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

Giulia Rampone *, Alexis D.J. Makin, Marco Bertamini

Department of Psychological Sciences, Eleanor Rathbone Building, University of Liverpool, Liverpool, L69 7 ZA, United Kingdom

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A B S T R A C T

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.

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

* Corresponding author. Tel.: +44 744 930 1514.
E-mail address: giulia@liverpool.ac.uk (G. Rampone).

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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, Friedenberg, & Kubovy, 1997; Friedenberg & 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 & Düngelhoff, 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 lateroccipital 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, Méndez-Bértolo, & 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