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Effects of unpleasant odors on emotion recognition: The right hemisphere and valence-specific hypotheses

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The right hemisphere has traditionally been considered as dominant in odor and emotion perception, whereas little is known about odor influence on emotion recognition. This study aimed to examine a possible difference in the recognition of basic emotions presented to the left or the right visual field following short-term left or right nostril treatment with an unpleasant odor. A total of 60 right-handed female participants completed an emotion recognition task in conditions of the right and left nostril treatment with an unpleasant odor (isovaleric acid). Results showed the right hemisphere advantage in speed, but not in the accuracy of basic emotion recognition after the right nostril treatment with an unpleasant odor, while the left nostril treatment had no effect. The right hemisphere and valence-specific hypotheses in emotion recognition were not confirmed, whereas the model of the right hemisphere dominance in odor perception was confirmed.

Key words: emotions, the right-hemisphere hypothesis, the valence-specific hypothesis, odor

Highlights:

- There is an effect of unpleasant odor on emotion recognition.
- Emotions are recognized faster by the right hemisphere.
- The left hemisphere has an advantage in accuracy in emotion recognition.
- There is a possible an intra-hemispheric interaction in emotion recognition.

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Emotion and odor perception is of fundamental importance in individuals' emotional and social lives. In olfactory perception, the primary response to an odor is an evaluation of how pleasant or unpleasant the odor is, thus creating a fundamental link with emotion perception (Herz, McCall, & Cahill, 1999). The olfactory system is associated with emotion perception (Savic, 2001, 2005) since there are structures common to emotion and odor perception in neurophysiologic systems of the brain. The olfactory pathways are projected directly into the limbic system (Dijksterhuis et al., 2002), and, in addition to the amygdala, play a key role in basic emotion recognition. There is a local and functional convergence between olfaction and emotion perception (Flohr et al., 2017; Herz, McCall, & Cahill, 1999; Savic, 2001, 2005). Odors can modulate the recognition of disgust (Seubert et al., 2010), or happiness (Leppänen & Hietanen, 2003), while in the ambient odor conditions Reaction Times (RTs) in simple visual or auditory tasks significantly decrease (Millot, Brand, & Morand, 2002). Background odors may modulate the perception of emotional facial stimuli (Syrjänen et al., 2018) or attention may be modulated due to the effects of ambient odors (Michael et., 2003; Seigneuric et al., 2010). This indicates that olfactory stimuli may affect the modalities of perception and attention. Cross-modal interactions between olfaction and emotion allow the influence of pleasant/unpleasant environmental odors on emotion recognition (perception).

A characteristic of olfaction and emotion recognition is brain lateralization. Emotional models demonstrate that emotion recognition is lateralized in the brain (Fusar-Poli et al., 2009; Najt, Bayer, & Hausmann, 2013; Stanković & Nešić, 2019; Wager et al., 2003), while olfactory models also indicate brain lateralization of odor perception (Royet et al., 2003; Zou et al., 2016). There are two conflicting models of hemispheric specialization in emotion recognition and odor perception. A dominant olfactory model of hemispheric specialization proposes that the right hemisphere (RH), specifically the right orbitofrontal cortex (right OFC) (Li et al., 2010), has an advantage in odor perception over the left hemisphere (LH) (Frasnelli et al., 2010; Savic & Gulyas, 2000). In the domain of emotional models, the RH hypothesis proposes the RH advantage over the LH in basic emotion recognition (happy, surprised, fearful, angry, disgusted, and sad faces) (Adolphs et al., 1996; Alves et al., 2009; Borod et al., 1998; Bourne & Hole, 2006). This view is based on clinical neurology studies indicating that deficits in basic emotion recognition are associated with RH lesions (Adolphs et al., 1996; Borod et al., 1998; Mandal et al., 1996). The RH damage plays a crucial role in the impaired recognition of basic facial emotional expressions, especially fearful faces (Meletti et al., 2003; Benuzzi et al., 2004), whereas the LH damage does not result in facial emotion recognition deficits (Adolphs et al., 1996).

The alternative olfactory models propose the advantage of the LH in pleasant odor perception, and the RH dominance in the perception of unpleasant odors (Bensafi et al., 2002; Henkin & Levy, 2001). The valence-specific hypothesis as an alternative model to the RH hypothesis in emotion recognition proposes the RH specialization for the recognition of negative basic emotions (fearful, angry, disgusted, and sad faces), and the LH specialization for positive emotions (happy and surprised faces) (Davidson et al., 1987; Prete, Laeng, & Tommasi, 2014; Wedding & Stalans, 1985). Surprise is a typically "cognitive" emotion that may be perceived as positive or negative depending on a cognitive assessment determined by beliefs (Baron-Cohen, Spitz, & Cross, 1993), whereas previous studies defined surprise as a positive emotion (Najt, Bayer, & Hausmann, 2013; Wedding & Stalans, 1985). The RH and valence-specific hypotheses correspond in regard to olfactory and emotion perception.

Neuroimaging studies have made a significant contribution to research on lateralization of olfactory perception. Early studies observed that exposure to a highly aversive odorant produces a strong hemodynamic response in the right OFC and both amygdalae, while the exposure to a less aversive odorant produces an increased hemodynamic response in the left OFC exclusively (Zald & Pardo, 1997). The OFC and the prefrontal cortex (PC) in the LH are more involved in memory and familiarity ratings, while the OFC, insula, PC, amygdala, temporal pole and superior frontal cortex, are more involved in emotional responses to odors (Royet & Plailly, 2004). The RH and the OFC play a key role in explicit odor hedonic judgment (Zou et al., 2016). Data from numerous fMRI studies have demonstrated a fundamental role of the OFC in odor valence, whereas the right medial OFC encodes the pleasantness and the lateral OFC encodes the unpleasantness of odors (Anderson et al., 2003; Gottfried, Deichmann, Winston, & Dolan, 2002; Rolls, Kringelbach, & de Araujo, 2003). Hence, the findings of this study are consistent with the valence-specific hypothesis in olfactory perception. This has implications on emotion perception (odor pleasantness/positive emotions vs. odor unpleasantness/negative emotions). In addition to the RH and valence-specific hypotheses, the Motivation model (Harmon-Jones, 2004) is a fundamental model of brain asymmetry in emotion recognition. The Motivation model suggests hemispheric organization according to withdrawal/approach motivation. Surprise, disgust, sadness, and fear are withdrawal-motivated emotions (RH processing), whereas happiness and anger are approach-motivated emotions (LH processing) (Najt, Bayer, & Hausmann, 2013). The Motivation model is not included in the conceptual framework of the present study. Recent cross-modal studies (Wilkinson et al., 2016) have reported only relative lateralization of emotion recognition, while the recognition of a happy or a fearful face positively correlates with the discrimination of an odor applied to the left nostril. This is inconsistent with the right-hemisphere and valence-specific hypotheses. Little is known about the hemispheric specialization for emotion recognition following monorhinal treatment with an unpleasant odor. Thus, from the viewpoint of the functional brain asymmetry, a cross-modal interaction between odors and emotion perception (recognition) is insufficiently known.

The aims of this study were to examine: a) differences between recognition of basic emotions presented to the left visual field (LVF) or the right visual field (RVF), following brief treatment of the left or right nostril with an unpleasant odor; b) whether the LVF has an advantage over the RVF in the recognition of basic emotions (the RH hypothesis); or the RVF has an advantage in the recognition of positive emotions (happy and surprised faces), whereas the LVF has an advantage in negative emotion recognition (fearful, angry, disgusted and sad faces) (Valence-specific hypothesis). Based on the dominant olfactory model of the RH (Frasnelli et al., 2010; Li et al., 2010; Savic & Gulyas, 2000) and the emotional model of the RH in emotion recognition (Adolphs et al., 1996; Alves et al., 2009; Borod et al., 1998; Bourne & Hole, 2006), we hypothesized that short-term treatment of the right nostril with an unpleasant odor would cause shorter RTs and higher recognition accuracy of basic emotions presented to the LVF compared to the RVF, while the treatment of the left nostril with an unpleasant odor would have no effect on emotion recognition. In line with previous studies demonstrating the RH dominance in emotion recognition (Adolphs et al., 1996; Alves et al., 2009; Borod et al., 1998; Bourne & Hole, 2006), we hypothesized shorter RTs and more accurate emotion recognition in LVF (RH) presentations than in RVF (LH) presentations.

The method used in this study was the exposure of facial emotional expressions and neutral faces presented using the Half Visual Field (HVF) technique. This condition was combined with a short-term monorhinal exposure to isovaleric acid. A concept underlying the HVF technique is a neurophysiological principle relying on the visual projections from the left and right hemiretina of the eyes to the left and right brain hemispheres, respectively. A stimulus (e.g., an emotional face) of short duration (max. 180 ms) initially presented to the LVF (vs. RVF) is perceived and processed in the RH (vs. LH) (Bourne, 2006). The received stimulus is processed by both hemispheres; however, differences in the LH and RH performance can be tested by the accuracy and RTs analysis. The monorhinal exposure to an unpleasant odor allows the stimulation of the LH (RH) by direct application to the left (right) nostril, due to ipsilateral projections of the olfactory system. The olfactory tracts are projected ipsilaterally; the right olfactory tract is projected to the RH, and the left to the LH (Powell, Cowan, & Raisman, 1965; Savic, 2001). We applied an unpleasant odor exclusively since numerous studies have examined and assessed the perception of pleasant odors (Frasnelli et al., 2015; Zou et al., 2016), whereas the effects of unpleasant odors on emotion recognition are insufficiently known.

Method

Participants

A total of 60 healthy Caucasian female university students (aged 19 to 24 years; *M* = 20.38, *SD* = 0.90) participated in the study. All participants were right-handed as assessed by the Edinburgh Handedness Inventory-Short Form (Veale, 2014). The inclusion criteria were normal or corrected-to-normal vision and dextrality in order to prevent a potential confounding effect, since patterns of lateralization are more consistent in right-handed than in left-handed participants (Bourne, 2006). Participants reported the absence of nasal septal deviations, chronic nose disorders, and acute respiratory problems at the time of the experiment (e.g., cold symptoms). No monetary compensation was provided. This study was approved by the Ethics Committee of the Faculty of Medicine, University of Niš.

Stimuli

Forty-eight color photographs of female faces were taken from the Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998), 24 photographs of facial expressions of emotions (happy, surprised, fearful, angry, disgusted, and sad – 4 photographs for each face) and 24 photographs of neutral faces. We used female faces exclusively since previous studies have reported differences between the perception of male and female faces with respect to observers' gender (Little, DeBruine, & Jones, 2005). Isovaleric acid dissolved in diethyl phtalate at a concentration of 1:50 was used as an unpleasant stimulus, as in a study by Adolph and Pause (2012).

Procedure

The experiment was carried out at the laboratory of experimental research, Department of Physiology at the Faculty of Medicine, University of Niš, Serbia, and was conducted in accordance with the ethical standards of the American Psychological Association and World Medical Association (The Declaration of Helsinki). Participants were instructed to close their left or right nostril using the left hand, prior to entering the laboratory, and keep it closed until the end of the experiment. Next, participants were seated in a fixed position at a distance of 800mm in front of a computer monitor (15,6", 1366 x 768 resolution) set up at eye level. Participants were instructed to keep their heads still and fix their gaze on the monitor ahead during the experiment. We used an open-source software environment (PsychoPy; Peirce, 2009) to expose participants to stimuli and collect data. An open bottle containing an unpleasant odor was placed directly under participants' left or right nostril for 10 s with the instruction not to increase or decrease the respiratory rate. The bottle was then removed and participants were instructed to assess the valence of the exposed odor on a scale ranging from –4 (*very unpleasant*) to +4 (*very pleasant*). The task of facial emotion recognition was performed afterward. A fixation cross appeared at the center of a black monitor screen (1500 ms), followed by a photograph of an emotionally neutral or emotional face (170ms) presented to the LVF or the RVF (in a pseudo-random sequence), subsequently covered by a mask (1000ms). Each response was followed by an interstimulus interval (500 ms) (Figure 1).

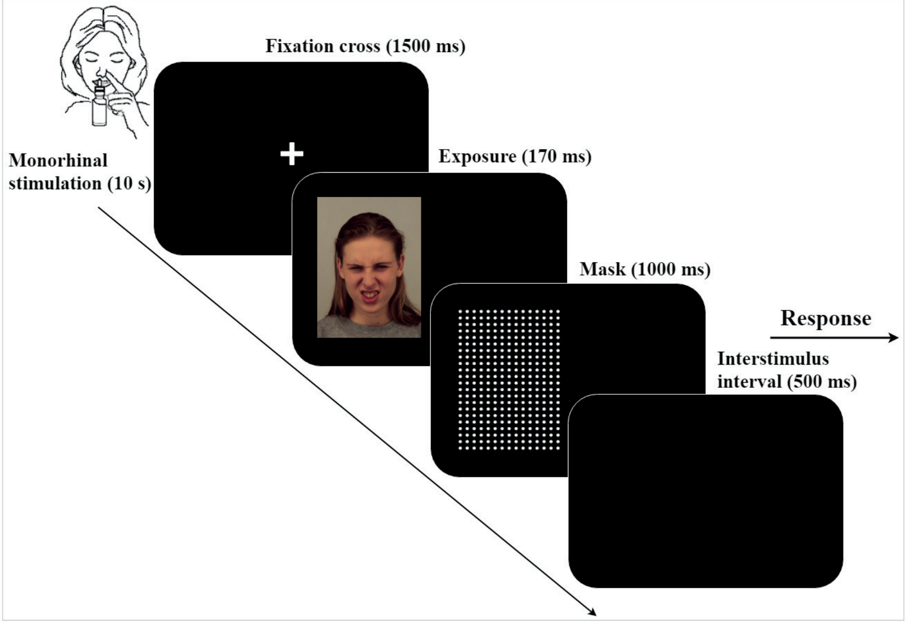

Figure 1. Emotional recognition task flow.

Participants were instructed to press the "down" key on the keyboard with their right-hand middle finger "as quickly and accurately as possible", if an "emotional face" appeared on the monitor or to press the "left" key with their index finger if a "neutral face" was displayed. A forced binary choice for testing emotion recognition or emotionally neutral faces, presented to the LVF and the RVF, was based on a previous study (Najt, Bayer, & Hausmann, 2013). All of the photographs (height 90mm x width 90mm) were presented to the LVF or the RVF at the angle of 6.3°. The experiment started with 12 practice trials that were excluded from the statistical analysis, followed by a total of 192 trials, 96 for emotionally neutral and 96 for emotional faces. The number of photographs of positive facial expressions (8) was smaller than the number of photographs of negative (16) and neutral faces (24). Each photograph appeared four times.

We applied the experimental technique of repeated measures with counterbalancing in order to minimize the effects of sequential variables. The experimental procedure was carried out within two weeks. The convenient sample of our study was randomly divided into two groups of equal size. We tested the first group of participants using the left nostril treatment with an unpleasant odor during the first week, while we conducted testing with the right nostril treatment during the second week. We tested the participants in the second group using the right nostril treatment with an unpleasant odor during the first week, and with the left nostril treatment during the second week. The average duration of the experiment per each participant was about 25 minutes in the first week and about 20 minutes in the second week.

Statistical Analysis

We used repeated Measures ANOVA 2 x 2 x 2 for testing the RH hypothesis; Treatment (left nostril vs. right nostril), HVF (LVF vs. RVF) and Emotions (emotional face vs. neutral face). The valence specific hypothesis was tested with repeated Measures ANOVA 2 x 2 x 2; Treatment (left nostril vs. right nostril), HVF (LVF vs. RVF), and Emotions (positive vs. negative). Consistent with the methodology of previous studies (Najt, Bayer, & Hausmann, 2013; Wedding & Stalans, 1985) positive emotions were created by happy and surprised faces, whereas negative emotions were created by fearful, angry, disgusted, and sad faces. Basic emotion recognition was tested with repeated Measures ANOVA 2 x 2 x 6; Treatment (left nostril vs. right nostril), HVF (LVF vs. RVF), and Emotions (happy, surprised, fearful, angry, disgusted, and sad faces). Bonferroni correction was applied in case of a statistically significant interaction, while η_p^2 was used as a measure of effect size. Statistical analysis was performed by using the JASP Version 0.11.1 (https://jasp-stats.org/).

Results

There was no statistically significant difference in a subjective assessment of the valence of an unpleasant odor used for the treatment of the left nostril, $M = -1.22$, $SD = 1.49$ and the right nostril, $M = -1.50$, $SD = 1.35$, ($t(1, 58) = 1.22$, *ns*).

The Right-hemisphere Hypothesis in Emotion Recognition

In the corresponding analysis for mean RTs, results showed no statistically significant effect of emotions, ($F(1, 59) = 2.44$, *ns*), or treatment, ($F(1, 59) = 0.01$, *ns*). There was a statistically significant effect of HVF, ($F(1, 59) = 10.13$, $p < .01$, $\eta_p^2 = .14$); RTs were shorter in the LVF, $M = 0.55$, $SD = 0.15$, compared with the RVF, $M = 0.58$, $SD = 0.19$. There was no statistically significant interaction between treatment and emotions, ($F(1, 59) = 0.82$, *ns*), treatment and HVF, ($F(1, 59) = 2.58$, *ns*), or emotions and HVF, ($F(1, 59) = 0.44$, *ns*).

In the analysis of accuracy, results showed no statistically significant effect of treatment, ($F(1, 59) = 0.09$, *ns*), or emotions, ($F(1, 59) = 1.88$, *ns*). A statistically significant effect of HVF was found, ($F(1, 59) = 7.24$, $p < .01$, $\eta_p^2 = .10$); recognition accuracy in the RVF, $M = 0.79$, $SD = 0.15$, was higher compared with the LVF, $M = 0.76$, $SD = 0.16$. Furthermore, there was no statistically significant interaction between treatment and emotions, ($F(1, 59) = 0.17$, *ns*), or treatment and HVF, ($F(1, 59) = 1.18$, *ns*), whereas there was a statistically significant interaction between HVF and emotions, ($F(1, 59) = 11.01$, $p < .01$, $\eta_p^2 = .15$); with more accurate recognition of emotional faces in the RVF, $M = 0.82$, $SD = 0.09$, compared with emotional faces in the LVF, $M = 0.76$, $SD = 0.12$, ($t(1, 59) = -4.95$, $p < .001$). There was also more accurate recognition of emotional faces in the RVF compared with neutral faces in the LVF, $M = 0.77$, $SD = 0.14$, ($t(1, 59) = 2.31$, $p < .05$); and more accurate recognition of emotional faces in the RVF, compared with neutral faces in the RVF, $M = 0.75$, $SD = 0.16$, ($t(1, 59) = 2.66$, $p < .01$) (Figure 2).

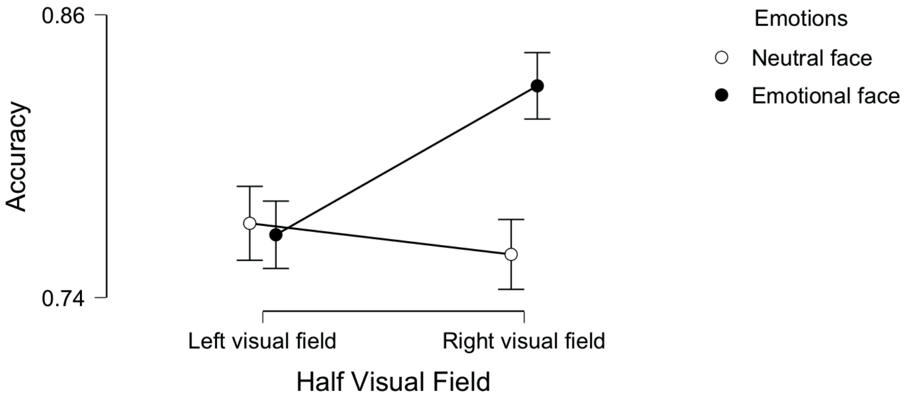

Figure 2. Interaction of Emotions and Half Visual Field. Error bars show standard error.

The Valence-specific Hypothesis in Emotion Recognition

In the corresponding analysis for mean RTs, results showed a statistically significant effect of HVF, ($F(1, 59) = 7.68$, $p < .01$, $\eta_p^2 = .11$) with faster recognition of faces presented to the LVF, $M = 0.54$, $SD = 0.15$, compared with the RVF, $M = 0.59$, $SD = 0.16$. In addition, there was a statistically significant effect of emotions, ($F(1, 59) = 14.87$, $p < .001$, $\eta_p^2 = .20$), with faster recognition of positive, $M = 0.54$, $SD = 0.12$, than negative emotions, $M = 0.58$, $SD = 0.11$. There was no statistically significant effect of treatment and no statistically significant interaction between treatment and emotions, ($F(1, 59) = 0.14$, *ns*), or HVF and emotions, ($F(1, 59) = 0.37$, *ns*). Results showed an interaction of treatment with HVF, ($F(1, 59) = 4.56$, $p < .05$, $\eta_p^2 = .07$); participants whose right nostril was treated with an unpleasant odor demonstrated faster recognition of faces presented to the LVF, $M = 0.53$, $SD = 0.15$, compared with the RVF, $M = 0.59$, $SD = 0.15$, ($t(1, 59) = –3.68$, $p < .001$) (Figure 3).

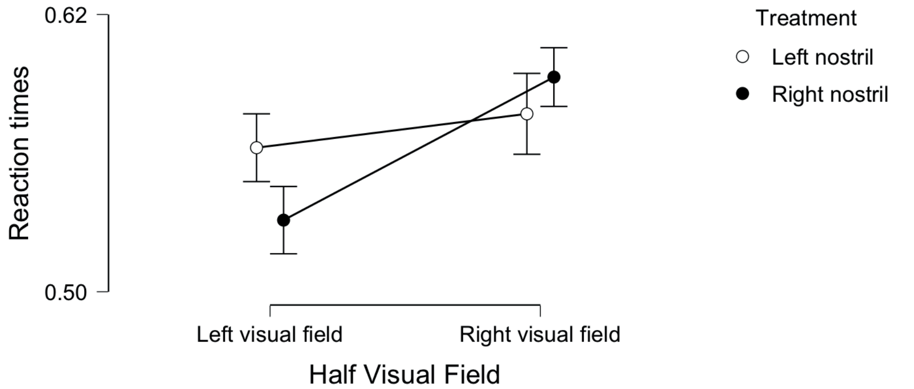

Figure 3. Interaction of treatment and Half Visual Field. Error bars show standard error.

In the analysis of accuracy, results showed a statistically significant effect of HVF, ($F(1,59) = 30.40$, $p < .001$, $\eta_p^2 = .34$), with more accurate recognition of faces presented to the RVF, $M = 0.85$, $SD = 0.12$, compared with the LVF, $M = 0.78$, $SD = 0.16$; in addition, there was an effect of emotions, ($F(1,59) = 54.07$, $p < .001$, $\eta_p^2 = .47$), with more accurate recognition of positive, $M = 0.87$, $SD = 0.14$, than negative emotions, $M = 0.76$, $SD = 0.15$. There was no statistically significant effect of treatment and no statistically significant interaction between treatment and HVF, ($F(1,59) = 2.28$, *ns*), treatment and emotions ($F(1,59) = 0.97$, *ns*), and HVF and emotions, ($F(1, 59) = 2.47$, *ns*).

Basic Emotion Recognition

In the corresponding analysis for mean RTs results showed no effect of treatment, ($F(1, 59) = 0.22$, *ns*); however, there was an effect of emotion, ($F(5, 59) = 5.73$, $p < .001$, $\eta_p^2 = .08$). Results showed an effect of HVF, ($F(1, 59) = 7.68$, $p < .01$, $\eta_p^2 = .11$); with faster recognition of faces presented to the LVF, $M = 0.53$, $SD = 0.16$, compared with the RVF, $M = 0.57$, $SD = 0.16$, while there was no interaction between treatment and emotions, ($F(5, 59) = 0.84$, *ns*). There was an interaction between treatment and HVF, ($F(1, 59) = 4.42$, $p < .05$, $\eta_p^2 = .07$); odor treatment to the right nostril caused faster recognition of faces presented to the LVF, $M = 0.52$, $SD = 0.15$, compared with the RVF, $M = 0.58$, $SD = 0.14$, ($t(1, 59) = -3.98$, $p < .001$). Results showed an interaction between emotions and HVF, ($F(5, 59) = 11.78$, $p < .001$, $\eta_p^2 = .16$). Recognition of a fearful face was faster in the LVF, $M = 0.52$, $SD = 0.20$, compared with the RVF, $M = 0.63$, $SD = 0.26$, ($t(1, 59) = -2.41$, $p < .05$); recognition of a disgusted face was faster in the RVF, $M = 0.49$, $SD = 0.17$, compared with the LVF, $M = 0.58$, $SD = 0.17$, ($t(1, 59) = 3.44$, $p < .001$); recognition of a sad face was faster in the LVF, $M = 0.37$, $SD = 0.24$, compared with the RVF, $M = 0.71$, $SD = 0.32$, ($t(1, 59) = 6.68$, $p < .001$), and recognition of a surprised face was faster in the RVF, $M = 0.58$, $SD = 0.76$, compared with the LVF, $M = 0.76$, $SD = 0.22$, ($t(1, 59) = 5.76$, $p < .001$) (Figure 4).

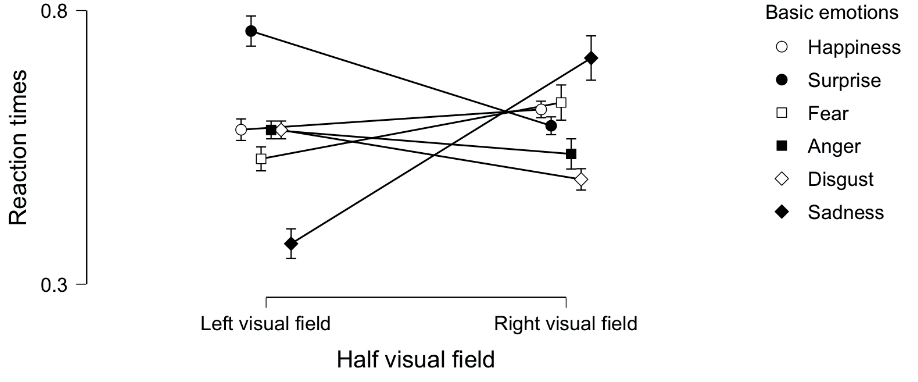

Figure 4. Interaction of Basic Emotions and Half Visual Field. Error bars show standard error.

In the analysis of accuracy, results showed no effect of treatment, (F(1, 59) = 0.00, *ns*), whereas there was an effect of emotions, (F(5, 59) = 39.58, p < .001, η_p^2 = .40). There was an effect of HVF, (F(1, 59) = 24.45, p < .001, η_p^2 = .29); the accuracy of basic emotion recognition presented to the RVF, M = 0.83, SD = 0.16 was higher compared with the LVF, M = 0.76, SD = 0.12. Results showed no interaction between treatment and emotions, (F(5, 59) = 0.52, *ns*), and treatment and HVF, (F(1, 59) = 3.42, *ns*).

Discussion

The hypothesis of this study that short-term treatment of the right nostril with an unpleasant odor causes shorter RTs and higher recognition accuracy of basic emotion presented to the LVF (vs. RVF) was partially confirmed. Participants, on average, recognized basic emotions presented to the LVF (RH) faster, compared with those presented to the RVF (LH), in cases of the right nostril treatment with an unpleasant odor, whereas the treatment of the left nostril did not have any significant effects. Since previous studies have reported the advantage of the RH over the LH in odor perception (Bensafi et al., 2002; Frasnelli et al., 2010; Henkin & Levy, 2001; Li et al., 2010; Savic & Gulyas, 2000), this possibly indicates that participants' shorter RTs to all basic emotions presented to the LVF, occur due to the RH specialization for odor perception. In odor perception, the right OFC (Li et al., 2010), the right medial OFC and the right insula (Frasnelli et al., 2010) play a key role, thus indicating the RH dominance in odor perception (Frasnelli et al., 2010; Savic & Gulyas, 2000). Following the treatment of the right nostril with an unpleasant odor, the neural activation within a branched network of the RH olfactory system increases, thus resulting in the improvement of behavioral performances related to odors. Therefore, the stimulation of the branched network of the RH olfactory system with an unpleasant odor increases emotional performances causing faster recognition of basic emotions by the RH. This is supported by recent studies (Wilkinson et al., 2016) reporting that the association between olfaction and emotions depends on intra-hemispheric rather than on inter-hemispheric interactions due to the ipsilateral configuration of olfactory projections in the brain.

Interestingly, the participants whose left nostril was treated with an unpleasant odor also reacted slightly faster to basic emotions presented to the LVF than those presented to the RVF; however, this difference was not statistically significant. On a speculative level, results possibly demonstrate that despite the RH dominance in odor perception (Savic, 2001), the LH also plays a role in the olfactory system due to inter-hemispheric interaction since the left nostril stimulation by an odorant causes greater activation of the right thalamus (Savic & Gulyas, 2000). In addition, a slightly faster response to basic emotions in the LVF following the treatment of the left nostril with an unpleasant odor may be due to cooperation between the LH and RH, enabled by a contralateral communication between the olfactory tract i.e., via the anterior olfactory nuclei and the anterior commissure (Powell, Cowan, & Raisman, 1965). However, this requires further testing.

The RH hypothesis (Borod et al., 1998) and the valence-specific hypothesis (Davidson et al., 1987; Prete et al. 2014; Wedding & Stalans, 1985) in emotion recognition, examined in this study were not confirmed. Contrary to expectations, results showed the LH advantage in the recognition accuracy of emotional and neutral faces and the RH advantage regarding shorter RTs to all faces. Emotional faces were more accurately recognized by the LH than the RH. Furthermore, in line with these findings, positive and negative emotions were on average recognized more accurately by the LH, whereas the RTs were shorter in the RH. Positive emotions were recognized faster and more accurately than negative emotions. This is consistent with previous findings of cross-cultural (Scherer & Wallbott, 1994) and cross-sectional studies (Becker et al., 2011) demonstrating superiority in recognizing positive emotions, and particularly in the perception of happy facial expressions. Happy faces are less ambiguous and more communicative than facial expressions representing negative emotions. The interpretation of results regarding basic emotion showed a significant interaction between emotion and HVF i.e., facial expressions of fearful and sad faces were recognized faster in the LVF (RH), whereas surprised and disgusted faces were recognized faster in the RVF (LH). This indicates the inconsistency of the RH and valence-specific hypotheses, as reported in previous studies (Alves, Aznar-Casanova, & Fukusima, 2009; Najt, Bayer, & Hausmann, 2013; Stafford & Brandaro, 2010; Stanković et al., 2015). The findings of the present study confirmed *relative equivalence* of both hemispheres in basic emotion recognition, rather than an absolute hemispheric asymmetry of the brain. Thus, both hemispheres are specialized for basic emotion recognition and the advantage of one hemisphere over the other may be only relative and not absolute (Tamietto, Corazzini, de Gelder, & Geminiani, 2006; Stanković & Nešić, 2019).

Results have indirectly confirmed the RH hypothesis in hemispheric specialization for odor perception (Frasnelli et al., 2010; Savic & Gulyas, 2000) since the treatment of the right nostril leads to shorter RTs in the recognition of positive and negative emotions by the RH if an unpleasant odor condition is included in the statistical model. This confirms the association between the olfactory system and emotion recognition, due to common neurophysiological structures in the limbic system, primarily within the RH (Savic, 2001, 2005). Recent studies have demonstrated the increasing importance of the principles of crossmodal integration in the perceptual system (Chen et al., 2018) since most stimuli and events in everyday environments are multisensory. This crossmodal integration was confirmed by the results of our study.

The obtained results cannot be generalized to males, elderly persons, and left-handed participants, thus limiting the findings of the present study. We used a forced binary choice in the task (emotional or neutral faces). Hence, the RTs and accuracy values for basic emotion were calculated indirectly which is less reliable than a multiple choice scale. The advantage of binary choice, over multiple choice face-related emotion is decreased response latency, since cognitive processing is reduced to a choice between two alternatives. Multiple choices allow more precise measurements of recognition accuracy; however, response latency is significantly prolonged. Subsequent replication studies should apply a multiple choice procedure in basic emotion recognition. The unbalanced number of faces representing positive and negative emotions should be taken into account for the interpretation of the achieved advantage in positive over negative emotion recognition. The achieved advantage of faster positive emotion recognition may have resulted from a smaller number of stimuli, since repeating a larger number of negative stimuli may become monotonous over time. The study did not include a control group without odor treatment. Thus, future studies might carry out a more comprehensive assessment of the lateralization of emotion recognition using a control group design. Future studies should answer the question of whether the familiarity/unfamiliarity with odors and the duration of exposure to an unpleasant odor via the left or the right nostril have significant effects on RTs and accuracy in basic emotion recognition by the LH or the RH. Furthermore, subsequent research should examine the dominant and alternative emotional and olfactory models using a wider range of pleasant and unpleasant odors.

Conclusion

The right nostril treatment with an unpleasant odor generally causes faster recognition of basic emotions presented to the LVF (RH) than to the RVF (LH), while the treatment of the left nostril does not affect the recognition of basic emotions presented either to the LVF or the RVF. The RH and valence-specific hypotheses in basic emotion recognition were not confirmed, since basic emotions were recognized more accurately by the LH and faster by the RH. Positive emotions were recognized faster and more accurately compared with negative emotions. This is in line with a cross-cultural concept demonstrating positive emotions as more communicative and recognizable compared with negative emotions. The RH model in odor perception was indirectly confirmed since short-term treatment of the right nostril with an unpleasant odor enhanced emotional performances of the RH. This study confirms the importance of cross-modal interactions between the olfactory system and emotion recognition.

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Uticaj neprijatnih mirisa na prepoznavanje emocija: Hipoteza desne hemisfere i hipoteza specifične valence

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Desna hemisfera je tradicionalno smatrana dominantnom u percepciji mirisa i emocija, dok se malo zna o tome kako mirisi utiču na prepoznavanje emocija. Cilj ovog istraživanja je bio da ispita moguću razliku u prepoznavanju bazičnih emocija prezentovanih u levom i desnom vidnom polju nakon kratkotrajnog izlaganja leve ili desne nozdrve neprijatnom mirisu. Ukupno 60 desnorukih ispitanica je uradilo zadatak prepoznavanja emocija u uslovima izlaganja leve ili desne nozdrve neprijatnom mirisu (izovalerična kiselina). Rezultati su pokazali da desna hemisfera prednjači u brzini, ali ne i u tačnosti prepoznavanja emocija nakon izlaganja desne nozdrve neprijatnom mirisu, dok izlaganje leve nozdrve neprijatnom mirisu nije imalo efekta. Hipoteza desne hemisfere i hipoteza specifične valence u prepoznavanju emocija nisu potvrđene, dok je model dominacije desne hemisfere u percepciji mirisa potvrđen.

Ključne reči: emocije, hipoteza desne hemisfere, hipoteza specifične valence, miris

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