowed to rest between each block and instructed to give their answers as quickly and as precisely as possible.

EEG was recorded from 32 electrodes according to the 10-10 classification system with a reference electrode placed in a frontocentral position (AFz). A common average reference was recalculated off-line from the following 20 electrodes: F3, F4, F7, F8, C3, C4, CPz, Cz, Pz, Fz, T7, T8, TP7, TP8, P7, P8, P3, P4, CP3, and CP4. The EEG was amplified (resolution: $0.16 \mu\text{V}$; band-pass:

high-pass with a 1 s time constant and low-pass equal to 100 Hz), digitized at a rate of 256 Hz, and stored on a Deltamed™ system. Electrode impedance was kept below 5 k Ω . Codes were synchronized to stimulus delivery and used for averaging sample epochs offline. ERPs averaging were made for 1250 ms, including a 250 ms baseline before stimulus onset and a 1 s interval after stimulus onset. ERPs were extracted by averaging separate trials for all subjects and for each experimental condition and electrode. During the averaging procedure, trials contaminated with ocular movements or artifacts (>100 μ V) were rejected and data were low-pass filtered (cut-off: 40 Hz).

Only RTs ranging between 300 and 1500 ms were taken into account. Because our specific hypotheses depend on the task, repeated measure ANOVAs were separately performed for each task on RTs and error rates with Statistica™ software (Statsoft, France, 1998) for three main factors: *Trial* (repeated, switched), *Familiarity* (unknown, celebrities), and *Expression* (neutral, expressive). The electrophysiological data were occipito-temporal ERP components maximal for electrodes P7 (left hemisphere) and P8 (right hemisphere). Mean amplitudes were analyzed at four temporal windows (90-130 ms; 150-190 ms; 210-250 ms; 260-300 ms) corresponding to the P1, N170, P2, and N250 components. Repeated-measure ANOVAs were used for each task with the same main factors as the behavioral part in addition to the *Electrode* factor (P7, P8). Whenever necessary, planned comparisons were made.

Electrophysiological results showed no effect for the P1 component, indicating that the processing of familiarity and expression did not interact during this stage of face detection [15]. Because many effects appeared during the following time windows and in the behavioral data, Table 1 depicts main effects and interactions for these results. Only effects related to our hypotheses will be described.

For the N170 component, celebrities elicited more negative amplitudes than unknown faces in the familiarity task (celebrities minus unknown: -0.73 μ V) as did expressive faces compared to neutral ones when subjects discriminated emotional expression (expressive minus neutral: -0.74 μ V). Grand average ERPs at P7 and P8 for the *familiarity* effect in the familiarity task and for the *expression* effect in the expression task are depicted in Fig. 1. Most importantly in this time frame, three-way *trial* x *familiarity* x *expression* interactions were observed in both tasks. No interaction was found in repeated

trials, whereas three-way *familiarity x expression x electrode* interactions in both tasks were observed in switched trials. In the left hemisphere (P7), there was no significant interaction, but an interaction occurred between familiarity and expression for both tasks in the right hemisphere (P8: Familiarity task: $F(1,14)=6.90$, $p=0.02$; Expression task: $F(1,14)=5.14$, $p=0.04$). As hypothesized, there was a significant *expression* effect in the familiarity task but only for unknown faces ($p=0.009$; unknown expressive minus unknown neutral: $-0.63 \mu\text{V}$), while in the expression task, there was a *familiarity* effect only for expressive faces ($p=0.003$; celebrities expressive minus unknown expressive: $-0.84 \mu\text{V}$). Fig. 2 presents grand average ERPs during switched trials at P7 and P8 for the *expression* effect in the familiarity task depending on the familiarity of the face and for the *familiarity* effect in the expression task depending on the expression of the face. The right-lateralized interactions in the N170 time frame are indicated with arrows.

In the same fashion as the N170, *familiarity* effects were observed in the familiarity task for the two later ERP components (celebrities minus unknown: $-1.20 \mu\text{V}$ and $-1.26 \mu\text{V}$ for the P2 and the N250 respectively; Fig. 1) and *expression* effects in the expression task (expressive minus neutral: $-1.62 \mu\text{V}$ and $-0.98 \mu\text{V}$ for the P2 and the N250 respectively; Fig. 1). Most importantly, *trial x familiarity x expression* interactions appeared in these two time windows due to *familiarity x expression* interactions found in both tasks only for switched trials (Fig. 2). As observed at around 170 ms in the right hemisphere (P8), these interactions are explained by an *expression* effect for the unknown faces in the familiarity task (unknown expressive minus unknown neutral: $-0.79 \mu\text{V}$, $p=0.014$ and $-0.40 \mu\text{V}$, $p=0.02$ for the P2 and the N250 respectively) and a *familiarity* effect for the expressive faces in the expression task (celebrities expressive minus unknown expressive: $-0.70 \mu\text{V}$, $p=0.014$ and $-0.47 \mu\text{V}$, $p=0.016$ for the P2 and the N250 respectively).

Behavioral results show that celebrities were processed faster and more accurately than unknown faces in the familiarity task (celebrities minus unknown for RTs: -65.6 ms; for errors: -3.8% ; Fig. 1) as did neutral faces compared to expressive ones in the expression task (neutral minus expressive for RTs: -55.5 ms; for errors: -3.9% ; Fig. 1). Most importantly concerning errors, *trial x familiarity x expression* interactions were further identified, showing that *familiarity x expression* interactions appeared in both tasks only for switched trials (Fig. 2). Supporting our hypotheses and as

found for ERPs, an *expression* effect in the familiarity task and a *familiarity* effect in the expression task were observed. In the familiarity task, expressive unknown faces were more accurately discriminated than neutral ones (-3.7%, $p=0.028$) and in the expression task, an advantage was found for expressive celebrities compared to expressive unknown faces (-6.3%, $p=0.001$).

Overall, the ERP results confirm our hypotheses and indicate that facial familiarity and expression interact in the right hemisphere at approximately 170 ms after stimulus onset during switching to familiarity and expression tasks with competitor priming. These interactions gain both hemispheres at around 230 ms. The first interaction appears during the N170 component, a correlate of face/expression discrimination [1, 4 5 14 16], probably because the subjects had to discriminate familiarity and expression. The time course of familiarity and expression processing may differ depending on task parameters (passive viewing or recognition of faces) and then one process may differently influence the other [2].

Our results also indicate that the right hemisphere is critical for early identity/expression overlapping. According to Joyce et al. [13], the N170 amplitude is correlated with detection of diagnostic facial cues. Hemispheric differences have mainly been explained by the right/holistic vs. left/analytic processing of faces. This right hemisphere advantage in holistic processing is found in ERP studies of the well-known inversion effect, the composite illusion or both [12]. It is possible that in the present study right/holistic processing first encoded the face as a whole (a "gestalt"), including both familiarity and expression diagnostic facial features. In contrast, left/analytic processing of faces is defined by featural perceptual mechanisms which selectively process one part of the face. Thus, we suggest that the left hemisphere selectively processes familiarity or expression diagnostic features as a function of the task, as opposed to the right hemisphere which processes the global face in the two tasks. We do not suggest that this hemisphere is task-independent, because the right-lateralized interactions were not the same for both tasks, but the two facial dimensions perhaps are always processed and represented in this hemisphere.

Behavioral results indicate that subjects were more accurate and faster in discriminating celebrities than unknown faces in the familiarity task and neutral faces than expressive ones in the expression task. Furthermore, during switched trials, emotional expression of an unknown face

reduced errors in the familiarity task, while familiarity did the same among expressive faces in the expression task, confirming our two hypotheses. When emotional expression influences familiarity recognition, an advantage for familiar faces expressing happiness was found [2, 27]. Baudouin and collaborators entitled their study "When the smile is a cue to familiarity". Conversely, in the present study, fewer errors were found for unknown faces with negative expressions. This result suggests that negative expressions may act as cues to unfamiliarity. Interactions between familiarity and expression may be dependent of the emotional valence of the expression. Three types of emotions (positive, neutral, negative) should be used in future studies to investigate this hypothesis. In the expression task, celebrities permit the better detection of negative expressions. According to behavioral and fMRI studies [7, 8, 9, 10, 20, 25], facial identity serves as a reference from which expressions are more easily derived. This identity-dependent processing of expression [8, 10] may prime the retrieval of a familiar representation of the expression in memory. As hypothesized, our behavioral data show that familiarity and expression of faces interact in subjects' accuracy in both directions when selective attention and relations between stimuli are manipulated.

It should be pointed out that the specific roles of selective attention (switching) and relations between stimuli (competitor priming) are not distinguished by these results. That is, switching with competitor priming classically deteriorates performance [26]. However, in the present study, a classical switch cost was found only for RTs (switched minus repeated trials for familiarity task: 76.6 ms; for expression task: 73.6 ms; Table 1) and did not interact with facial discriminations. In contrast for errors, expressive unknown faces in the familiarity task and expressive famous faces in the expression task were better performed during switched trials, such an effect being the opposite of the switch cost. In the study of Waszak and collaborators [26], competitor priming is created between two unrelated dimensions (a word and a picture). Conversely, in the present study, the two dimensions are related (and appear to interact), and one can prime the processing of the other. These results suggest that specific relations between subsequent stimuli designed in this task-switching may explain facial interactions rather than switching only. Nevertheless, we assume that the specific roles of each manipulation must be further investigated.

Another methodological point is that we chose to use four expressive stimuli to avoid an adaptation effect, but their variability relative to neutral faces may be the cause of the superior discrimination of the latter, and may also bias effects observed on ERPs. However, if we do not take into account differences between expressive and neutral faces, interactions remain between celebrities and expression in the expression task and between unknown faces and expression in the familiarity task, which confirm our hypotheses, despite a possible effect of item novelty.

In conclusion, our experiment revealed interactions between facial familiarity and expression starting in the right hemisphere at around 170 ms after face presentation when subjects discriminated either familiarity or emotional expression during switched trials when the unattended dimension was previously attended. These interactions appear in both hemispheres at around 230 ms after stimulus onset and are observed as well in errors. This experiment confirms previous findings on the major role of the right hemisphere in perceiving many facial dimensions. It should be noted that ERPs cannot precisely localize neural activities. Techniques with higher spatial resolutions must be conducted. Because this study used specific switched discriminations tasks, future studies must indicate whether other interactions appear depending on task parameters (e.g. depth of processing), procedure (e.g. attentional load and relations between stimuli), emotional valence, stimulus variance.

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Figure and table legends

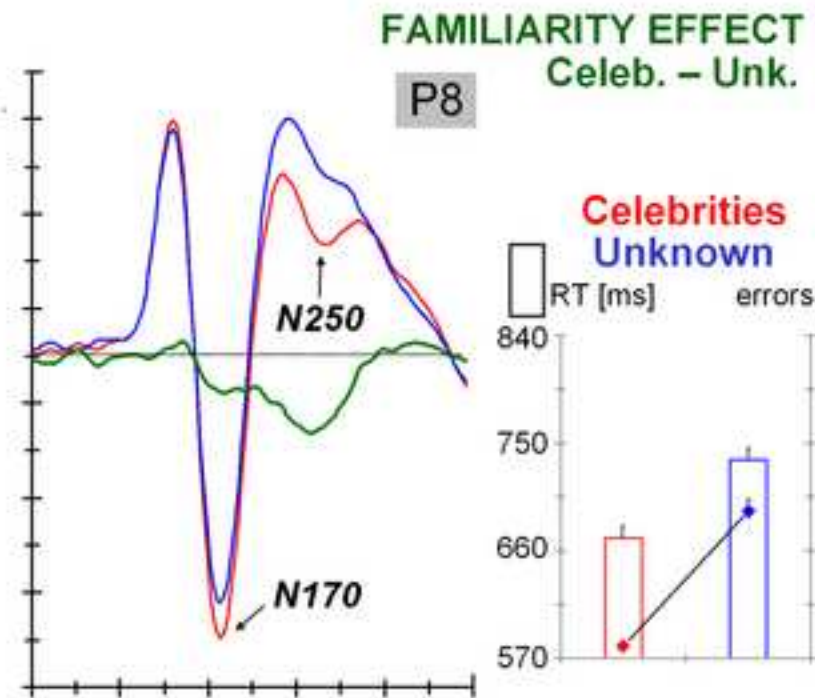
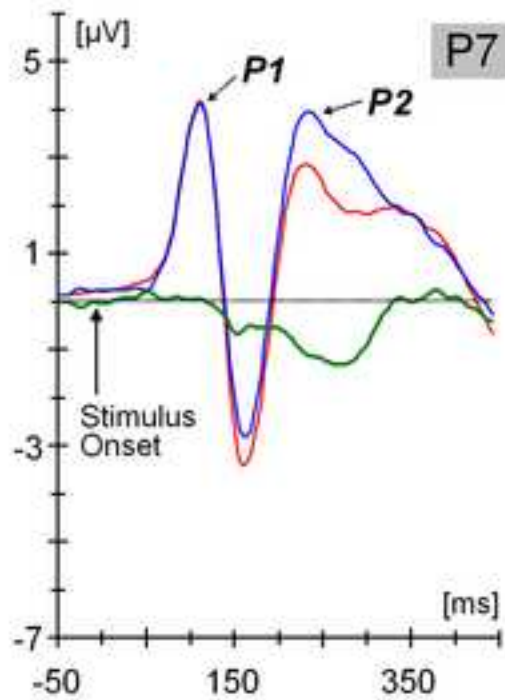
Table 1 Main effects and interactions for electrophysiological and behavioral ANOVAs depending on the tasks.

Fig. 1 Grand average ERP waveforms at two occipito-temporal electrodes (P7 in left hemisphere; P8 in right hemisphere) and mean reaction times and errors (bars represent standard errors) elicited in the familiarity task for celebrities and unknown faces (top) and in the expression task for expressive and neutral faces (bottom). Note the subtraction waveforms corresponding to the *familiarity* effect (celebrities minus unknown) at the top and to the *expression* effect (expressive minus neutral) at the bottom.

Fig. 2 Grand average ERP waveforms at P7 and P8 and mean reaction times and errors (bars represent standard errors) elicited by the *expression* effect (expressive minus neutral: subtraction waveforms) in the familiarity task (left) for the celebrities (top) and unknown faces (bottom) and by the *familiarity* effect (celebrities minus unknown: subtraction waveforms) in the expression task (right) for the expressive (top) and neutral faces (bottom) during switched trials. Note the arrows showing the early right-lateralized interactions during the N170 time window.

Figure1
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Familiarity task



Expression task

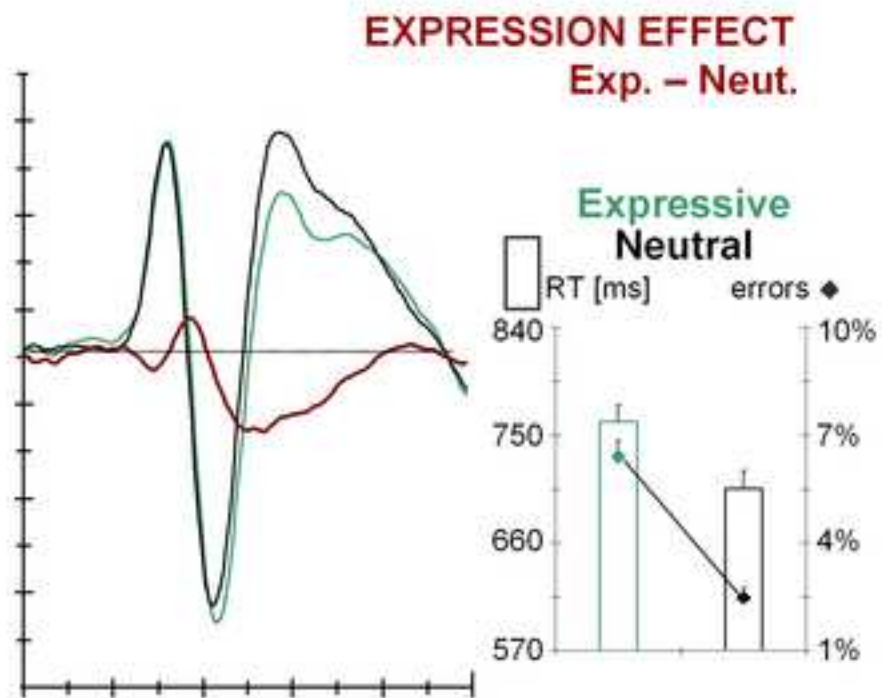
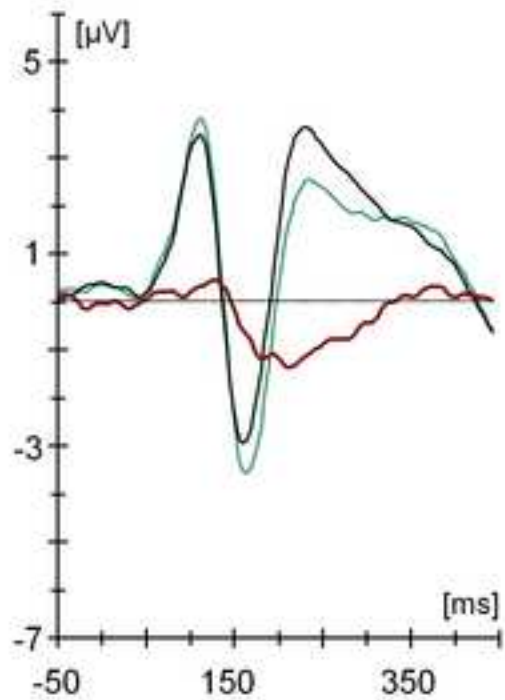


Figure 2

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SWITCHED TRIALS

Familiarity task

EXPRESSION EFFECT (Exp. - Neut.)

Expression task

FAMILIARITY EFFECT (Celeb. - Unk.)

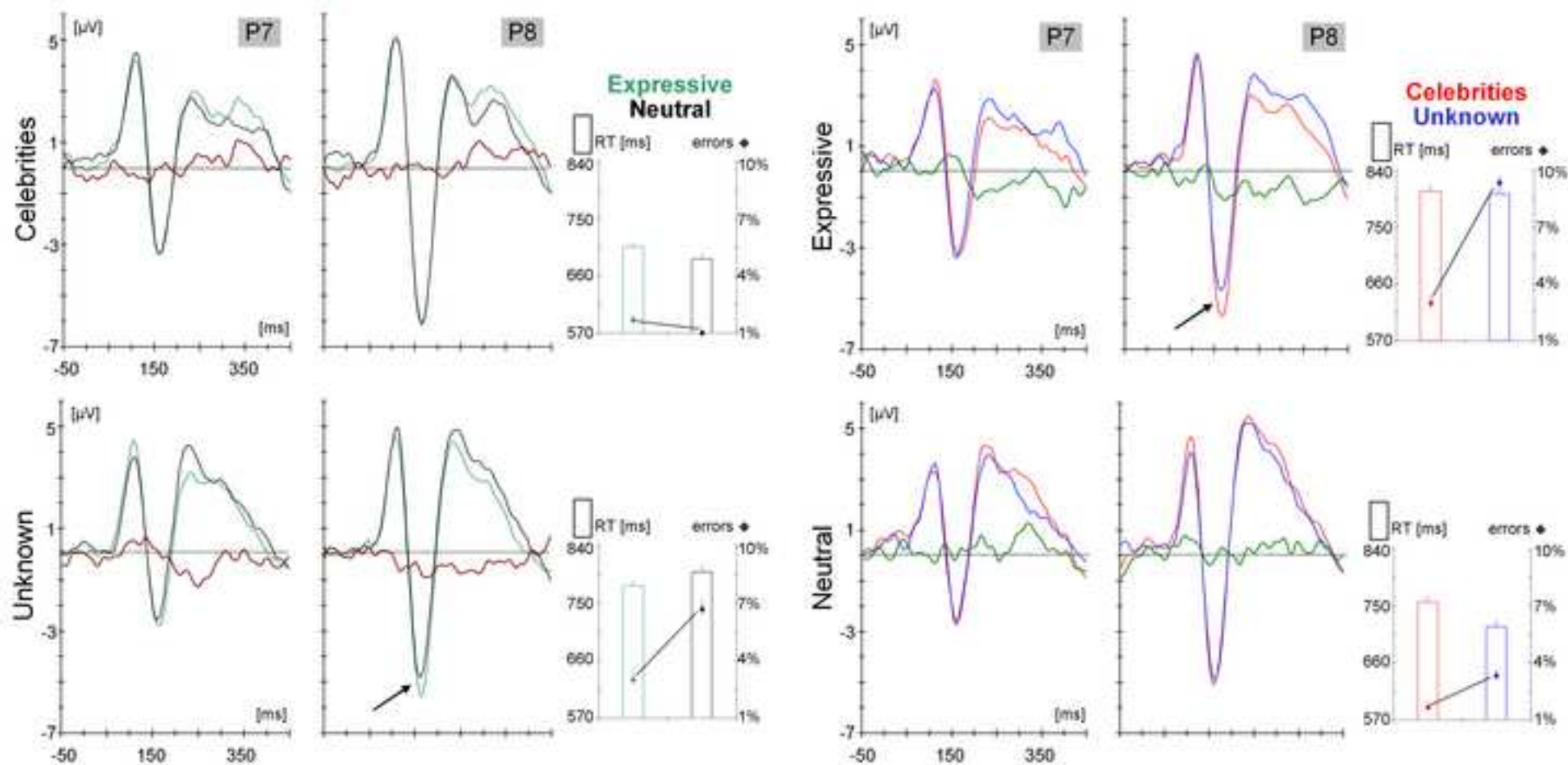


Table1

Familiarity task		<i>F</i>	<i>p</i>	Expression task		<i>F</i>	<i>p</i>
ERPs							
N170	<i>Electrode</i>	6.99	0.019	<i>Trial</i>	15.09	0.002	
	<i>Familiarity</i>	25.03	0.0002	<i>Expression</i>	10.18	0.007	
	<i>Trial x Familiarity x Expression</i>	12.57	0.003	<i>Trial x Familiarity x Expression</i>	8.09	0.013	
P2	<i>Trial</i>	15.29	0.002	<i>Expression</i>	112.6	<0.0001	
	<i>Familiarity</i>	58.69	<0.0001	<i>Trial x Familiarity x Expression</i>	7.60	0.015	
	<i>Trial x Familiarity x Expression</i>	4.53	0.051				
N250	<i>Familiarity</i>	28.19	0.0001	<i>Trial</i>	11.07	0.005	
	<i>Trial x Electrode</i>	5.02	0.042	<i>Electrode</i>	4.95	0.043	
	<i>Trial x Familiarity x Expression</i>	4.49	0.053	<i>Expression</i>	17.73	0.0009	
				<i>Trial x Familiarity x Expression</i>	5.44	0.035	
Behavior							
RTs	<i>Trial</i>	38.42	<0.0001	<i>Trial</i>	22.40	0.0003	
	<i>Familiarity</i>	33.32	<0.0001	<i>Expression</i>	52.66	<0.0001	
Errors	<i>Familiarity</i>	16.71	0.001	<i>Expression</i>	14.52	0.002	
	<i>Trial x Familiarity x Expression</i>	7.80	0.014	<i>Trial x Familiarity x Expression</i>	4.51	0.052	
Repeated trials							
ERPs							
N170	<i>Electrode</i>	6.97	0.019	<i>Expression</i>	7.94	0.014	
	<i>Familiarity</i>	9.42	0.008				
P2	<i>Familiarity</i>	29.68	<0.0001	<i>Expression</i>	59.85	<0.0001	
N250	<i>Familiarity</i>	53.43	<0.0001	<i>Electrode</i>	5.56	0.034	
				<i>Expression</i>	9.14	0.009	
Behavior							
RTs	<i>Familiarity</i>	10.22	0.006	<i>Expression</i>	8.75	0.01	
Errors	<i>Familiarity</i>	10.79	0.005	<i>Expression</i>	11.71	0.004	
Switched trials							
ERPs							
N170	<i>Electrode</i>	6.90	0.02	<i>Expression</i>	5.73	0.031	
	<i>Familiarity</i>	5.10	0.04	<i>Familiarity x Expression x Electrode</i>	8.77	0.01	
	<i>Familiarity x Expression x Electrode</i>	11.98	0.004				
P2	<i>Familiarity</i>	32.13	<0.0001	<i>Expression</i>	93.07	<0.0001	
	<i>Familiarity x Expression</i>	7.47	0.016	<i>Familiarity x Expression</i>	10.95	0.005	
N250	<i>Familiarity</i>	7.79	0.014	<i>Expression</i>	20.32	0.0005	
	<i>Familiarity x Expression</i>	5.12	0.04	<i>Familiarity x Expression</i>	8.64	0.011	
Behavior							
RTs	<i>Familiarity</i>	45.67	<0.0001	<i>Expression</i>	54.11	<0.0001	
Errors	<i>Familiarity</i>	7.98	0.014	<i>Expression</i>	8.73	0.01	
	<i>Familiarity x Expression</i>	6.13	0.027	<i>Familiarity x Expression</i>	4.70	0.048	