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The Posterior Sustained Negativity Revisited—An SPN Reanalysis of Jacobsen and Höfel (2003)

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Abstract: Symmetry is an important cue for the aesthetic judgment of beauty. Using a binary forced-choice format in a cued mixed design, Jacobsen and Höfel (2003) compared aesthetic judgments of beauty and symmetry judgments of novel graphic patterns. A late posterior sustained negativity elicited by symmetric patterns was observed in the symmetry judgment condition, but not in the beauty judgement condition. Therefore, this negativity appeared to be mainly driven by the task.In a series of studies, Bertamini, Makin, and colleagues observed a comparable sustained posterior negativity (SPN) to symmetric stimuli, mainly taken to reflect obligatory symmetry processing independent of task requirements. We reanalyzed the data by Jacobsen and Höfel (2003) using similar parameters for data analysis as Bertamini, Makin, and colleagues to examine these apparent differences. The reanalysis confirmed both a task-driven effect on the posterior sustained negativity/SPN to symmetric patterns in the symmetry judgment condition and a strong symmetry-driven SPN to symmetric patterns. Differences between the references used for analyses of the electroencephalogram (EEG) had an effect. Based on the reanalysis, the Jacobsen and Höfel (2003) data also fit well with Bertamini's, Makin's, and colleagues' account of obligatory symmetry processing.

Keywords: symmetry processing; aesthetic judgments of beauty; posterior sustained negativity; SPN

1. Introduction

The aim of the present article is to review previous work with respect to the processing of symmetry in aesthetic and non-aesthetic episodes. As will be shown, depending on the task structure, the quality of the symmetry processing differs, even when identical stimuli are used. In an effort to investigate the aesthetic judgment of beauty as uncontaminated as possible, we had designed a set of stimuli that controls for a large number of influencing factors [1]. Novel, graphic patterns that consist of 86–88 single individual triangles set into a rhombic cutout of a circle had been configured. The small triangles formed larger triangles, squares, rectangles, or more or less irregular geometric shapes (see Figure 1). All of the 252 resulting graphic patterns have the same luminosity, while they differ in their graphic or geometrical content and therefore differ regarding complexity and symmetry. By using novel graphic patterns, influences on the aesthetic judgment of beauty such as appeal to social status, prestige, financial interest, and the like were reduced. As these patterns were novel for our participants, the stimuli had to be processed in the experimental situation, and memory-based aesthetic judgments were therefore not available for our laymen participants. Of course, all of the factors that we experimentally controlled for in these studies may have had an influence on their own.

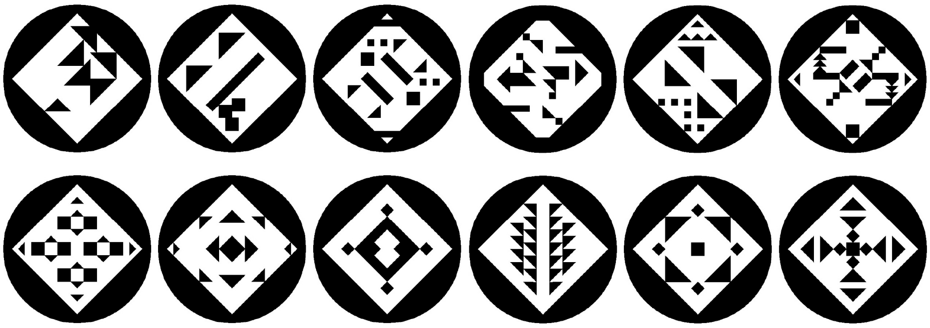

Figure 1. Stimulus examples from Jacobsen and Höfel [2]. The graphic patterns in the upper row are not symmetric, ranging from not beautiful to beautiful (left to right). Patterns in the lower row are symmetric, also ranging from not beautiful to beautiful.

Previous research suggests that beauty is the most prominent concept in the domain of aesthetics [3–6]. Therefore, we have explored which stimulus features of the patterns individuals use to compute their aesthetic judgment of beauty. As the stimuli had been designed to differ exclusively with respect to symmetry and complexity, the available perceptual cues for judgment were limited. In several experiments with different kinds of symmetry we have shown that the symmetrical features are most often used in a positive way to guide the judgment. Very rarely, if at all, symmetry is a negatively valenced cue in the aesthetic judgment of beauty. That said, one has to bear in mind that the participants in these studies were art laymen. Furthermore, we modeled the individual judgment policies by multiple regression. There is considerable individual variation even though the used patterns are rather simple and mainly differ regarding symmetry aspects. Judgment policies ranged from a very highly linear use of symmetry cues in a simple judgment rule to complex configural use of perceptual cues. This suggests that there may be different processing modes of symmetry features. These different processing modes may entail a holistic or a very detailed and more analytic way of processing symmetry cues.

When turning to the cognitive neuro-scientific approach, we were limited to group-level analyses to explore different processing modes using event-related brain potentials (ERPs) or functional magnetic resonance imaging (fMRI). In order to get data at the group level, we used the participants' individual judgments to compute the group averages. Therefore, the stimuli to compute the group-averages differed between participants, but our stimuli had been designed to allow exactly that. However, the information regarding which particular aspect of symmetry had been used by a given participant for his or her judgment process was lost in this group level analysis and is only available at the behavioral level.

We have then used task analysis to identify sub-processes involved in the aesthetic processing of our stimuli. Generally, we instructed participants to engage in an evaluative aesthetic processing mode, for instance, by asking them to judge the beauty of the presented stimuli, which we then contrasted with a structurally identical task (symmetry judgment) that lacked the evaluative component. This experimental approach has been devised in terms of *descriptive* for the symmetry and *evaluative* for the beauty judgments. Note that symmetry is the relevant feature for both tasks. In one case, it is an objectively identifiable feature of the pattern needed to perform the symmetry judgment task, and in the other case, it is the stimulus feature that almost all participants use to derive their aesthetic judgment of beauty. The experimentally induced mode of processing resulted in double dissociations in mental chronometry as well as topographical distribution of our ERP data. Symmetry is processed in fundamentally different ways under these two processing modes. This group-level result turned up even though individual judgment policies differed substantially.

The functional imaging-data of the same task corroborated these findings [7]. While lacking the temporal resolution of the ERPs, the fMRI-data also revealed different networks sub serving the processing of symmetry in these two different mental modes.

One can readily argue that aesthetic judgments do not necessarily occur in every single episode in which we contemplate the beauty, elegance, harmony, or the like for a given stimulus; mere contemplation may also occur when processing the beauty, for instance, while not deriving a judgment. It is also readily sensible that we do not always engage in aesthetic processing even of beautiful stimuli. In a pragmatic processing mode, possibly under everyday stressful work conditions, beauty may be lost, and we process a given stimulus merely for its practical aspects. In addition, there may be events where the beauty of an entity is so striking that it distracts us from our current behavior and mental processing [8]. Numerous other sub-processes of aesthetic processing may be conceivable. In our analysis of the sub-components of our tasks, we contrasted the contemplation of beauty with a mere viewing and the evaluative categorization process that preceded a response.

ERPs can also be used for mental chronometry to separate sub-processes in time. The earlier ERP components, such as the N1, which are frequently associated with perceptual processing, did not differ between different processing modes. However, the voluntary engagement into different processing modes of symmetry led to different qualities of the later symmetry processing as indicated by the striking double dissociation in both time and topography [2].

In contrast to our findings, Bertamini, Makin, and colleagues suggest an automatic processing of symmetry independent of the mental mode (e.g., [9]). By using similar abstract black and white patterns, they replicated our finding of differences in the late symmetry processing [2]. Compared to random patterns, symmetrical patterns evoked a more negative-going waveform 250–1000 ms after stimulus onset [10]. In subsequent studies that used different abstract patterns, e.g., dot patterns, these findings extended over different kinds of regularities: reflectional, rotational, and translational symmetry [11–13]. This sustained posterior negativity (SPN) differs between the types of regularity. The SPN is larger for reflectional symmetry than for the other two types [11]. Bertamini, Makin, and colleagues assume a general regularity-sensitive network instead of a unique network for reflectional symmetry, whereas reflectional patterns seem to be the preferred stimuli that produce the largest brain response [9]. The SPN occurs whether the task requires the processing of symmetrical features of the stimuli or the processing of a non-symmetrical feature, e.g., the number of objects [12]. Although the magnitude of the SPN changes with different task requirements [11,14] and is therefore not completely stimulus driven. Nevertheless, the late component of the ERP occurs whenever the stimulus is symmetrical, and it has been concluded that the SPN is compulsory when the presented stimulus shows a geometrical regularity [9].

Taking these two strands of research together, an apparent discrepancy with respect to stimulus processing arises. While the work by Bertamini, Makin, and colleagues (e.g., [10–13]) suggests an obligatory symmetry processing that is reflected by the SPN, a more diverse pattern arises from the three ERP studies by Höfel and Jacobsen [2,8,15]. While Jacobsen and Höfel [2] observed a double dissociation between the evaluative aesthetic judgment task and the descriptive symmetry judgment task, with a posterior sustained negativity arising only in the symmetry judgment condition, a posterior sustained negativity was observed in the viewing as well as in the evaluative contemplation condition of Höfel and Jacobsen [8]. The latter suggesting a spontaneous elicitation of the symmetry processing ERP (SPN/posterior sustained negativity). Further, differences in the analysis parameters of the ERPs such as filtering, reference and eye movement correction, as well as in stimulus selection for ERP derivation might account for the discrepancy. In the evaluative judgment condition of our study, ERPs were based on the subjective ratings of the participants. These highly concurred with the stimulus' symmetry status, but were not identical. As a consequence, it seems worthwhile to reanalyze the data by Jacobsen and Höfel to elucidate potential effects of stimulus selection and analysis parameters. If the posterior sustained negativity/SPN hinges on stimulus selection such as the objective symmetry status of a stimulus, then we should observe an ERP pattern in this reanalysis that resembles the data observed and reported by Bertamini, Makin, and colleagues. The same holds for ERP analysis parameters. We would also predict these to have a smaller contribution. If, on the other hand, the observed ERP pattern in Jacobsen and Höfel [2] is exclusively driven by task differences between the descriptive and the evaluative judgment, then the ERP pattern of this reanalysis should not differ substantially from the original analysis of Jacobsen and Höfel [2].

2. Materials and Methods

The data of Jacobsen and Höfel [2] were available for reanalysis. In this study, nine participants (6 men, mean age: 22.4 years, one left-handed) viewed the patterns (as described above) on a screen and either performed an evaluative aesthetic or a descriptive symmetry judgment in a binary forced-choice task, using a mixed design. The task was indicated by a cue at the beginning of each trial. Stimuli were presented in four blocks with 63 trials each. Each trial consisted of a fixation cross (800 ms) and a cue (1200 ms), which was followed 800 ms later by a pattern (3000 ms) to be judged. The ITI varied between 800 and 1600 ms. The task (evaluative aesthetic judgment vs. descriptive symmetry judgment) was pseudo-randomly assigned to the stimuli and the sequence of the items was also pseudo-randomized with the constraint that a maximum of 3 trials of a task or answer category (yes/no) appeared.

The electroencephalogram (EEG) was recorded from 25 scalp locations (nose reference). The vertical and horizontal electroculogram (EOG) was also recorded. Epochs contaminated with ocular or other artifacts were excluded using a standard deviation criterion. One to three days before the main experiment, participants were familiarized with the stimulus set (printed on cards) to avoid anchoring effects.

Detailed methods can be found in [2].

Main differences from Bertamini et al. (e.g., [10,11]) in the ERP analysis consist in the filter settings, the reference, the electrode sensors, and the time window for statistical analysis. While Jacobsen and Höfel used a bandpass filter of 0.2–25 Hz, Bertamini and Makin exclusively used a lowpass of 25 Hz. In this reanalysis, analyses were conducted for both filter settings (bandpass-filtering (0.2–25 Hz) and lowpass-filtering (25 Hz) only) Moreover, the impact of referencing was explored by re-referencing the data to the average reference in addition to the original nose reference. A time window of 300 to 1000 ms was used for the statistical analysis (Jacobsen and Höfel (2003) used a time window of 600–1000 ms. All analyses reported in the present article were also done using this time window and a comparable pattern of results was obtained). The EEG sensors used by Bertamini, Makin, and colleagues, PO7 and PO8, were not available in our data set. Therefore, we used an aggregate of the sensors P7, P8, O1, and O2, while previously Jacobsen & Höfel used a topographic 3×5 sensor grid for statistical analysis. Epochs of 1200 ms including a 200 ms pre-stimulus baseline were used for the reanalysis. Here, we report the outcome of three different analyses. The first analysis used the bandpass filter, and the ERPs were derived based on subjective ratings of the participants. This analysis is closest to the original one and explores whether discrepancies between the studies might result from the different choices of sensors for the parametrization of the ERPs. The second analysis additionally considered the objective stimulus parameters. That is, ERPs were derived based on the objective symmetry (symmetric vs. non-symmetric) in conjunction with the participants' responses (symmetric vs. non-symmetric in the descriptive symmetry judgment and beautiful vs. not beautiful in evaluative aesthetic judgment). Finally, in a third analysis, we analyzed the data using only the 25 Hz lowpass filter and converted the data to the average reference in order to perform the analysis in a way as similar as possible to the one described by Bertamini, Makin, and colleagues. Statistical comparisons were performed using repeated measures analysis of variance with the factors Task (evaluative aesthetic vs. descriptive symmetry judgment) and objective regularity status of the stimuli, labeled Symmetry (symmetric vs. non-symmetric stimuli).

3. Results of the Reanalysis

The study by Jacobsen & Höfel [2] found an SPN only under the descriptive symmetry judgment task, but not in the evaluative aesthetic task. Results of our reanalysis of the data set yielded comparable results despite the modified analysis parameters (Figure 2A). Stimuli judged as symmetric in the descriptive task evoked enhanced parieto-occipital negativity compared with the stimuli that were judged as non-symmetric, while in the evaluative aesthetic task no significant differences were found (Task × Symmetry: $F(1,8) = 9.01$, $p = 0.017$; Symmetry: $p = 0.006$ and $p = 0.5$ for the symmetry and beauty task, respectively). In addition, the main effect of symmetry reached significance ($F(1,8) = 5.59$, $p = 0.033$).

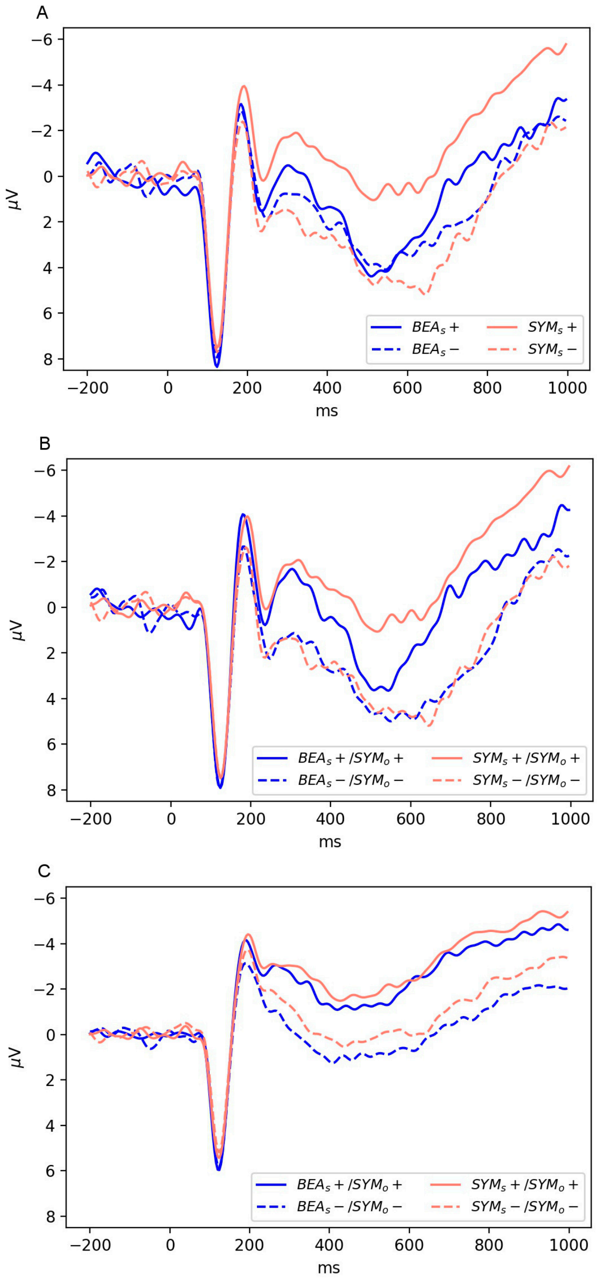

Figure 2. ERP waveforms averaged across the sensors P7, O1, O2, and P8. (**A**) ERPs (nose reference, bandpass filtered at 0.2–25 Hz) for stimuli that were subjectively judged as beautiful (BEA_s+), symmetric (SYM_s+), not beautiful (BEA_s-), or not symmetric (SYM_s-); (**B**) ERPs (nose reference, bandpass filtered at 0.2–25 Hz) for stimuli that were subjectively judged as beautiful (BEA_s+), symmetric (SYM_s+), not beautiful (BEA_s-), or not symmetric (SYM_s-) when the objective symmetry was considered. Only objectively symmetric stimuli (SYM_o+) were included in the beautiful (BEA_s+)/symmetric ERPs (SYM_s+) and only objectively non-symmetric stimuli (SYM_o-) for the not beautiful (BEA_s-)/not symmetric ERPs (SYM_s-) ERPs; (**C**) ERPs (average reference, lowpass filtered at 25 Hz) for stimuli that were subjectively judged as beautiful (BEA_s+), symmetric (SYM_s+), not beautiful (BEA_s-), or not symmetric (SYM_s-) when the objective symmetry was considered.

When the a priori symmetry was considered in the analysis (Figure 2B), the pattern of results was similar. Symmetric stimuli evoked a posterior negativity compared with non-symmetric stimuli (Symmetry: $F(1,8) = 9.62$, $p = 0.015$; Task $\times$ Symmetry: $F(1,8) = 2.00$, $p = 0.195$). The symmetry effect was largely due to the descriptive task as shown by explorative post-hoc testing (Symmetry: $p = 0.004$ and $p = 0.122$ for the descriptive and evaluative task, respectively). Supplementary Figure S1 illustrates ERPs for the aesthetic task for the analysis when all stimuli were used compared with the analysis when objective symmetry was considered.

Moreover, when the data (using a lowpass of 25 Hz only) was analyzed using the average reference (Figure 2C) (data with original nose reference are shown in Supplementary Figure S2), symmetric stimuli evoked enhanced negativity irrespective of the task (Symmetry: $F(1,8) = 14.58$, $p = 0.005$; Symmetry: $p = 0.008$ for both the descriptive symmetry and the evaluative aesthetic task). Performing the descriptive symmetry compared with the evaluative aesthetic judgments was reflected in an enhanced posterior negativity (Task: $F(1,8) = 8.35$, $p = 0.02$) An additional ERP analysis with the same parameters completely disregarded the participants' responses and explored task effects using the objective symmetry status only (Supplementary Figure S3). Results are comparable (Symmetry: $p = 0.002$; Task: $p = 0.06$, Interaction: n.s.).

4. Discussion

The aim of the present article was to elucidate discrepancies in factors causing the posterior sustained negativity/SPN in two strands of research. Bertamini, Makin, and colleagues posit that the SPN is a fairly obligatory electrophysiological response that reflects the processing of symmetric stimuli, and other research has demonstrated that symmetry is an important feature extracted already early in the visual processing stream [16–19]. In the research by Jacobsen and Höfel, the posterior sustained negativity appeared to be task-dependent and/or driven by spontaneous processes. In the present reanalysis, various parameters of ERP analysis have been compared. The task-specific modulation of the SPN as found in Jacobsen and Höfel was replicated when analyzing posterior sensors only. The use of objective symmetry to avoid different proportions of symmetrical and non-symmetrical stimuli in the ERPs of the two tasks also indicates a task-specific contribution to the posterior negativity: If the SPN was independent of task requirements, the waveforms of symmetrical stimuli should have been similar in both judgment tasks. However, the reanalysis clearly shows distinct waveforms. Symmetry status resulted in significant main effects in the different analyses. When the average reference was used, the main effects of the task, evaluative vs. descriptive, was evident and there was no significant interaction. This result shows that both the account of Bertamini, Makin, and colleagues as well as the account of Jacobsen and Höfel have merit. Symmetry effects were observed for both accounts.

The stimuli of our studies [2,8,15] all consisted of a circle with a rhombic cutout in which smaller geometric shapes were positioned. This means that all of our stimuli had a good degree of symmetry, because of the outer shape of the graphic pattern. Although the graphic patterns differ in symmetry because of the smaller elements inside the cutout, it is conceivable that all of our stimuli elicit a certain degree of symmetric processing. This would not allow for any symmetry-related differences between our ERPs in the symmetric and non-symmetric conditions. In any case, however, even if we would consider an SPN to be present in all our conditions, we still find a relatively more negative going ERP in the symmetric conditions of the descriptive symmetry judgment task. In contrast, this relative negativity is not present to the same degree in the symmetric conditions of the evaluative aesthetic judgment task, even when using objective symmetry and different EEG sensors for this reanalysis, as compared to the original findings. Only when the average reference was used, an enhanced negativity to the symmetric stimuli was evident also during evaluative aesthetic judgments. The choice of reference can have a substantial impact on ERPs [20]. The differences might be explained by partially different neuroelectric sources in the two tasks that become evident when different references are used. Using the average reference resulted in an ERP pattern with a morphology closely resembling an SPN to symmetric stimuli, irrespective of the task. There was also a task effect on the ERPs that was statistically independent of the SPN. Thus, when analyzed with contemporary SPN analysis settings, the data by Jacobsen and Höfel (2003) contain an SPN to symmetric stimuli irrespective of task.

Taken together, this indicates that there is also a strategy-dependent reflection of a process present in the ERPs, which does not hinge on the symmetry aspect of the stimuli per se but is contingent on the mode of processing that the participants adopt.

5. Conclusions

The SPN or posterior sustained negativity to symmetric stimuli, as we had termed it earlier [2], was observed under conditions of an evaluative judgment of beauty and a descriptive judgment of symmetry in the present reanalysis of the original data. Task effects were also present. Taken together, the reanalysis supports the notion of obligatory occurrence of the SPN and a modulation of the ERP by task requirements.

Supplementary Materials: The following are available online at www.mdpi.com/2073-8994/10/1/27/s1, Figure S1: ERP waveforms (nose reference, bandpass filtered at 0.2–25 Hz) in the aesthetic task averaged across the sensors P7, O1, O2 and P8 for the stimuli that were subjectively judged either as beautiful (BEA_S+) or not (BEA_s-). Averages were created for all stimuli or only for those that were objectively symmetric (SYM_o+) or not (SYM_o-), Figure S2: ERPs (nose reference, lowpass filter at 25 Hz) for stimuli that were subjectively judged as beautiful (BEA_s+), symmetric (SYM_s+) , not beautiful (BEA_s-) or not symmetric (SYM_s-) when the objective symmetry was considered. Only objectively symmetric stimuli (SYM_o+) were included in the beautiful (BEA_s+)/symmetric ERPs (SYM_s+) and only objectively non-symmetric stimuli (SYM_o-) for the not beautiful (BEA_s-)/not symmetric ERPs (SYM_s-), Figure S3: ERPs (average reference, lowpass filter at 25 Hz) for objectively symmetric (SYM_o+) and non-symmetric (SYM_o-) stimuli that were either judged for beauty (BEA; evaluative task) or symmetry (SYM; descriptive task). Participants' responses were disregarded in this analysis.

Author Contributions: Thomas Jacobsen designed the study. Andreas Löw analysed the data. Thomas Jacobsen, Stina Klein, Andreas Löw interpreted the data and wrote the manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

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