Budapest University of Technology and Economics

Department of Cognitive Science

Psychology PhD School

Pál Vakli

Neural correlates of configural processing in person perception

PhD Thesis

Thesis booklet

Supervisor:

Prof. Gyula Kovács

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Synopse of the presented studies and theses

Configural processing refers to the processing of the relationship between different features of a stimulus. Configural processing is fundamental in the perception of faces, and recent evidence suggests that it is also important in the perception of the whole person as well. Furthermore, in a highly influential review, Maurer, Le Grand, & Mondloch (2002) argued that configural processing is not a unitary phenomenon, instead, it can be subdivided into three distinct processes. The dissertation presents four studies that investigated the neural correlates of configural processing in humans, using behavioral and electrophysiological measures.

First-order relational properties refer to the basic configuration that is shared by each and every human face—two eyes above a nose which is in turn above a mouth. The processing of these properties is assumed to underlie face detection and categorization. It is also well known that the way we perceive faces is not only determined by the physical properties of the given face, but also by the properties of the previously viewed faces as well—in other words, face perception is prone to visual aftereffects (for a review, see Webster & MacLeod, 2011). However, previous investigations yielded mixed results regarding whether the neural substrates of face aftereffects encode the first-order relational properties of the face (e.g. Butler et al., 2008; Watson & Clifford, 2006). This issue was investigated in the first study by examining face aftereffects using highly schematized face-like stimuli.

When the first-order relations of a face are detected, the stimulus is processed as a Gestalt—the features of the face are integrated into a unified representation. This so-called holistic processing makes it difficult to process the facial features independently from one another (for a review, see Rossion, 2013). More recently, similar effects has been described in the perception of the whole person as well, which was taken as evidence for „holistic person processing” (Aviezer, Trope, & Todorov, 2012). This suggests that similarly to facial features, the face and different body parts are integrated into a single perceptual representation. However, as of today, the electrophysiological correlates of this process are less known. The second study addressed this issue by measuring the event-related potential components evoked by different face-hands configurations.

While first-order relations are important for face detection, the recognition of individual faces is assumed to rely on subtle variations in the spatial interrelationship between face parts, called second-order relational properties. Evidence shows that the encoding of individual face representations takes place in the time window of the N170 component of the event-related potential (for a review, see Rossion & Jacques, 2011). However, it is unclear whether the N170 also marks the encoding of the second-order relational properties of faces. This was examined in the third study by investigating whether the N170 is sensitive to an image transformation (vertical stretching) that alters the second-order relations of faces.

More recently, there has been a shift in the focus of research on the neural correlates of face individuation from traditional event-related potential techniques to the investigation of the so-called „steady-state" visual evoked potentials evoked by the periodic presentation of visual stimuli. Previous studies revealed that the face-evoked steady-state response shows adaptation to face identity, as the magnitude of the response was reduced when the same face was repeated compared to a condition in which different identitiy faces were presented in succession (Rossion & Boremanse, 2011). This repetition suppression effect has been taken as evidence that the steady-state potential is a robust marker of face individuation in the human brain (Rossion & Boremanse, 2011). Nevertheless, it is not clear whether this effect is robust enough to generalize across changes in the more dynamic aspects of faces, such emotional expression, orientation, and viewpoint. In the fourth study, we investigated whether face individuation, as reflected in the steady-state response, is independent of changes in these properties.

The following research questions were addressed in the dissertation:

1. *Can high-level face aftereffects be evoked by stimuli that lack veridical face parts but retain the first-order relational properties of the face?*
2. *What are the event-related potential correlates of the integrated processing of the face and non-face body parts?*
3. *Is the N170 sensitive to image transformations altering the second-order relational properties of faces?*
4. *Is neural adaptation to facial identity, as reflected in the repetition suppression of the steady-state visual-evoked potential, invariant to the changeable properties of the face?*

Thesis point I.: Adaptation to schematic stimuli that lack veridical face parts but retain the first-order relational properties of the face induces high-level aftereffects in face perception.

In the first study (Vakli, Németh, Zimmer, Schweinberger, & Kovács, 2012), we investigated whether high-level aftereffects in the perception of faces can be evoked by schematic face-like adapting stimuli. These stimuli consisted of white dots placed in the position of the eyes and the mouth and embedded in a grey oval. Thus, the individual parts of these images could not be interpreted as features of a typical human face, but their arrangement preserved the basic configuration of human faces—that is, the first-order relational properties. Prolonged viewing of the expanded or contracted versions of these images biased the perceived distortion of the subsequently presented veridical faces in the opposite direction. This face distortion aftereffect was observed with adapting images of different size and contrast polarity, suggesting the adaptation of higher-level, non-retinotopic processing sites. Importantly, inverting the adapting images eliminated the aftereffect, in line with the well-known detrimental effect of inversion on configural processing. These results suggest that the neural substrates of face aftereffects are sensitive to the basic face configuration, that is, they encode the first-order relational properties of the face.

Thesis point II.: The amplitude of the P2 component of the event-related is modulated by different face-hands configurations, suggesting that the P2 reflects the operation of perceptual mechanisms responsible for the integrated processing of visually presented body parts.

In the second study (Vakli, Németh, Zimmer, & Kovács, 2016), we examined the electrophysiological correlates of the integrated processing of faces and body parts by measuring the event-related potentials evoked by the presentation of different face-hands configurations. The results revealed a modulation of the amplitude of the P2 component of the event-related potential. In particular, when the hands were rotated to obtain a biologically implausible configuration, a reduction of the P2 amplitude was observed relative to the condition in which the face and hands were retained in their veridical configuration and were supplemented with visual cues to highlight further the overall body posture. This suggests that the P2 reflects the perceptual integration of different body parts, and is a likely electrophysiological correlate of holistic person processing.

Thesis point III.: Altering the second-order relational properties of the face modulates the adaptation effect measured on the N170 component of the event-related potential.

In the third study (Vakli, Németh, Zimmer, Schweinberger, & Kovács, 2014), we examined whether the N170 component of the event-related potential is modulated by changes in the second-order relational properties of the face. We used a control stimulus lacking any shape information and faces that were either unaltered or vertically stretched, as stretching alters the second-order relations by displacing the features of the face. We found that the prolonged viewing of unaltered adaptor faces resulted in the reduction of the N170 amplitude evoked by the subsequently presented veridical test faces when compared to the condition in which participants were adapted to the control image. This adaptation effect on the N170, however, was reduced in magnitude when vertically stretched adaptor faces were used instead of the unaltered ones. This suggests that the N170 marks face processing mechanisms that proceed by extracting variations in the spatial interrelationship between the different parts of a face.

Thesis point IV.: Neural adaptation to face identity, as reflected in the reduction of the steady-state visual-evoked potential, is largely invariant to emotional expression but sensitive to the orientation and viewpoint of the face.

In the fourth study (Vakli, Németh, Zimmer, & Kovács, 2014), we presented participants with faces periodically at a constant rate. Concurrent electroencephalographic measurements revealed a large response at the stimulation frequency—the steady-state visual-evoked potential. When the same identity face was presented repeatedly, a reduction of the steady-state response was observed when compared to the condition in which different identity faces were presented in succession, in accordance with previous findings (Rossion & Boremanse, 2011). This reduction emerged despite the continuous change in the size of the faces, suggesting that the reduction of the response is not due to low-level image-based adaptation. Importantly, a similar effect was observed even when the emotional expression of faces changed continuously. Changes in the orientation or the viewpoint of the faces, however, eliminated the effect. This argues against the involvement of an abstract three-dimensional representation of face identity. Instead, the steady-state response might reflect the activity of cortical sites that represent faces at an intermediate level of abstraction.

Discussion

The observation that the prolonged viewing of schematic face-like stimuli biases the perception of veridical faces suggests that the adaptation of cortical sites sensitive to first-order relational properties contribute significantly to high-level face aftereffects. These cortical sights might involve the fusiform face area, which has been shown to be sensitive to the disruption of first-order relational properties by scrambling of the face parts (Liu, Harris, & Kanwisher, 2010). Since the expanded and contracted schematic adaptors differed only in the distances between their parts, these results also suggest that the neural substrates of the face aftereffects encode the subtle variations in the spatial interrelationship between face parts—that is, second-order relational properties. We found evidence that the encoding of these properties probably takes place in the time window of the N170 component—the adaptation effect measured on the N170 was modulated by vertical stretching, an image manipulation that displaces the features of the face. This is in line with previous observations showing that the N170 reflects the encoding of individual face representations (Rossion & Jacques, 2011). In contrast, the later P2 component might reflect the operation of configural processing mechanisms that are not only involved in face perception, but engage in the integrated processing of the face and other body parts. This is suggested by the observation that face-hands configurations modulate the amplitude of the P2 component.

Besides the more traditional event-related potential method, we investigated face processing by means of steady-state potentials evoked by the periodic presentation of face stimuli. On the one hand, the finding that the steady-state potential shows adaptation to face identity despite changes in the size and the emotional expression of faces suggests the involvement of higher level processing stages. On the other hand, its sensitivity to orientation and viewpoint changes argue against the involvement of an abstract three-dimensional representation of face identity. Instead, it appears that the face-evoked steady-state response taps into face representation that is specific to the in-plane and in-depth orientation of the face. By and large, these results are consistent with a framework in which invariance to dynamic facial attributes gradually emerges in the neural representation of faces along the ventral occipito-temporal cortex (Freiwald & Tsao, 2010).

Publications attached to the thesis points:

1. Vakli, P., Németh, K., Zimmer, M., Schweinberger, S. R., & Kovács, G. (2012). Face distortion aftereffects evoked by featureless first-order stimulus configurations. *Frontiers in Psychology, 3,* 566. doi:10.3389/fpsyg.2012.00566
2. Vakli, P., Németh, K., Zimmer, M., & Kovács, G. (2016). The electrophysiological correlates of integrated face and body-part perception. *The Quarterly Journal of Experimental Psychology,* 1-12. doi:10.1080/17470218.2015.1127981
3. Vakli, P., Németh, K., Zimmer, M., Schweinberger, S. R., & Kovács, G. (2014). Altering second-order configurations reduces the adaptation effects on early face-sensitive event-related potential components. *Frontiers in Human Neuroscience, 8,* 426. doi:10.3389/fnhum.2014.00426
4. Vakli, P., Németh, K., Zimmer, M., & Kovács, G. (2014). The face evoked steady-state visual potentials are sensitive to the orientation, viewpoint, expression and configuration of the stimuli. *International Journal of Psychophysiology, 94,* 336-350. doi:10.1016/j.ijpsycho.2014.10.008

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