Consciousness and Cognition 51 (2017) 166–180

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Face proprioception does not modulate access to visual awareness of emotional faces in a continuous flash suppression paradigm

Sebastian Korb[a,c,*], Sofia A. Osimo[a,1], Tiziano Suran[a,1], Ariel Goldstein[b,1], Raffaella Ida Rumiati[a]

[a] Neuroscience and Society Lab, SISSA, Via Bonomea 265, 34136 Trieste, Italy
[b] Cognitive Science Department, The Hebrew University of Jerusalem, Mount Scopus, Jerusalem 91905, Israel
[c] Faculty of Psychology, Department of Applied Psychology: Health, Development, Enhancement and Intervention, University of Vienna, Liebiggasse 5, 1010 Vienna, Austria

ARTICLE INFO

Keywords:
Multisensory integration
Visual awareness
Facial expression
Facial mimicry
Embodied cognition

ABSTRACT

An important question in neuroscience is which multisensory information, presented outside of awareness, can influence the nature and speed of conscious access to our percepts. Recently, proprioceptive feedback of the hand was reported to lead to faster awareness of congruent hand images in a breaking continuous flash suppression (b-CFS) paradigm. Moreover, a vast literature suggests that spontaneous facial mimicry can improve emotion recognition, even without awareness of the stimulus face. However, integration of visual and proprioceptive information about the face to date has not been tested with CFS. The modulation of visual awareness of emotional faces by facial proprioception was investigated across three separate experiments. Face proprioception was induced with voluntary facial expressions or with spontaneous facial mimicry. Frequentist statistical analyses were complemented with Bayesian statistics. No evidence of multisensory integration was found, suggesting that proprioception does not modulate access to visual awareness of emotional faces in a CFS paradigm.

1. Introduction

Vision is the dominant sense in humans, and the study of visual processing is a central topic in cognitive neuroscience. However, most of our everyday experiences are multisensory. For example, the sight of an approaching truck is accompanied by the noise of its engine, and by the feeling of an air current when the truck drives past us. There is currently great interest in investigating how stimuli across different senses interact, and there is debate about what types of multisensory integration can occur unconsciously, i.e. outside of awareness (e.g. Gelbard-Sagiv, Faivre, Mudrik, & Koch, 2016; Moors, Boelens, van Overwalle, & Wagemans, 2016).

Multisensory integration, which emerges after a period of neural maturation during infancy, improves our ability to perceive, understand, and react to the world. For example, the co-occurrence of related inputs in distinct sensory modalities typically leads to stronger and faster behavioral responses (Stein, Stanford, & Rowland, 2014; Yau, DeAngelis, & Angelaki, 2015). Multisensory integration occurs both subcortically in the deep layers of the superior colliculus, as well as in several cortical areas including the posterior parietal and the superior temporal cortices (Alais, Newell, & Mamassian, 2010; Stein, Jiang, Wallace, & Stanford, 2001;

* Corresponding author at: Faculty of Psychology, Department of Applied Psychology: Health, Development, Enhancement and Intervention, University of Vienna, Liebiggasse 5, 1010 Vienna, Austria.
E-mail addresses: Sebastian.korb@univie.ac.at (S. Korb), sofia.osimo@sissa.it (S.A. Osimo), tsuran@sissa.it (T. Suran), ariel.goldstien@gmail.com (A. Goldstein), rumiati@sissa.it (R.I. Rumiati).
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.concog.2017.03.008
Received 28 October 2016; Received in revised form 9 March 2017; Accepted 26 March 2017
Available online 05 April 2017
1053-8100/

Stein et al., 2014). It has been suggested that multisensory integration can occur in the absence of conscious perception in one or more sensory modalities (Faivre, Mudrik, Schwartz, & Koch, 2014; Stein et al., 2001, 2014), although the level of unconscious processing and integration is currently debated (Gelbard-Sagiv et al., 2016).

Multisensory integration has been studied extensively in relation to visual awareness. One powerful means to study visual awareness is the binocular rivalry paradigm, which consists in presenting different visual stimuli to each eye (Blake & Logothetis, 2002; Blake & Wilson, 2011; Logothetis, 1998). During binocular rivalry, visual awareness is restricted to one stimulus at a time, and alternates between the two competing stimuli. Interestingly, dominance (awareness) of each stimulus can be influenced by presenting congruent or incongruent stimuli in another sensory modality. For example, the time of visual awareness of the image shown to one eye can be increased during simultaneous presentation of congruent (related) auditory, tactile, or olfactory stimuli (Chen, Yeh, & Spence, 2011; Lunghi, Binda, & Morrone, 2010; van Ee, van Boxtel, Parker, & Alais, 2009; Zhou, Jiang, He, & Chen, 2010).

A special case of binocular rivalry is called Continuous Flash Suppression (CFS; Tsuchiya & Koch, 2005). By presenting flashing patterns to one eye, awareness of the image shown to the other eye can be continuously suppressed for several seconds. In the breaking CFS (b-CFS) variant of the CFS paradigm the main dependent variable is response time (RT) from trial onset until the suppressed stimulus "breaks" suppression and becomes consciously perceived, as indicated by participant's button press (for a review see Stein, Hebart, & Sterzer, 2011). As for binocular rivalry, time of awareness during b-CFS can vary based on familiarity and salience of the suppressed stimulus (Jiang, Costello, & He, 2007a). Suppression typically breaks faster (RTs are shorter) for high salience stimuli, for example fearful facial expressions (Yang, Zald, & Blake, 2007), faces with direct compared to averted gaze (Stein, Senju, Peelen, & Sterzer, 2011), or pictures of spiders in spider phobics (Schmack, Burk, Haynes, & Sterzer, 2015). However, low-level visual features, like luminance or spatial frequency, can affect suppression time and must be properly controlled in b-CFS paradigms (Gelbard-Sagiv et al., 2016; Gray, Adams, Hedger, Newton, & Garner, 2013; Hedger, Gray, Garner, & Adams, 2016; Yang & Blake, 2012).

Recently, it was found that faster awareness of suppressed visual stimuli can be achieved by simultaneously providing congruent vestibular or proprioceptive stimulation (Salomon, Kaliuzhna, Herbelin, & Blanke, 2015; Salomon, Lim, Herbelin, Hesselmann, & Blanke, 2013). In one study (Salomon et al., 2013) images of palm-up or -down hands were suppressed in a b-CFS paradigm, while participants positioned their own right hand in a palm up or down position on the table. Position of participant's hand and of the pictures of hands could thus be congruent (e.g. both palm-up), or incongruent (one up and one down). Results showed that in the CFS condition suppression breaks approximately 60 ms faster in congruent compared to incongruent trials, suggesting that proprioception can result in faster awareness of congruent visual stimuli. No effect of multisensory congruence was found when hand pictures were shown to both eyes (NOCFS condition).

Detection of emotional expressions, especially in the face, represents another case of proprioceptive-visual integration. Indeed, theories of embodied cognition have long proposed that proprioceptive changes induced by spontaneous facial mimicry (i.e. the matching of facial movements in the observer's and another person's face), contribute to the recognition of emotional facial expressions in others (Barsalou, 2008; Niedenthal, 2007; Niedenthal, Mermillod, Maringer, & Hess, 2010; Wood, Rychlowska, Korb, & Niedenthal, 2016). In line with this, facial mimicry predicts judgments of smile authenticity (Korb, With, Niedenthal, Kaiser, & Grandjean, 2014), and the blocking of facial mimicry or the altering of proprioceptive feedback from the face can disrupt or slow down visual emotion discrimination (Baumeister, Papa, & Foroni, 2016; Korb et al., 2016; Rychlowska et al., 2014; Stel & van Knippenberg, 2008; Wood, Lupyan, Sherrin, & Niedenthal, 2015). Importantly, facial mimicry might occur in the absence of visual awareness of the emotional face (Dimberg, Thunberg, & Elmehed, 2000; Mathersul, McDonald, & Rushby, 2013; Tamietto et al., 2009), possibly through a subcortical "low" route (Méndez-Bértolo et al., 2016; Tamietto & de Gelder, 2010). Moreover, although the matter has not yet been investigated, it can be assumed that participants are typically unaware of their own facial mimicry. The reason for this is that facial mimicry often consists in muscular activity of very small amplitude, which cannot be visually perceived (Wood et al., 2016).

Altogether, there is substantial evidence suggesting that the proprioception of one's own face improves accuracy and speed during the visual discrimination of facial expressions (but see Hess & Fischer, 2013). This form of multisensory integration is likely to occur without awareness of both the stimulus face and the own proprioceptive signal. It remains unknown, however, if access to visual consciousness, or in other words the time required to become aware of a facial expression, can be modulated through congruent or incongruent proprioceptive information. Moreover, should such an effect be found, it begs the question whether facial feedback of spontaneous or voluntary facial movements is required.

To address these questions, three different b-CFS experiments were carried out in 97 healthy participants. Proprioceptive feedback was induced either through voluntary posing of facial expressions (experiments 1 and 2), or through spontaneous facial mimicry (experiment 3). Experiments 1 and 2 were inspired by Salomon et al.'s (2013) finding that proprioception affects visual awareness, but used as stimuli faces instead of hands. Congruent compared to incongruent proprioceptive facial feedback was expected to result in faster awareness of visually suppressed facial expressions. Because of the potential influence of low-level visual features on suppression times, great care was taken in preventing differences in low-level visual features across stimulus categories, and trials with inverted faces (CFS-inverted condition) and without suppression (NOCFS) served as control conditions. After failing to find evidence in support of the hypothesis that proprioception of *voluntary* facial expressions modulates access to visual awareness, experiment 3 investigated if proprioception of *spontaneous* facial mimicry modulates suppression times. In addition to frequentist null hypothesis significance testing (NHST) using linear mixed models (LMMs), Bayesian analyses were computed to quantify the evidence for the absence of effects. Experimental procedures were in agreement with the declaration of Helsinki and received institutional approval. Data, experimental scripts, and analysis scripts are provided at https://osf.io/6devx.