Heart-evoked potentials and emotional processing of faces with varying levels of threat ambiguity

Madalina Buciuman & Simone Schütz-Bosbach

Department of Psychology, Ludwig-Maximilians-Universität München

Abstract

Several previous accounts suggest a relationship between interoception and affective processing and preliminary evidence exists that interoceptive cues might be used in order to aid affective decision-making. A useful way of tracking interoceptive processing in an online manner is by means of the heart-evoked potentials (HEPs). The current study attempted to investigate interoceptive focus as measured by HEPs in relationship with emotional processing while making affective judgements of neutral-angry morphed faces with different levels of threat ambiguity (low, medium and high ambiguity). Subjective evaluations of the emotionality of the faces and emotion-specific ERP data (N170, EPN, LPP) to the face stimuli were simultaneously collected. We found a significant difference in terms of HEPs amplitudes between the high ambiguity and medium ambiguity conditions, such that HEPs were more positive while making judgements about highly ambiguous stimuli. HEP amplitudes were also marginally more positive in the high ambiguity relative to the low ambiguity condition. Also, HEP amplitudes were negatively correlated with the amplitudes of the late-stage emotion-specific ERPs (LPP) only in the high and medium ambiguity conditions and positively correlated with the self-report affective judgements only in the medium ambiguity condition. Our results provide evidence for the dynamic involvement of interoceptive cues in the affective decision-making process, such that interoceptive focus at cortical level is increased under high threat ambiguity. This is in line with the constructive, inference-based accounts of emotion and could have relevant therapeutical applications for psychopathologies in which threat attribution is abnormal, as interoceptive focus can be modulated through different methods.

Introduction & Objectives

A plethora of studies have highlighted a link between interoceptive processing and emotion (Herbert et al., 2007). Moreover, it has been proposed that interoceptive cues might be used to inform decision-making in contexts of high uncertainty (Furman et al., 2013; Gu & FitzGerald, 2014). Therefore, it seems plausible that interoceptive cues might be relevant for attributing emotional salience especially under high uncertainty, consistent with contemporary theories of constructed emotion (Barrett, 2017) and active inference (Seth & Friston, 2016).

A promising way of tracking interoceptive processing at neural level is by means of the heart-evoked potential (HEP), a deflection detectable in the EEG signal time-locked to the R-wave. HEPs are related to the conscious heartbeat-perception ability (Pollatos & Schandry, 2004) and are differentially modulated by emotional content (Couto et al., 2015b). Importantly, the HEP amplitude measured in the anticipatory period before a gain or loss predicts the feedback-related P3 amplitudes to the outcomes, pointing to a role of interoceptive cues in evaluating salient outcomes (Marshall et al., 2019).

The first objective of this study was to investigate to what extent the heart-evoked potentials, as a marker of state interoceptive focus, differ while making decision about faces with different degrees of threat ambiguity. We hypothesized that HEPs will be more pronounced while making judgements about highly ambiguous stimuli, as the interoceptive cues would be used as additional sources of information. The second objective was to investigate to what extent there is an association between HEPs and behavioral (subjective evaluations) and electrophysiological markers (LPP, ERP, N170) of emotional processing.

Methods

Sample and procedure: 27 Participants (12 female, 15 male, Mage = 26.89, SDage = 4.44) performed a morphed-face affective evaluation task (described in Figure 1) while EEG and ECG data was recorded.

Electrophysiological data recording and analysis: The EEG data was continuously recorded using a 64-channel active electrode system (500 Hz), while ECG data was collected using a bipolar electrode montage. The data was down-sampled to 250 Hz, re-referenced to the common average reference, bandpass-filtered between 0.1 Hz and 40 Hz, bad channels interpolated, visual artifacts identified and removed based on ICA components and additional artifacts removed based on a moving-window approach.

HEP.

- CFA removal
- Epoch -200 – 1000 ms relative to R-wave (between 0.8 and 2.8 s after the faces) + baseline correction
- Topography identified using a non-parametric permutation-based approach for the 200 - 600 ms interval after the R-peak, based on which a central cluster (C1, C2, Cz) showing highest differences between ambiguity conditions was identified. All results presented are based on the mean amplitude of these 3 electrodes.

N170, EPN, LPP.

- Epoch -200 – 1200 ms relative to the faces + baseline correction
- N170 – mean amplitude 130 – 200 ms (PO8, PO10)
- EPN – mean amplitude 230 – 330 ms (O1, O2, Oz, POz)
- LPP – mean amplitude 400 – 800 ms (CPz, CP1, CP2, Pz, Cz)

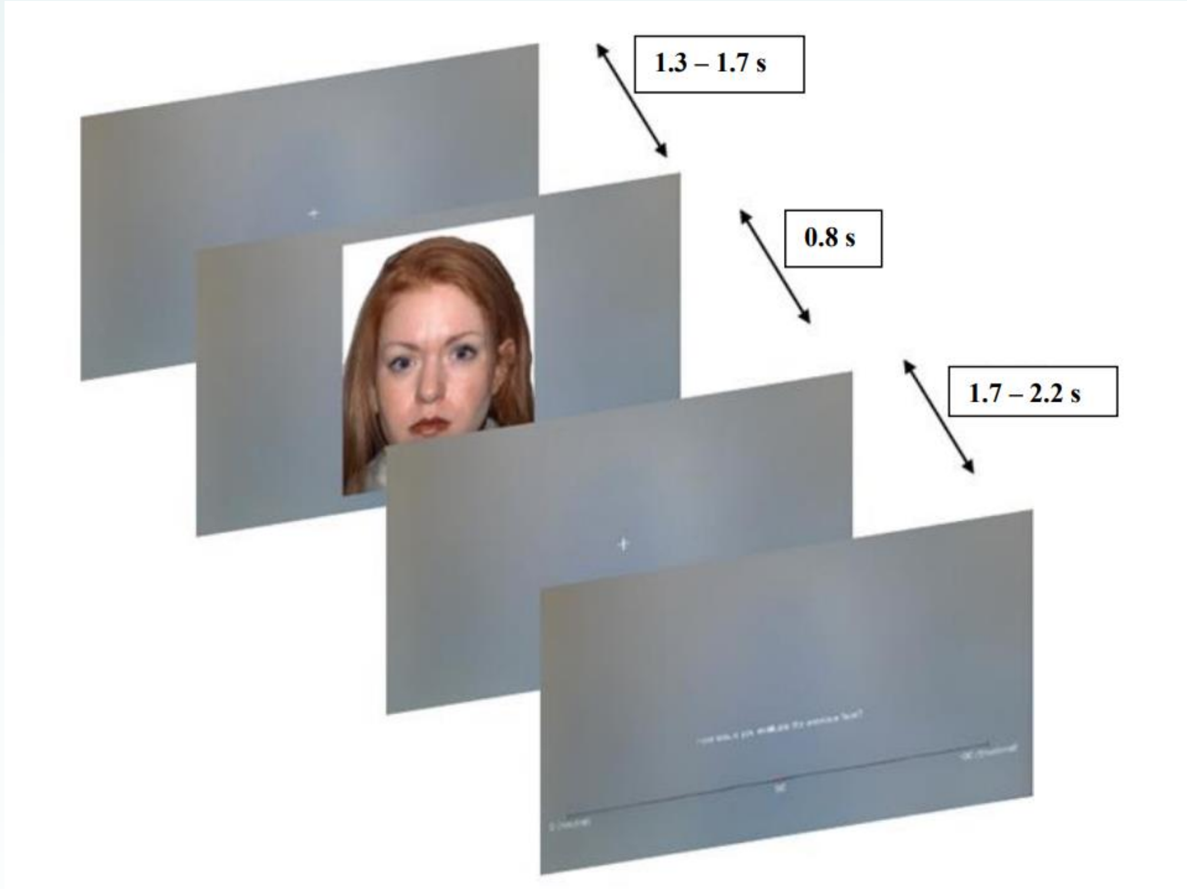

Figure 1. The task consisted of 600 trials grouped in 5 blocks. In each trial, a face picture with varying degrees of threat ambiguity (from 100% neutral or angry to 50% neutral-angry) was presented. After a randomly variable ISI, participants were asked to evaluate the previous face in terms of emotionality on an analog scale ranging from 0 (completely neutral) to 100 (completely emotional) by moving a cursor initially set in the middle with the left and right arrows.
For the presented analyses, the ambiguity levels of the faces were grouped in high (50%/60% neutral/emotional), medium (70%/80% neutral/emotional) and low ambiguity (90%/100% neutral/emotional).

Results

A 3-way repeated-measures ANOVA with the factors *Ambiguity* (high, medium, low), *Emotion* (angry, neutral) and *Time* (200 - 400 ms, 400 - 600 ms) showed only a significant main effect of *Ambiguity* (p = 0.011). Post-hoc Bonferroni-corrected T-test showed that the HEP amplitudes in the high *Ambiguity* condition were more positive than in the medium *Ambiguity* (p = 0.00031) and marginally more positive than in the low *Ambiguity* (p = 0.052) conditions.

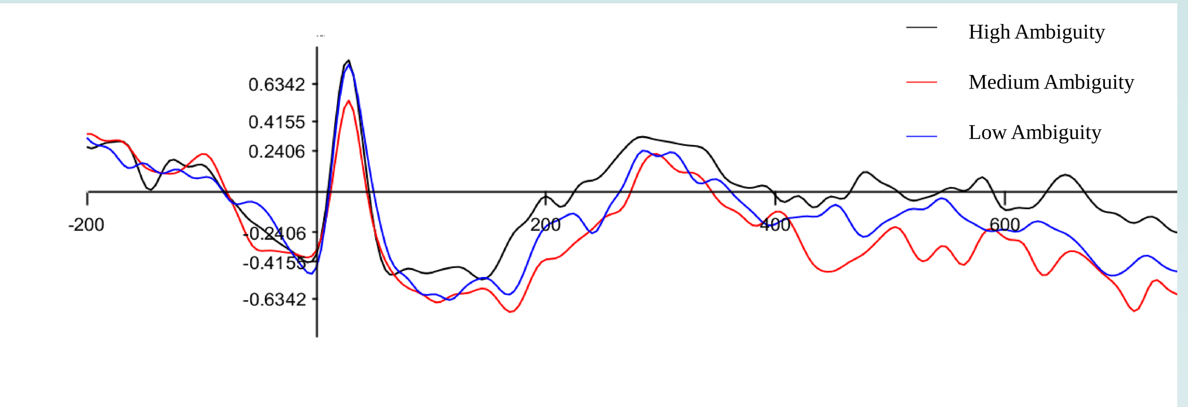

Figure 2. HEP time-course at the central electrode cluster (C1, C2, Cz).

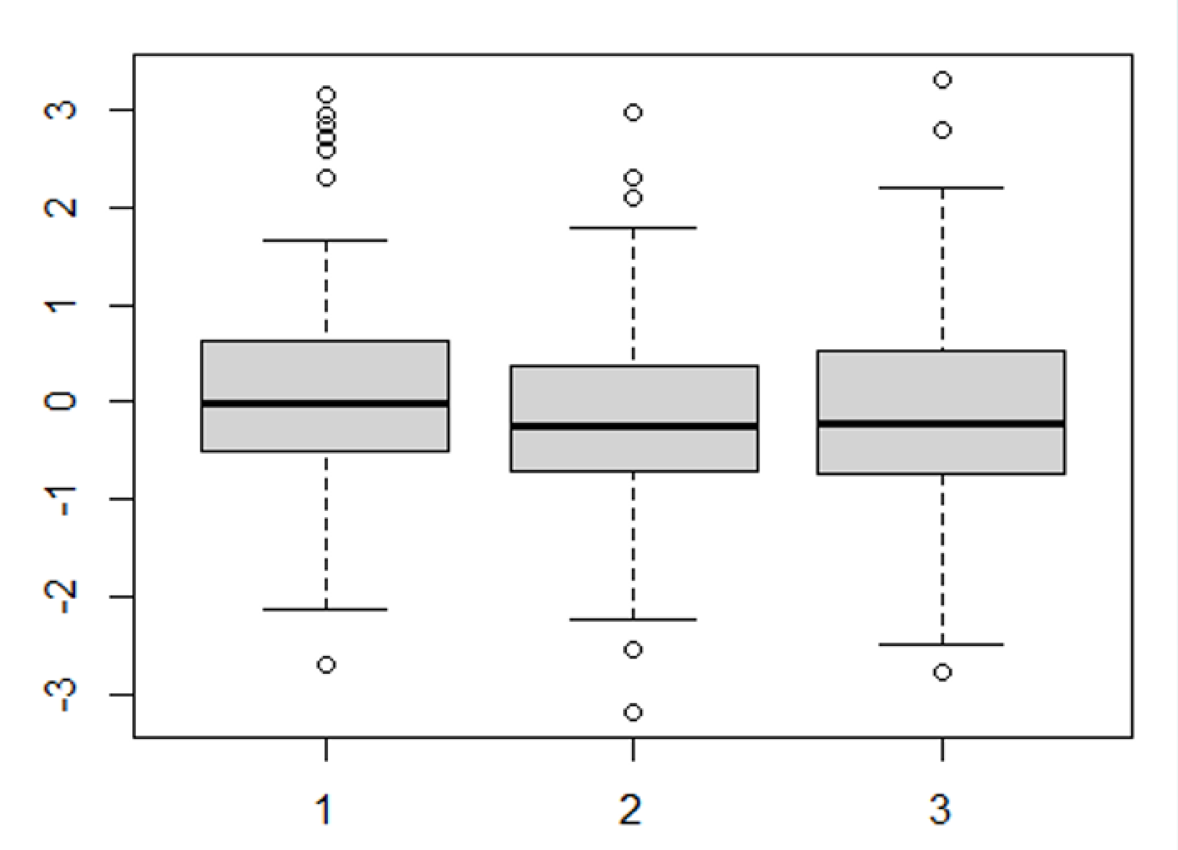

Figure 3. Statistical plots of the HEP amplitudes for the 3 *Ambiguity* conditions (1 – high ambiguity, 2 – medium ambiguity, 3 – low ambiguity)

		Subjective Ratings	N170	EPN	LPP
High Ambiguity	HEP (200 – 600)	0.19	-0.009	-0.1	**-0.4***
Medium Ambiguity	HEP (200 – 600)	**0.4***	0.03	-0.002	**-0.49****
Low Ambiguity	HEP (200 – 600)	0.28	-0.04	-0.18	-0.28

* p < 0.05, ** p < 0.01

Table 1. Partial correlations between the HEP amplitudes at high, medium and low ambiguity levels, subjective evaluations of the emotionality of the faces and emotion/face-specific ERPs (controlling for the effect of emotion).

Conclusion

The current results provide evidence for the dynamic involvement of interoceptive cues in the affective decision-making process, such that interoceptive focus measured at cortical level is increased under high threat ambiguity and correlates with affective ratings and late-stage neuro-cortical processing of emotional information.

These results can be interpreted as supporting the idea that interoceptive cues are flexibly used as a source of information for affective judgements in contexts of high uncertainty, as also suggested by contemporary theoretical accounts of active interoceptive inference and constructed emotion. Provided future research addressing the limitations of this study and using more experimental designs confirms this idea, this would not only open the path to a clearer understanding of the relationship between interoception and emotion, but also offer insights into the potential use of interoceptive training for ameliorating affective difficulties in specific clinical populations.

References

Barrett, L. F. (2017). The theory of constructed emotion: an active inference account of interoception and categorization. *Social cognitive and affective neuroscience*, *12*(1), 1-23.

Couto, B., Adolfi, F., Velasquez, M., Mesow, M., Feinstein, J., Canales-Johnson, A., ... & Manes, F. (2015b). Heart evoked potential triggers brain responses to natural affective scenes: a preliminary study. *Autonomic Neuroscience*, *193*, 132-137.

Furman, D. J., Waugh, C. E., Bhattacharjee, K., Thompson, R. J., & Gotlib, I. H. (2013). Interoceptive awareness, positive affect, and decision making in major depressive disorder. *Journal of affective disorders*, *151*(2), 780-785.

Gu, X., & FitzGerald, T. H. (2014). Interoceptive inference: homeostasis and decision-making. *Trends in Cognitive Science*, *18*(6), 269-70.

Herbert, B. M., Pollatos, O., & Schandry, R. (2007). Interoceptive sensitivity and emotion processing: An EEG study. *International Journal of Psychophysiology*, *65*(3), 214–227.

Marshall, A. C., Gentsch, A., Blum, A. L., Broering, C., & Schütz-Bosbach, S. (2019). I feel what I do: Relating interoceptive processes and reward-related behavior. *NeuroImage*, *191*, 315-324.

Pollatos, O., & Schandry, R. (2004). Accuracy of heartbeat perception is reflected in the amplitude of the heartbeat-evoked brain potential. *Psychophysiology*, *41*(3), 476-482.

Seth, A. K., & Friston, K. J. (2016). Active interoceptive inference and the emotional brain. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1708), 20160007.