

# Electrophysiological analysis of the affective congruence between pattern regularity and word valence



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## ABSTRACT

Reflection symmetry is an important property of human designs and biological organisms, and it is often judged to be beautiful. Previous reaction-time based studies have shown a *congruency effect*, where reflection symmetry facilitates processing of positive words, and random patterns facilitate negative words. But what is the neural basis of affective responses to symmetry? In Experiment 1 we recorded ERPs from posterior electrode clusters while participants viewed reflection or random patterns with either a positive or negative word superimposed. In the Discriminate Regularity task, participants categorized the patterns (reflection or random). In the Discriminate Word task, they categorized the words as positive or negative. In Experiment 2, participants classified words and patterns on each trial. We found a difference between ERP waves from *congruent* (reflection with positive word, random with negative word) and *incongruent trials* (reflection with negative, random with positive). This *congruency effect* began around 200 ms, and persisted up to 1000 ms post stimulus, and was only present in the Discriminate Word task. We suggest that when evaluating words, participants automatically evaluate the background pattern as well, and this alters early visual processing.

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## 1. Introduction

Symmetry is linked to beauty, and is associated with positive valence. In this study we explore the visual processing of symmetry using a paradigm in which symmetric patterns are presented together with positive or negative words. It has been suggested that reward mechanisms exist along all stages of visual processing and that these networks produce aesthetic experiences. Therefore, we predicted that event related potentials should respond to congruency between visual regularity and word valence.

## 2. Perception of symmetry

The artificial environment created by humans is full of symmetrical designs. Symmetry appears in visual art and architecture (Carlson, 1999), but also in literature and music (Ball, 2008), where it overlaps with terms like “harmony”, “proportion” and “balance”. Moreover, symmetry is everywhere in the biological world. The origin of life rises from a fascinating strategy of the eukaryotic genome: the mitotic spindle. Thanks to its mirror symmetrical

configuration, cells replicate in two identical copies. Moreover, a rigid genetic coding tuned to symmetry controls the distribution of cells bilaterally along the main axis during the embryogenesis of most species. If development is unimpeded, most animals become anatomically symmetrical, and thus symmetry is also an indicator of mate quality (Møller, 1992; Møller & Thornhill, 1998; Swaddle & Cuthill, 1994). A preference for symmetry is well documented in several animal species, such as finches (Swaddle & Cuthill, 1994), honeybees, chicks (Clara, Regolin, & Vallortigara, 2007; Wignall, Heiling, Cheng, & Herberstein, 2006) and gazelles (Møller et al., 1996). Humans also perceive symmetrical faces and bodies as more attractive (Bertamini, Byrne, & Bennett, 2013; Rhodes et al., 1998; Cárdenas & Harris, 2006).

The visual system perceives symmetry efficiently (Treder, 2010; Tyler, 1995; Wagemans, 1995; Barlow & Reeves, 1979; Palmer & Hemenway, 1978; Bruce & Morgan, 1975); possibly because the strict correspondence of position, shape and measure along a central axis fosters the economy of processing (Koffka, 1935/1962). Gestalt psychologists assigned a high level of “goodness” to symmetrical patterns (Wertheimer, 1923; Koffka, 1935/1962) and Palmer (1991) confirmed that symmetrical structures are rated high in “goodness”. Preference for symmetry can also be explained by the *fluency hypothesis* (Winkielman, Schwarz, Fazendeiro, & Reber, 2003), which states that people are sensitive to the ease of their own perceptual or cognitive operations, and that fluent

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processing is experienced as hedonically positive (Reber, Schwarz, & Winkielman, 2004; Reber, Wurtz, & Zimmermann, 2004).

There have been several neuroimaging studies looking at symmetry (see Treder, 2010). Functional MRI studies have discovered symmetry-related activations in the Lateral Occipital Cortex (Tyler et al., 2005; Sasaki, Vanduffel, Knutsen, Tyler, & Tootell, 2005) and other extrastriate regions like V3a, V4, V7 (Sasaki et al., 2005). Of particular interest for our work, Jacobsen and Hofel (2003) reported a symmetry related ERP component at occipital sites, called the Sustained Posterior Negativity (SPN). After the visual evoked potential, amplitude was more negative for symmetrical than random patterns, at least up to 1100 ms post stimulus onset. The authors suggested that the SPN results from accurate and sustained visual analysis of the pattern before deciding whether it was symmetrical. However, the SPN can also be recorded when participants do not attend to regularity (Hofel & Jacobsen, 2007) and when either random or reflection patterns are targets (Makin, Wilton, Pecchinenda, & Bertamini, 2012b). The LORETA source localization technique identified the SPN neural generator in the lateral extrastriate visual cortex (Makin et al., 2012b), providing evidence that the brain regions identified in fMRI studies generate this ERP.

Makin et al. (2013) further demonstrated that the SPN is sensitive to different visual regularities: reflection, rotation and translation. However, reflection symmetry seems to be the preferred stimulus for visual regularity detectors, producing the largest SPN. This is in agreement with psychophysical studies, which have repeatedly shown reflection symmetry to be the most salient regularity (Makin, Pecchinenda, & Bertamini, 2012a; Bertamini, Friedenber, & Kubovy, 1997; Friedenber & Bertamini, 2000).

Other studies have focused on the emotional reaction to symmetry. For example, Bertamini, Makin, and Pecchinenda (2013a) used an affective priming procedure where symmetrical or random patterns were briefly presented, and then a word appeared. Participants had to classify the word as positive (e.g. Love) or negative (e.g. Hate) as quickly as possible. It was predicted that people would have been quicker to respond in the *congruent conditions*, where a positive word followed a symmetrical pattern or a negative word followed a random pattern than, in the *incongruent conditions* (symmetry then negative or random then positive). The expected reaction time advantage for congruent conditions was found, but only when participants had to attend to the prime as well as the word. Nevertheless, these results confirmed a link between the symmetry-random and positive-negative dimensions. It might be possible this happened at the level of conceptual categories, and the results do not have to be explained by an immediate affective response to the stimuli (but see Pecchinenda, Bertamini, Makin, & Ruta, 2014, for behavioral evidence for automatic affective responses).

The current work re-examined the congruence effects found in affective priming studies by using EEG techniques. The experiment was a modified version of the affective picture-word interference task (Stroop, 1935; Glaser & Dungelhoff, 1984; Houwer & Hermans, 1994) in which two stimuli – a target and a distractor – are presented superimposed. There are four possible relations between pictures and words: both target and distractor have positive or negative valence (*congruent conditions*); target is positive and distractor is negative or target is negative and distractor is positive (*incongruent conditions*). It is possible that presenting words and patterns superimposed would induce participants to process regularity and valence dimensions simultaneously.

We hypothesized that the brain is sensitive to the difference between congruent trials (reflection with positive word; random with negative word) and incongruent trials (reflection with negative word; random with positive word). We recorded Event Related Potential (ERP) waveforms produced by congruent and incongruent conditions.

The *congruency effect* was explored on several ERP components and time-windows, where previous research has demonstrated ERP responses to regularity or valence independently. We mainly focused on the Sustained Posterior Negativity, which is known to be sensitive to symmetry and sustained for the whole exposure time of the stimulus. If congruence sensitive potentials overlapped considerably with the SPN, it would suggest that visual networks that are sensitive to symmetry are also sensitive to valence.

We also focused ERP components usually modulated by emotional variables. The Early Posterior Negativity (EPN) is the first ERP response to the emotional content of visual stimuli. It peaks around 200–300 ms after stimulus onset with later occipital scalp distribution (see Citron, 2012; Hajcak, MacNamara, & Olvet, 2010). The EPN responds preferentially to high emotional valence and arousal, and is larger for stimuli with either positive or negative valence than stimuli with neutral valence (Junghofer, Bradley, Elbert, & Lang, 2001; Schupp, Junghofer, Weike, & Hamm, 2004a; Schupp et al., 2004b; Schacht & Sommer, 2009a,b; Scott, Donnell, Leuthold, & Sereno, 2009). This emotional response is thought to be automatic and effortless (Kissler, Herbert, Winkler, & Junghofer, 2009) and could reflect spontaneous attention capture by emotionally salient stimuli (Schupp et al., 2007; Schacht & Sommer, 2009a,b). ERPs associated with early emotion discrimination and symmetry recognition share similar topography, and the SPN begins around the same time of the EPN. If the congruent/incongruent difference emerges at this early time point, it would suggest the evaluation of the patterns happens immediately after the initial visual analysis is complete.

We also analyzed the Late Posterior Positivity (LPP), or Late Positive Complex (LPC). LPP belongs to a group of positive components associated to explicit evaluation of a stimulus (Citron, 2012). Contrarily to EPN, LPP has been found only when the emotional content of the stimuli was task-relevant or when semantic processing was required (Fischler & Bradley, 2006). It peaks between 500 and 800 ms over centro-posterior regions (Citron, 2012; Hajcak et al., 2010) and its amplitude is consistently larger for emotional stimuli than neutral (Hinojosa, Mendez-Bertolo, & Pozo, 2010; Kanske & Kotz, 2007; Schacht & Sommer, 2009a). This component seems to be more sensitive to differences in valence than EPN, with greater positivity bias in some cases (Herbert, Kissler, Junghofer, Peyk, & Rockstroh, 2006; Herbert, Junghofer, & Kissler, 2008; Kissler et al., 2009) but greater negative bias in others (Schacht & Sommer, 2009b; Kanske & Kotz, 2007). Because LPP is associated to voluntary evaluation of emotion, a *congruency effect* observed on LPP, would indicate the link between symmetry/random and positive/negative dimensions happens at a later conceptual level.

Additionally, possible alterations of Visual Evoked Potentials (VEP) were also contemplated. After all, the N1 component is sensitive to regularities (Makin et al., 2012b) with greater amplitude for reflection and rotation patterns than random or translation patterns (Makin et al., 2013). N1 amplitude modulations have also been observed in response to arousing and valenced words (Kissler et al., 2009; Scott et al., 2009). In light of previous literature showing N1 sensitivity to both pattern regularity and word valence, we investigated whether N1 amplitudes would differ between congruent and incongruent trials.

This study consisted of two experiments. Experiment 1 was divided in two tasks. Half of the subject classified the valence of the words in the first task, and classified the regularity of the pattern in the second task. The other half of subjects performed the same tasks but with opposite order. In Experiment 2, all participants attended to word valence and pattern regularity simultaneously. After each trial, they classified either regularity or word valence, but they did not know in advance which response was required (for this reason, they were forced to pay attention to both patterns and words). We considered this to be an

important factor, since previous studies suggest that symmetry and words must be attended to produce a *congruency effect* (Bertamini et al., 2013b).

### 3. Experiment 1

In Experiment 1, stimuli consisted of black and white abstract patterns with a two-fold reflectional symmetry or random organization. These patterns were generated in the same way as those presented in Bertamini, Makin, and Rampone (2013b). All patterns had a word with either positive or negative valence superimposed on them (Fig. 1).

Experiment 1 consisted of two tasks. In one task participants attended to the regularity dimension, and pressed one button for reflection and the other for random (we will name it the Discriminate Regularity task). In the other task participants classified word valence. They pressed one button for positive and another button for negative (Discriminate Word task). Half of subjects performed the Discriminate Regularity task first and Discriminate Word task second, while the order was switched for the other participants.

We focused our analysis on ERPs described in previous literature. First, We were interested in whether the amplitude of Sustained Posterior Negativity (SPN), which is sensitive to symmetry, would differ on congruent and incongruent trials. Second, we explored possible modulations of ERP usually involved in the processing of valence, such as EPN and LPP. In addition, we also investigated whether congruent and incongruent conditions would alter visual evoked potentials, like P1 and N1.

## 4. Methods

### 4.1. Participants

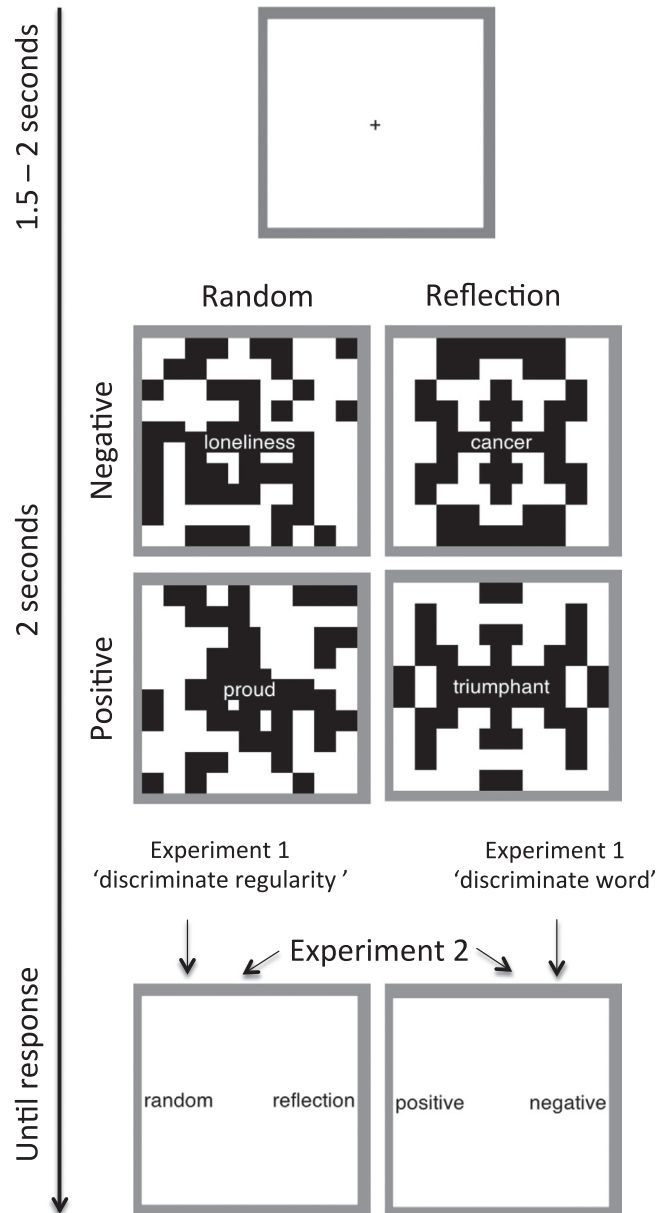
Forty participants were involved in this study (aged 18 to 40, 9 males, 3 left handed). Participants had normal or corrected to normal vision. The study had local ethics committee approval and was conducted in accordance with the Declaration of Helsinki (revised 2008).

### 4.2. Apparatus

EEG was recorded using a BioSemi Active-Two amplifier in an electrically shielded, and darkened room. EEG was sampled continuously at 512 Hz from 64 AgCl scalp electrodes arranged according to the international 10–20 systems. Two additional electrodes, called *Common Mode Sense* (CMS) and *Driven Right Leg* (DRL) were used as reference and ground. Bipolar VEOG and HEOG electrodes were positioned above and below the right eye, and on the outer canthi of both eyes, respectively. The EOG data was obtained from 4 external channels of the same BioSemi amplifier.

### 4.3. Stimuli

Stimuli were generated using the *Psychopy* software (Peirce, 2007) and presented on a CRT monitor with resolution 1280 by 1024 pixel at 60 Hz. The stimuli consisted of patterns generated from a black and white checkerboard (10 × 10). New patterns were created in each trial so that there was never a repetition of the same pattern. The square was approximately 10° of visual angle. Words were selected from the Affective Norms for English Words (ANEW) database (Bradley & Lang, 1999), which provides standardized valence, frequency and arousal scores for each word. There were 72 negative words ( $M=1.90$ ) and 72 positive words ( $M=8.17$ ), with the valence difference highly significant ( $p < 0.001$ ). These words were matched for mean frequency and arousal ( $p > 0.26$ ). A complete list of the words is provided in supporting material for Bertamini et al. (2013). There were four possible combinations of stimuli, as shown in Fig. 1: random with negative words (*random-negative*), random with positive words (*random-positive*), reflection with negative words (*reflection-negative*) and reflection with positive words (*reflection-positive*).



**Fig. 1.** Trial structure of the Experiments. In both Experiments trials began with a fixation screen of variable duration from 1.5 to 2 s. Stimuli were presented at fixation for 2 s. They consisted of abstract novel patterns, reflection or random, superimposed on a word with positive or negative valence. Therefore there were four possible combinations: *random-negative* and *reflection-positive* were the congruent conditions; *random-positive* and *reflection-negative* were the incongruent conditions. In the Discriminate Word task of Experiment 1, the response-screen asked participants to report the valence of the word as positive or negative. In Discriminate Regularity task of Experiment 1, the response-screen asked them to report the patterns as random or reflection. In Experiment 2, one of the two response-screens might appear after stimulus presentation, and participants could not predict which judgment would be required when viewing the stimuli. The position of words on the response screen indicated whether to press the left or right button to enter a particular response. Positioning was reversed in half the trials.

### 4.4. Procedure

Participants sat 140 cm from the monitor with no head constraint or chin rest. After the electrodes were attached, participants were told to fixate on a central cross during the baseline period and when the patterns were on the screen.

Participants used the 'A' and 'L' buttons of a computer keyboard to enter their responses. Each trial started with a variable inter trial interval (ITI, 1.5 to 2 s) in which a fixation cross was presented. After this, a black and white pattern with a valence word written on the top was presented and remained on the screen for 2 s. The trial structure is shown in Fig. 1.



In the Discriminate Regularity task, at the end of each trial the response screen asked to report the regularity of the pattern (“Reflection...Random” or “Random...Reflection”). In Discriminate Word task, participants saw a similar response screen and were required to report the valence of the word (“Positive...Negative” or “Negative...Positive”). The left or right position of the words on the response screen varied between trials, and the position indicated which key to press. For example, if the word Reflection was on the left of the response screen, and the pattern was a reflection, then the correct key was the left key. The configuration of the response screen was counterbalanced across other factors and not predictable for the participants. Participants, therefore, did not know which hand to respond with until the response screen appeared. This procedure was the same used in [Makin et al. \(2012b\)](#) to prevent the development of lateralized motor preparation potentials during the stimulus presentation ([Murray et al., 2004](#)).

Each task consisted of 144 trials and was divided into four blocks of 36 trials each. Participants were allowed to take a break to rest between blocks. The tasks followed one after the other with a longer break between them. A practice session, of 20 trials, preceded each task and reproduced the design of the experiment to ensure participants understood the instructions.

#### 4.5. EEG analysis

We used the EEGLAB toolbox in Matlab to analyze the EEG trace offline. Raw data from 64 scalp electrodes were re-referenced to a scalp average, and low pass filtered at 25 Hz. Data was resampled at 128 Hz to reduce file size, and segmented into  $-0.2$  to  $+2$  s epochs, with a  $-0.2$  to 0 s baseline. After this, Independent Components Analysis ([Jung et al., 2000](#)) was used to remove artifacts produced by blinks and eye movements. Data was reformed as 64 components, and an average of 7.85 components were removed from each participant (min=4, max=13). After ICA, trials with amplitude greater than  $\pm 100 \mu\text{V}$  at any electrode were excluded.

The average proportion of excluded trials did not differ significantly between any of the conditions analyzed in both tasks (ranging between 11% and 13% of excluded trials).

Participants were instructed to fixate throughout the trials, and the ICA procedure was employed to eliminate eye movement artifacts. However, this is not enough to remove the cortical consequences of eye movements from the ERP signal. We thus analyzed the activation of horizontal and vertical eye movements channel in all conditions. EOG raw data were epoched ( $-0.2$  to 1 s) but were not subjected to any other treatment. Mean EOG activity for the conditions did not differ in any of the two tasks ( $p > 0.1$ ). This analysis was necessary to ensure eye artifacts did not distort the results.

In line with previous research on symmetry-related ERPs ([Makin et al., 2013](#); [Makin et al., 2012b](#)) and emotion words ERPs ([Scott et al., 2009](#)) we measured amplitudes of specific ERP deflections in the following time intervals: P1 from 100 to 130 ms, N1 from 170 to 200 ms, Sustained Posterior Negativity from 250 to 1000 ms ([Makin et al., 2012b](#)), EPN component was analyzed at the time window 200–300 ms ([Kissler, Herbert, Peyk, & Junghofer, 2007](#); [Scott et al., 2009](#)). Grand-average ERPs were computed across four posterior electrodes on the right hemisphere (P6 P8 P10 P08) and homologous electrodes on the left hemisphere ([Scott et al., 2009](#)). LPP was analyzed from a cluster of four centro-parietal electrodes (Pz P1 P2 POz) accordingly to the main studies on this complex (see [Citron, 2012](#) and [Hajcak et al., 2010](#)).

#### 4.6. Experiment 1 results

Each participant saw 72 random patterns with negative words (*random-negative*), 72 random patterns with positive words (*random-positive*), 72 reflection patterns with negative words (*reflection-negative*) and 72 reflection patterns with positive words (*reflection-positive*). In the Discriminate Word task they attended to the words written on top of the patterns and reported the valence, as positive or negative. In the Discriminate Regularity task they attended to the patterns and reported the degree of regularity as reflection or random. Participants gave the correct response on most trials both in the Discriminate Word task (Mean correct=98%, SD=1.01%) and the Discriminate Regularity task (Mean correct=97%, SD=0.95%).

Note that participants responded after the trial, and responses were not speeded. We measured the proportion of correct responses but did not record reaction times. Speeded button presses during stimulus presentation were used in behavioral affective priming studies (e.g. [Bertamini et al., 2013](#)), but this procedure would have produced motor ERPs, which would have interfered with the effects of interest.

### 5. Event related potentials

We were interested in testing the *congruency effect* in posterior ERPs, which have previously been linked to symmetry and valence processing. The analysis was conducted on the time-windows:

100–130 ms (P1), 170–200 ms (N1), 200–300 (EPN) and 250–1000 ms (SPN) 500–800 ms (LPP). For each time window, we initially performed repeated measure ANOVAs with two within-factors [Task (Discriminate Word, Discriminate Regularity)  $\times$  Congruency (Congruent, Incongruent)]. We followed this by analyzing sub conditions of the congruent and incongruent trials [Task (Discriminate Word, Discriminate Regularity)  $\times$  Pattern regularity (reflection, random)  $\times$  Word valence (positive, negative)] where appropriate.

Grand-averages ERPs were collapsed across all 40 participants separately for the Discriminate Word ([Fig. 2A](#) and [B](#) and [Fig. 3A](#)) and the Discriminate Regularity tasks ([Fig. 2C](#), [D](#) and [Fig. 3B](#)). Topographic maps in [Fig. 2A'](#) and [C'](#) show the difference between reflection and random conditions at the SPN time window (250–1000 ms), while topographic maps in [Fig. 2B'](#) and [D'](#) show the difference between congruent and incongruent trials. [Fig. 3A](#), [B](#) and [A'](#), [B'](#) show EPR waveforms and topographic maps of sub conditions separately for the two tasks. The most important effect was the difference between *reflection-positive* and *reflection-negative* waves in the discriminate word task. This *congruency effect* was recorded at posterior electrodes from 200 to 1000 ms. This effect was absent in the discriminate regularity task.

### 6. Visual evoked potentials

The P1 component was different between the two tasks ( $F(1,39)=4.637$ ,  $p=0.04$ ), with a smaller peak in the Discriminate Word task than the Discriminate Regularity. Congruent and Incongruent conditions showed similar P1 in both tasks (Task  $\times$  Congruency:  $F(1,39)=0.695$ ,  $p=0.201$ ). In line with previous findings ([Makin et al., 2013](#), 2012a,b), P1 was identical between reflection and random trials ( $F(1,39)=0.003$ ,  $p=0.923$ ) and in both tasks (Task  $\times$  Regularity:  $F(1,39)=0.006$ ,  $p=0.940$ ). P1 was also similar for positive and negative words ( $F(1,39)=0.01$ ,  $p=0.923$ ) and in both tasks (Task  $\times$  Word valence:  $F(1,39)=0.068$ ,  $p=0.795$ ).

N1 showed a marginal effect of Task ( $F(1,39)=3.069$ ,  $p=0.80$ ), with Discriminate Word eliciting a smaller peak than Discriminate Regularity. Importantly, there was a Task  $\times$  Congruency interaction ( $F(1,39)=5.890$ ,  $p=0.02$ ), because in the Discriminate Word task, N1 was marginally larger in the congruent trials than incongruent trials ( $t(39)=-1.886$ ,  $p=0.06$ ), as shown in [Fig. 2B](#).

We explored this marginal effect further by analyzing sub-conditions separately ([Fig. 3A](#)). The N1 component showed three-way interaction Task  $\times$  Pattern regularity  $\times$  Word valence ( $F(1,39)=6.134$ ,  $p=0.02$ ). *Reflection-positive* stimuli elicited a greater N1 than *reflection-negative* stimuli in the Discriminate Word task ( $t(39)=-2.393$ ,  $p=0.022$ ), while there was no difference between *random-positive* and *random-negative* ( $t(39)=0.723$ ,  $p=0.5$ ). Hence, the congruent interaction between positive words and reflection patterns elicited a unique negative response after 200 ms from stimulus onset. [Fig. 2A](#) shows a more negative wave for reflection patterns than for random patterns ([Fig. 2A](#)), although this trend was not significant ( $F(1,39)=3.094$ ,  $p=0.086$ ). There were no other effects or interactions.

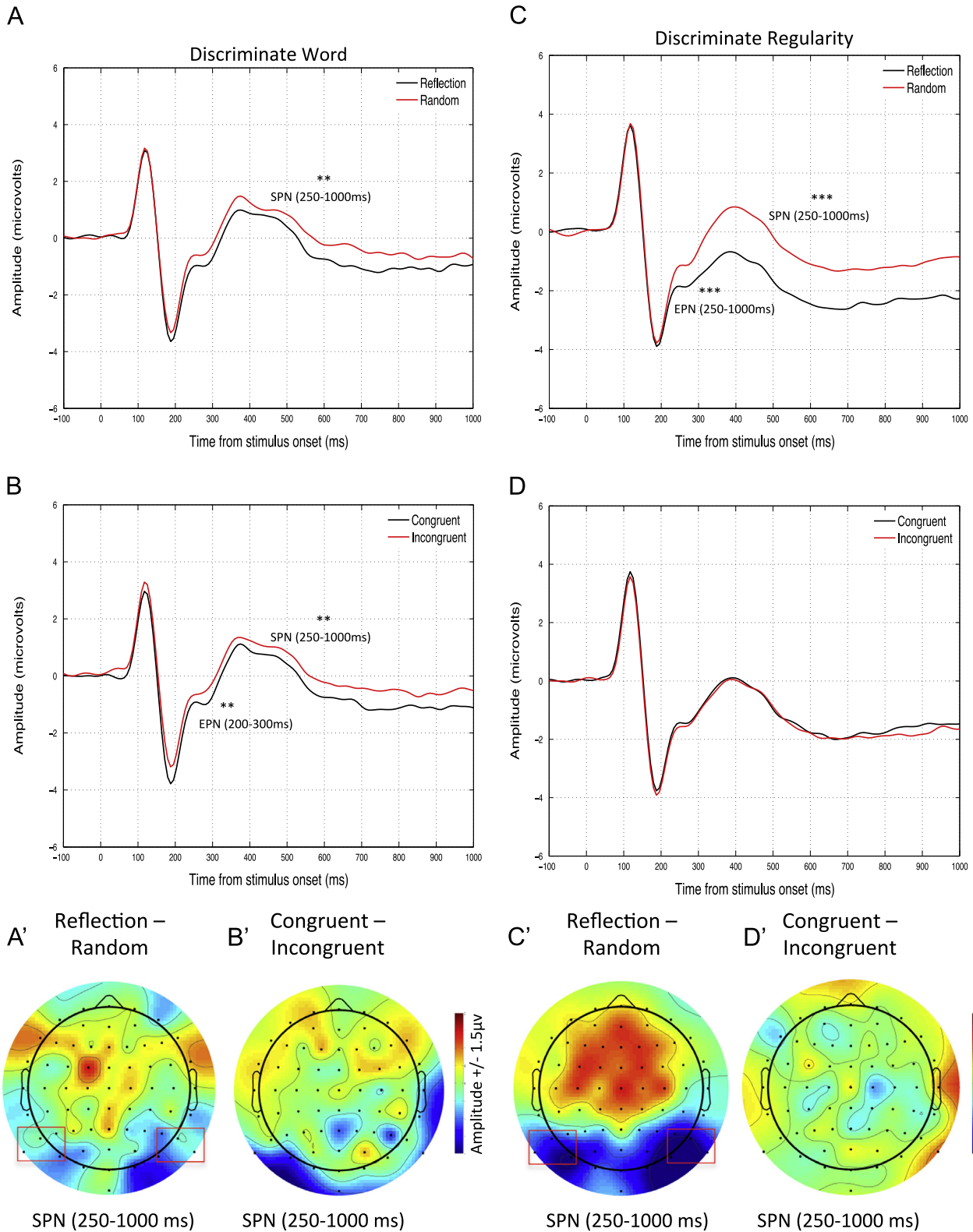
#### 6.1. Early posterior negativity and sustained posterior negativity

ERPs at the SPN latency were explored by analyzing the electrodes over the extrastriate visual area in the time windows 200–300 ms and 250–1000 ms from stimulus onset. There was a significant main effect of regularity in both components (EPN:  $F(1,39)=27.464$ ,  $p < 0.001$ ; SPN:  $F(1,39)=25.353$ ,  $p < 0.001$ ). Reflection patterns produced negative amplitude compared to random patterns. In the SPN time window, there was also a significant Task  $\times$  Pattern regularity interaction (EPN:  $F(1,39)=3.239$ ,  $p=0.08$ ;

$F(1,39)=20.186, p < 0.001$ ). In the Discriminate Regularity task the difference between reflection and random was highly significant ( $t(39)=-8.284, p < 0.001$ ); while it was weaker in the

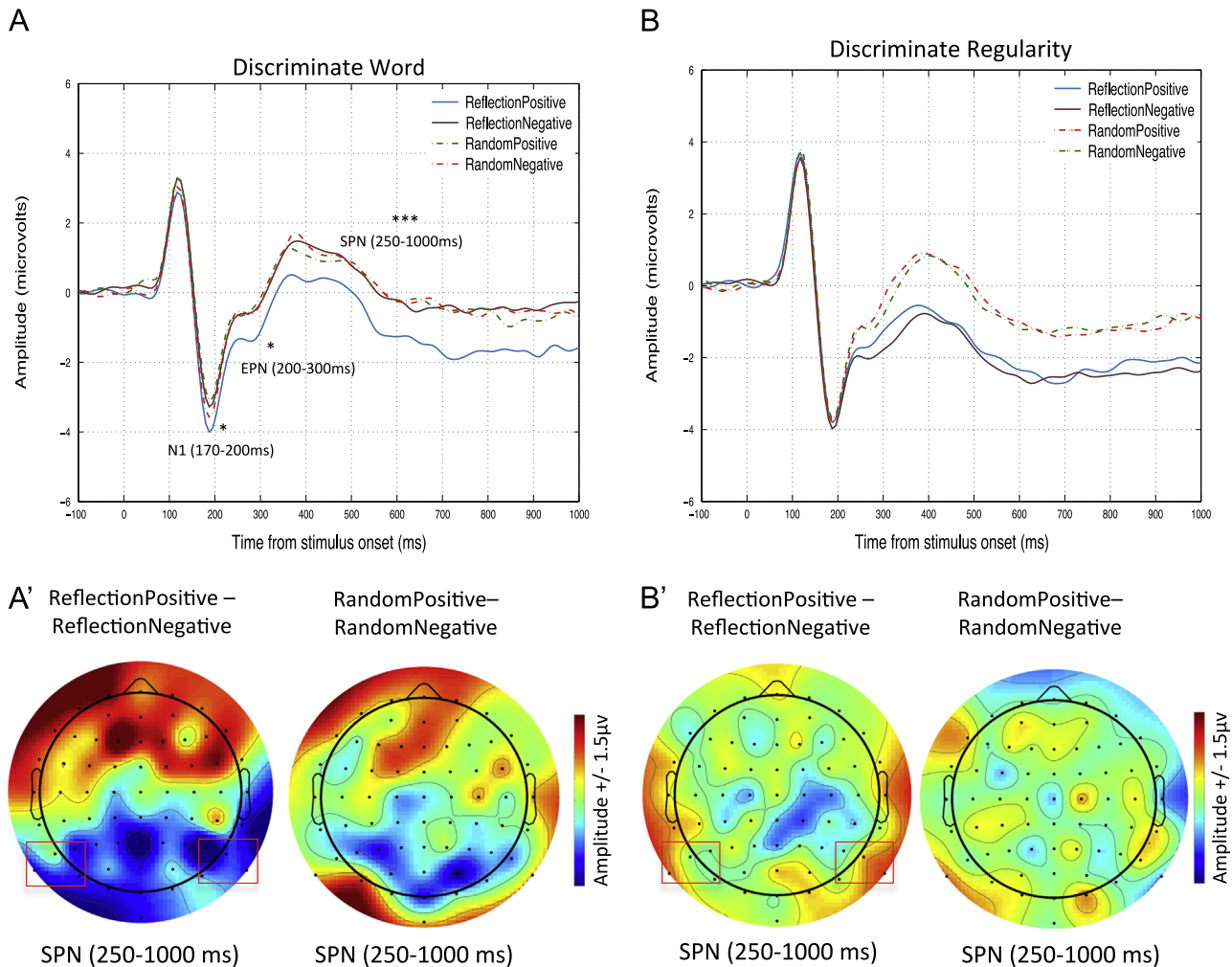
Discriminate Word task ( $t(39)=-3.220, p < 0.01$ ) (see Fig. 2A–C). Word valence did not produce any main effect ( $F(1,39)=1.064, p=0.31$ ), however, there was a significant Task  $\times$  Valence

### Experiment 1



**Fig. 2.** Grand Average ERPs [ $N=24$ ] from Experiment 1 the Discriminate Word task and the Discriminate Regularity task are plotted. Panels A and C show reflection random conditions. (B) and (D) show congruent and incongruent conditions. Insets (A')–(D') Topographic difference maps at the time window corresponding to the SPN component (250–1000 ms). Each map represents a head, and each black dot represents an electrode. The data show the difference between the two conditions. Red squares indicate the electrodes selected for analysis.

## Experiment 1



**Fig. 3.** Grand Average ERPs [ $N=24$ ] of the sub-conditions of the congruent and incongruent trial from Experiment 1 the Discriminate Word task and the Discriminate Regularity task. (A) and (B) show reflection-positive, reflection-negative, random-positive and random-negative waveforms. (A') and (B') Topographic difference maps at the 250–1000 ms time window for the two sub conditions. Red squares indicate the selected electrodes.

interaction ( $F(1,39)=5.228$ ,  $p=0.03$ ) because positive words elicited more negative deflection than negative words only in task Discriminate Word ( $t(39)=-2.437$ ,  $p=0.02$ ).

We were interested on the effect of pattern-words interaction on the SPN component. There was no main effect of Congruency (EPN:  $F(1,39)=0.98$ ,  $p=.33$ ; SPN:  $F(1,39)=2.182$ ,  $p=0.15$ ), but the interaction between Task  $\times$  Congruency was significant (EPN:  $F(1,39)=6.735$ ,  $p=.013$ ; SPN:  $F(1,39)=5.176$ ,  $p=0.03$ ). Paired sample  $t$ -test revealed a significant *congruency effect* in the Discriminate Word task (EPN:  $t(39)=-2.638$ ,  $p=0.01$ ; SPN:  $t(39)=-2.798$ ,  $p=0.008$ ), with congruent trials eliciting more negative amplitude than incongruent trials. There was no such effect in the Discriminate Regularity task (EPN:  $t(39)=1.177$ ,  $p=0.25$ ; SPN:  $t(39)=0.598$ ,  $p=0.553$ ).

We explored differences between the four sub-conditions. There was a significant three-way interaction Task  $\times$  Pattern regularity  $\times$  Word valence (EPN:  $F(1,39)=4.473$ ,  $p=0.041$ ; SPN:  $F(1,39)=7.113$ ,  $p=0.01$ ). In the Discriminate Word task the difference between *reflection-positive* and *reflection-negative* stimuli was significant (EPN:  $t(39)=-2.058$ ,  $p=0.04$ ; SPN:  $t(39)=-3.681$ ,  $p=0.001$ ). Conversely, the amplitudes of *random-positive* and *random-negative* conditions were almost identical (EPN:  $t(39)=1.210$ ,  $p=0.23$ ; SPN:  $t(39)=0.713$ ,  $p=0.5$ ). Therefore the

*congruency effect* observed in the Discriminate Word task seems to be exclusively related to the association between reflection patterns and positive words (see Fig. 3A).

The analysis of LPP revealed a main effect of Word valence ( $F(1,39)=4.889$ ,  $p=.033$ ) with negative words eliciting a more positive ERP than positive words. There were no other significant main effects or interactions.

Finally we also tested whether the above effects might be modulated by task order (Discriminate Word first, Discriminate Regularity first). However, task order had no significant effect on ERPs. In summary the most important effect was the difference between congruent and incongruent waves at posterior electrodes from 250 ms onwards. This congruency effect was only present in the discriminate word task, and no such effect was found in the discriminate regularity task.

## 6.2. Experiment 1 discussion

Experiment 1 investigated affective congruence between patterns and words with ERP techniques. Words with positive or negative valence, but equal level of arousal, were superimposed to black and white patterns containing reflectional symmetry or a random configuration. Importantly, participants performed two



separate tasks. In one task they judged the valence of the word and ignored the pattern below. In the other task, they classified the regularity of the pattern and ignored the word. The most important ERP result from Experiment 1 was a difference between congruent and incongruent waves in the Discriminate Word task. This persisted from around 200 ms to the end of the epoch. The topography and latency of this difference wave was similar to the symmetry-related SPN. In fact, this effect was extended to the N1 component, although the effect was not robust at this latency. Note that we analyzed the Early Posterior Negativity (EPN) separately from the SPN and found that these components overlapped in all conditions. For this reason, we considered these components together. The congruence effect in the Discriminate Word task was not limited only to the EPN latency, it persisted throughout the SPN interval.

The characteristics of other ERPs help explain why we only recorded a *congruency effect* in the Discriminate Word task. In the Discriminate Regularity task, there was a large SPN, with lower amplitude in the reflection than the random trials. The SPN was reduced, but still present, in the Discriminate Word task. This result suggests that regularity can be processed even if not attended, and other studies have also recorded the SPN under passive viewing conditions (Makin et al., 2013; Hofel & Jacobsen, 2007). Given this evidence that both patterns and words were processed in the Discriminate Word task, it is not surprising that we only found a *congruency effect* here. Conversely, in the Discriminate Regularity task, resources were focused on pattern regularity, and valence of words cannot be processed as a secondary task.

Note that the term *congruent* indicates the average of *reflection-positive* and *random-negative* conditions and *incongruent* is the average of *reflection-negative* and *random-positive* conditions. However, most of the *congruency effect* is attributable to the difference between reflection-positive and reflection negative waves, with little difference between random-positive and random-negative waves. Moreover, the reflection positive wave was distinctly different from the other three waves. We will return to this aspect in the General discussion.

The analysis of LPP revealed that overall negative words elicited a more positive ERP than positive words. The fact that there was no interaction with task suggested that words valence was not totally ignored in the Discriminate Regularity Task, but the contribution of attention would be important for emotional words to influence the processing of patterns (Bayer, Sommer, & Schacht, 2010; Hinojosa et al., 2010).

In summary, Experiment 1 suggested that reflection could be detected without effort (although the same processes are pronounced when regularity is attended and classified). This pre-attentive symmetry processing interacts with overt, explicit word-valence discrimination, resulting in a difference between congruent and incongruent trials. In Experiment 2 we investigated this issue further by forcing participants to attend to both word valence and pattern regularity on every trial.

## 7. Experiment 2

The design of Experiment 2 was identical to Experiment 1, but participants had to report either the regularity of the pattern or the valence of the word at the end of the trial, and they did not know which dimension would be probed in advance, while the stimuli were on the screen. Therefore, they were forced to attend to both shapes and words simultaneously. Experiment 2 essentially combined the two tasks (the Discriminate Word task and the Discriminate Regularity task) described above in Experiment 1 in one single experiment.

### 7.1. Experiment 2 method

Twenty-four participants<sup>1</sup> (aged 18 to 35, 5 male, 2 left handed) took part. None of these people participated in the Experiment 1. The stimuli were generated in the same way of the Experiment 1, whereas the procedure differed slightly. The response screen, presented immediately after the stimuli, might require either to report regularity or valence.

The type of response screen was counterbalanced across other factors, and, importantly, was not predictable for the participants. Participants therefore were forced to attend both to the pattern and the word.

A linear-detrend procedure was used to remove high amplitude drift from 4 participants. An average of 9.05 components were removed from each participant (min=4, max=13). The average proportion of excluded trials did not differ significantly either between trials with random and reflection patterns (13% vs 13%,  $p=0.7$ ) or between trials with negative and positive words (12% vs 13%,  $p=0.7$ ). However, the interaction between regularity and word valence was significant ( $p=0.03$ ). Slightly more trials excluded in the *random-positive* condition were more than in the *random-negative* condition (14% vs 12%,  $p=.02$ ), while there was no significant difference between *reflection-positive* and *reflection-negative* conditions (13% vs 12%,  $p=0.4$ ). EOG analysis was also conducted and did not reveal any significant main effect or interaction ( $p > .1$ ), suggesting eye movement artifacts were equally spread across all experimental conditions.

ERP analysis was identical to the Experiment 1. We took in consideration the time windows: 100–130 ms (P1), 170–200 ms (N1) and 250–1000 (SPN). Mean amplitudes were computed across the same electrodes of the Experiment 1, and conditions analyzed were the same as shown in Fig. 4A–C and A'–C'. LPP was also analyzed in the time window 500–800 ms at the same electrodes of Experiment 1.

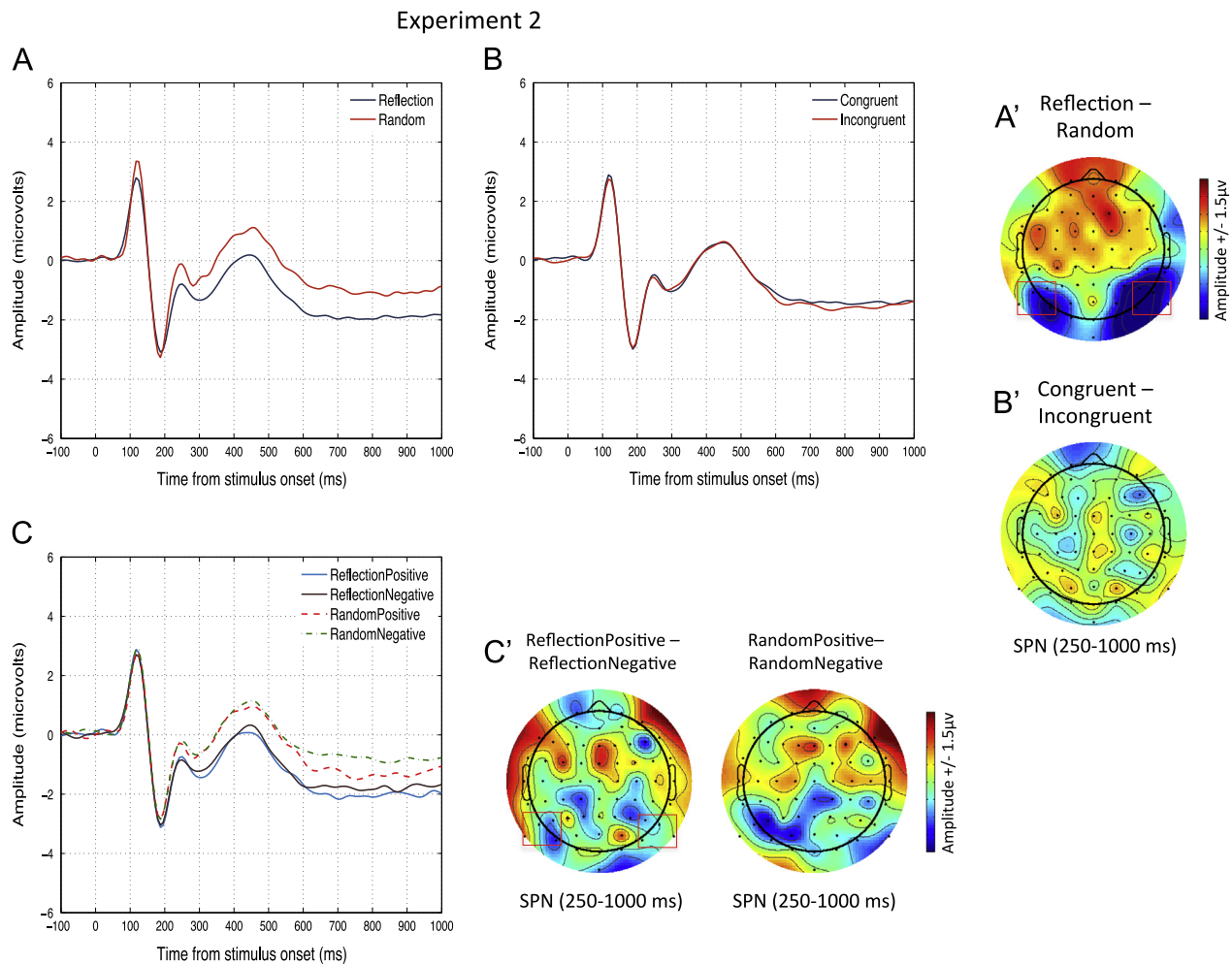
### 7.2. Experiment 2 results

The experiment consisted of one whole task of 288 trials. Twenty-four participants saw 72 reflection patterns with a positive word, 72 reflection patterns with a negative word, 72 random patterns with a positive word and 72 random negative patterns with a negative word. After each stimulus they might be required to report either the type of regularity of the pattern or the valence of the word. Importantly, participants could not predict what type of response screen they would have been prompted to. This procedure forced them to attend both to patterns and words simultaneously. Participants gave the correct response on most trials (Mean correct=93%, SD=2.13%).

### 7.3. Event related potentials

Congruent and Incongruent conditions did not differ in amplitude in the EPN or SPN time-windows (EPN:  $t(23)=0.245$ ,  $p=.809$ ; SPN:  $t(23)=0.637$ ,  $p=0.5$ ). There was a main effect of regularity: the amplitude of the reflection wave was significantly more negative the random wave (EPN:  $F(1,23)=14.230$ ,  $p < .001$ ; SPN:  $F(1,23)=28.562$ ;  $p < .001$ ). There were no other effects or interactions ( $F_s < 1.0$  and  $p_s > .1$ ). Also VEPs were not modulated by any

<sup>1</sup> Note that the number of participants in Experiment 2 (twenty-four) differs from the number of participants in Experiment 1 (forty). Because we did not observe a *congruency effect* in Experiment 2, one might argue this was due to a lack of power. However we analyzed the data from 24 participants on Experiment 1 and observed a similar pattern of results.



**Fig. 4.** Grand Average ERPs [ $N=24$ ] from Experiment 2 at the selected electrodes (indicated by the red squares). (A) Reflection and random (B) congruent and incongruent (C) reflection-positive, reflection-negative, random-positive and random-negative. (A')–(C') Topographic difference maps at the 250–1000 ms time window between the conditions.

factors in this experiment ( $F_s < 1.0$  and  $p_s > .1$ ). We also did not find any effect or interaction at the LPP level except for marginally higher amplitude for negative over positive words ( $F(1,23)=3.38$ ,  $p=0.08$ ).

#### 7.4. Experiment 2 discussion

In Experiment 2 we only observed difference between reflection and random patterns. This SPN replicates Experiment 1 and previous work (e.g. [Jacobsen and Hofel, 2003](#); [Makin et al., 2013](#)). However, we did not find a difference between congruent and incongruent trials, despite the fact that people had to attend to both regularity and word valence within the same trial. This differs from the significant *congruency effect* recorded in the Discriminate Word task in Experiment 1. One possibility is that participants did not attend to the words and patterns simultaneously in this Experiment 2, but rather classified and remembered one dimension, then the other.

## 8. General discussion

In this study we employed an ERP variation of the word-pattern interference task to investigate emotional responses to symmetry. Behavioral studies, employing a similar paradigm, reported a *congruency effect* between positive/negative words and reflection/

random patterns ([Bertamini et al., 2013a,b](#); [Makin et al., 2012a](#)). In two experiments we investigated equivalent congruence effects on ERPs. In specific we were interested to see whether the congruency between valence and pattern regularity affected the Sustained posterior Negativity, a symmetry specific ERP component ([Makin et al., 2012b, 2013](#)). Stimuli consisted in novel abstract patterns with random or reflection configuration. Words with positive or negative valence were superimposed on the patterns. In Experiment 1, participants performed two blocked tasks: One required a classification of words valence (positive or negative). The other task was to report the regularity of patterns (reflection or random). The crucial aspect of Experiment 1 was that both tasks could be performed ignoring the task-irrelevant factor. Conversely, in Experiment 2 both factors were task-relevant in all trials, and participants attended to words valence and patterns regularity simultaneously.

Our most important finding was a *congruency effect* in the Discriminate Word task on Experiment 1. From around 200 to 1000 ms, amplitude was lower in congruent trials than incongruent trials. This overlapped with the Sustained Posterior Negativity (SPN), both in terms of latency and topography. It is instructive that no congruency related ERPs were recorded in the Discriminate Regularity task of Experiment 1, or in Experiment 2, where participants attended to both word valence and pattern regularity on every trial. We also note that the *congruency effect* in the Discriminate Word Task of Experiment 1 was largely driven by the unique reflection-positive waveform.



How can we explain these results? It seems that the relationship between word valence and pattern regularity *only* affects ERP amplitude when participants are deliberately classifying the words as positive or negative and regularity was processed pre-attentively. It could be that participants were put into an evaluative mindset by the word valence classification task, and this overgeneralized, so people spontaneously evaluated the valence of the background patterns as well, and thus noticed relationships between the valence of patterns and words.

The situation was apparently different in the Discriminate Regularity task, in which there were no such *congruency effects*. Here regularity could have dominated early visual processing, so people did not read the central words at all, or at least did not process word valence. It seems that attention was focused on pattern regularity, and this competed with the processing of word valence. Although emotional words are known to elicit task-independent emotional effects (Schacht & Sommer, 2009a; Kissler et al., 2006), some degree of post-perceptual linguistic processing is required for this (Hinojosa et al., 2010; Bayer, Sommer, & Schacht, 2010). It seems that such a process did not occur in the Discriminated regularity task of Experiment 1.

What about the fact that the reflection-positive trials produced a unique wave in the Discriminate Word task? One explanation refers to the target status of patterns and words. Reflection patterns may be classified as targets in a 2AFC reflection/random discrimination task (Makin et al., 2012b), while the random patterns are non-targets (Rothermund & Wentura, 2004). Likewise, positive words are detected more quickly than negative words (Hinojosa et al., 2010; Hofmann, Kuchinke, Tamm, Vö, & Jacobs, 2009; Kuchinke, Vö, Hofmann, & Jacobs, 2007; Kuchinke et al., 2005; Unkelbach et al., 2008) so positive words might also be targets. This means that in trials where a reflection pattern is combined with positive words, two *target* stimuli are presented simultaneously. This perhaps explains why the reflection-positive word waveform differs from the others ERPs in the Discriminate Word task.

We also note that the unique *reflection-positive* wave resembles normal SPN for reflection symmetry, whereas the *reflection-negative* is similar to random waves. In other words, the symmetry-related SPN was present when positive words were presented on top of the patterns, but not when negative words were presented. It is possible that processing positive words required less sustained attention than negative words; so visual resources were freed to discriminate between regularity of the background patterns, and the familiar SPN component was observed. We could state this in a different way: negative words may activate extra-striate networks, and this blocks the processing of symmetry.

Negative words may block symmetry perception at other levels of the visual hierarchy as well. This is plausible if we consider that processing negative valence and symmetry might involve greater activation of the right hemisphere, for example. It is broadly accepted that the preferential neural substrate of emotions is the right hemisphere (Right Hemisphere Hypothesis, Borod, Haywood, and Koff (1997)). However, there is consistent evidence that the right hemisphere responds especially to negative emotion (the Valence Hypothesis; Davidson, 1995). Curiously, Makin et al. (2012b) reported a right lateralized posterior alpha desynchronization during reflection/random discrimination, which indicates right hemisphere preference for processing symmetry. The fact that both negative words and reflection background involve right hemispheric activation, suggests these two dimensions share common neural substrates.

In addition to modulations of the SPN and EPN in Experiment 1, we also found that LPP amplitude was greater for negative words, replicating other results (Hofmann et al., 2009; Gootjes, Coppens, Zwaan, Franken, & van Strien, 2011; Franken, Gootjes, &

van Strien, 2009; Kanske & Kotz, 2007; Schacht & Sommer, 2009b; Schupp et al., 2000; Cacioppo & Berntson, 1994). The networks that generated the LPP might interact with those which process symmetry, although the LPP was produced in conditions where there was no congruence effect, so the nature of these links is unclear.

The findings of this study can be contrasted with previous ERP studies on symmetry evaluation. Hofel and Jacobsen (2007) found that ERPs that distinguished between subjectively beautiful and ugly patterns were absent when there were no explicit instructions to evaluate the patterns aesthetically. Similarly, fMRI studies revealed a “beauty-induced” signal boost only when participants had to classify the symmetric/random stimuli as beautiful or not (Jacobsen, Schubotz, Hofel, & Cramon, 2006). These authors concluded that aesthetic evaluation of abstract patterns is an intentional rather than a spontaneous process. However, in the current study, we found some evidence for automatic evaluation of patterns, at least when people were engaged in a concurrent word evaluation task.

We can also contrast the ERP results with previous behavioral studies, which employed similar stimuli and paradigms. In their affective priming study, Bertamini et al. (2013a) presented a pattern for 250 ms, immediately followed by a word. When prime patterns were attended and classified, a *congruency effect* was found: words classification was faster on congruent trials when positive words were preceded by reflection or negative words were preceded by random, compared to incongruent trials (reflection then negative or random then positive). In Bertamini et al. (2013a) stimuli were not spatially and temporally overlapping as there were in the experiments reported here. However, it is possible that after the 250 ms of presentation, sustained responses to symmetry remained, so when words were presented, the visual system might be still tuned to symmetry/random, but it was not directly processing regularity any more, hence the interaction with word valence.

Similarly, in experiments on symmetry and valence that used the implicit association test (Bertamini et al., 2013b), patterns and words were alternated in a relatively fast sequence. Participants attended and processed both patterns and words, but never simultaneously. It can be seen that the results of Bertamini et al. (2013a, 2013b) are consistent with results of Experiments 1, in that there is a *congruency effect* in the absence of simultaneous classification of patterns and words.

## 9. Conclusions

Several behavioral studies have reported an automatic positive response to symmetry, and speculated that neural mechanisms involved in symmetry detection might be connected with those that produce positive affect. The current work supports this theory and shows that the brain is sensitive to the congruence between regularity and word valence dimensions. We recorded a difference between posterior ERP waves on congruent (reflection-positive word or random negative word) and incongruent (reflection negative or random positive) trials. As far as we know, our study is the first that investigates the this kind of regularity–valence interaction with EEG. Our results show that this *congruency effect* exists and occurs relatively early, around 200 ms after stimulus onset. However, this effect was not equivalent in all conditions. When observers evaluated word valence we found a *congruency effect*, but there was no such effect they judged pattern regularity. We suggest that this is due to the fact that word valence is easier and faster to evaluate, allowing time and resources to process the valence of the pattern.

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