Received: 16 January 2023 | Revised: 7 March 2023 | Accepted: 22 March 2023

DOI: 10.1111/psyp.14309

PSYCHOPHYSIOLOGY SPR WILEY

ORIGINAL ARTICLE

Modulation of the heartbeat evoked cortical potential by hypnotizability and hypnosis

Alejandro Luis Callara[1,2] | **Lorenzo Fontanelli**[3] | **Iacopo Belcari**[4] | **Gianluca Rho**[1] | **Alberto Greco**[1,2] | **Žan Zelič**[4] | **Laura Sebastiani**[4] | **Enrica L. Santarcangelo**[4]

[1]Department of Information Engineering, University of Pisa, Pisa, Italy

[2]Research Center "E. Piaggio", University of Pisa, Pisa, Italy

[3]Department of Clinical and Experimental Medicine, University of Pisa, Pisa, Italy

[4]Department of Translational Research and New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy

Correspondence
Laura Sebastiani, Department of Translational Research and New Technologies in Medicine and Surgery, University of Pisa, Via San Zeno 31, 56126, Pisa, Italy.
Email: laura.sebastiani@unipi.it

Funding information
European Commission under the NextGeneration EU Programme, Grant/Award Number: PNRR-M4C2-Investment 1.3, PE00000013-"FAIR and PNRR-Investment; European Research Council (ERC) under the European Union's Horizon 2020 Research and Innovation Program, Grant/Award Number: 801715-PUPILTRAITS; University of Pisa

Abstract

Hypnotizability is a psychophysiological trait measured by scales and associated with several differences, including interoceptive accuracy and the morpho-functional characteristics of interoception-related brain regions. The aim of the study was to assess whether the amplitude of the heartbeat evoked cortical potential (HEP), a correlate of interoceptive accuracy, differs in participants with low (lows) and high (highs) hypnotizability scores (assessed by the Stanford Hypnotic Susceptibility Scale, Form A) before and after the induction of hypnosis.

ECG and EEG were monitored in 16 highs and 15 lows during an experimental session, including open eyes baseline (B), closed eyes relaxation (R), hypnotic induction (IND), neutral hypnosis (NH), and post session baseline (Post). No significant difference was observed between groups and conditions in autonomic variables. The HEP amplitude was lower in highs than in lows at the right parietal site, likely due to hypnotizability related differences in the functional connection between the right insula and parietal cortex. It increased in highs and decreased in lows across the session, possibly due to the highs' preeminently internally directed attention and to the lows' possible disengagement from the task. Since interoception is involved in several cognitive-emotional functions, its hypnotizability related differences may contribute to the variability of experience and behavior in daily life.

KEYWORDS

heartbeat, HEP, hypnosis, hypnotizability, interoception

1 | INTRODUCTION

Hypnosis is a state of consciousness that can be self-induced or promoted through various procedures ("induction") enacted by other persons (Elkins et al., 2015). It is described as different from the ordinary state of consciousness (Pekala et al., 2006) and cannot be defined independently from self-reports, although many cortical correlates have been observed by imaging (Landry et al., 2017; Wolf et al., 2022) and EEG studies (Baghdadi & Nasrabadi, 2012; Hiltunen et al., 2021; Rho et al., 2021; Yargholi & Nasrabadi, 2015). Neutral hypnosis (NH) is a state following hypnotic induction without specific suggestions, that is, requests to imagine perception, memory,

and behavior different from the actual ones (for instance, analgesia, hallucination, movement) and to experience them as real and involuntary. According to the bio-psycho-social model of hypnosis (Jensen et al., 2015), the proneness to enter the hypnotic state and accept suggestions is influenced by contextual and individual factors, one of which is the psychophysiological trait of hypnotizability. It is substantially stable through life (Piccione et al., 1989), is measured by scales (Elkins et al., 2015) that classify high (highs, 15% of the general population), medium (mediums, 70%), and low (lows, 15%) hypnotizable individuals, and displays physiological correlates observable in the ordinary state of consciousness even in the absence of suggestions (Bocci et al., 2017; Ibáñez-Marcelo et al., 2019; Rashid et al., 2022; Santarcangelo & Scattina, 2016; Spina et al., 2020).

Hypnotizability and hypnosis could be relevant to the integration of bodily signals with ongoing conscious and unconscious mental processes at high levels of the central nervous system (Quadt et al., 2018). Their integration, in fact, differs according to cognitive-emotional states (Gentsch et al., 2019; Kritzman et al., 2022) and traits (Judah et al., 2018; Zhou et al., 2022), and interoceptive information is conveyed to a few brain structures displaying hypnotizability related morpho-functional differences, that is, the insula, cingulate cortex, and cerebellum (Landry et al., 2017; Picerni et al., 2019). Moreover, the highs' sensitivity to interoceptive signals—the self-reported mode of interpretation of bodily signals—is different and more "adaptive" than in the lows and mediums, indicating a good relationship with the body and a tendency to positively interpret bodily signals (Diolaiuti et al., 2020). In contrast, the interoceptive accuracy—the ability to detect bodily signals—which can be tested using the heartbeat count is lower in highs than in lows, although only during the first of three heartbeats count trials (Rosati et al., 2021). Dissociation between interoceptive accuracy and sensitivity can occur as they reflect different levels of processing of interoceptive signals (Garfinkel et al., 2015; Suksasilp & Garfinkel, 2022).

The results of heartbeat count have been associated with the amplitude of the cortical potential evoked by heartbeat (HEP), which has been related to cardiac afferents, despite the presence of some non-interoceptive information (Desmedt et al., 2018). It is obtained by averaging electrophysiological signals (such as the EEG and MEG) synchronized to the R-peaks or T-peaks of a simultaneously recorded ECG signal (Park & Blanke, 2019b). The HEP amplitude is sensitive to different levels of arousal (Luft & Bhattacharya, 2015), consciousness (Candia-Rivera, 2022), focus of attention (Petzschner et al., 2019), presence of exteroceptive signals (Al et al., 2020), and emotional conditions or responses (Park & Blanke, 2019b), thus it is usually studied in association with the autonomic state indicated by heart rate variability (HRV; Zaccaro et al., 2022). The amplitude of the earlier HEP component, which reflects cardiac interoceptive accuracy (200–350 ms), has been associated with heartbeat counting scores, although not unanimously (Park & Blanke, 2019b), and is more pronounced at the medial-right fronto-central sites. The amplitude of the later component (400–600 ms) is related to the proneness to not worry about body sensations, stress-induced changes in cardiac output, emotional arousal, dysregulation of emotions, and some clinical disorders (Baranauskas et al., 2021; Luft & Bhattacharya, 2015).

In contrast to exteroceptive cortical potentials, the HEP amplitude decreases during deep sleep with respect to light sleep and is like the latter during REM sleep (Lechinger et al., 2015). Moreover, similar HEP amplitude during REM and light sleep (Billeci et al., 2021) or wakefulness (Simor et al., 2021) has been described, thus overcoming the effect of the thalamic gate during deep sleep and the disrupted brain activity during REM.

Since the heartbeat count indicated lower interoceptive accuracy in highs than in lows (Rosati et al., 2021), the aim of the present study was to assess whether this finding is supported by differences in the HEP amplitude and whether the HEP amplitude changes during neutral hypnosis in highs and lows differentially.

2 | METHOD

2.1 | Subjects

A priori power analysis performed by G*Power3.1 (Faul et al., 2009) for repeated measures ANOVA indicated that for the expected $\eta^2 = 0.3$ (Pollatos et al., 2005) and $\alpha = .05$, the sample size of 16 participants for each group would be enough to achieve power = 0.89. After the approval by the Bioethics Committee of the University of Pisa (n.17/2021), participants of both sexes were recruited among the right-handed (Edinburgh Handedness Inventory, score ≥ 16) students at the University of Pisa who had undergone hypnotic assessment through the Italian version of the Stanford Hypnotic Susceptibility Scale, form A (SHSS: A (range: 0–12), Weitzenhoffer & Hilgard, 1959) in the latest 6 months. Details regarding the hypnotizability SHSS scales are available in Sheehan and McConkey (1982). After their written informed consent, 16 highs (SHSS score (mean ± SD): 10.18 ± 1.19; age: 25.14 ± 3.82 years; 9 females and 7 males not different between each other for age and SHSS score) and 16 lows (SHSS score: 0.20 ± .56; age: 26.47 ± 4.82 years; 7 females and 9 males not different between each other for age and SHSS score) with medical, neurological and

psychiatric negative anamnesis, no attention/sleep disturbance and drugs intake in the latest 6 months were enrolled. The final group was composed of 16 highs and 15 lows because one of the male lows was excluded from analyses owing to technical problems in the ECG recording. The two groups were homogeneous in terms of education (master's students). Six highs and 3 lows reported the basic experience of meditation. Medium hypnotizable individuals (mediums) were not enrolled to maximize the effects of hypnotizability on the studied variables during hypnosis (De Pascalis et al., 2000; Elkins et al., 2015).

2.2 | Experimental procedure

The experimental sessions took place in the afternoon, between 3 and 5 p.m., at least 3 h after the last meal and caffeine-containing beverage intake, in a sound- and light-attenuated, temperature-controlled (22°C) room. Alcohol consumption was prohibited during the preceding 24 h. On the day of the experimental session, all participants completed the Tellegen Absorption Scale (TAS, Tellegen & Atkinson, 1974; Tellegen, 1981), whose score indicates the proneness to be deeply absorbed in mental activities (range: 1–34). They were also interviewed about their last night's sleep satisfaction (range: 0–10) and were invited to sit in an armchair with their head, legs, and arms supported, and prepared for EEG recording. Finally, they were informed that every instruction will be given to them by the same experimenter sitting nearby and that at a certain point they will have to listen to a pre-recorded voice (SHSS: A induction modified owing to the direct request to close eyes in R). The experimental session consisted of open eyes baseline (B, 3 min), closed eyes relaxation (R, 3 min), hypnotic induction modified from the SHSS, A (IND, divided into IND1 and IND2, 3 min each), neutral hypnosis (NH, 3 min), Post (post hypnosis, 3 min). At the end of the session, participants were invited to score the degree of change in their state of consciousness experienced during the session (range: 0–10). None of the participants showed EEG sleep episodes.

2.3 | Signal acquisition and analysis

A telemetric Nautilus EEG system (g.tec, Schiedlberg) was used to acquire ECG and EEG signals according to a modified International 10–20 System. In detail, leads were placed in positions F3, F7, C3, T7, P3, PO3, F4, F8, C4, T8, P4, PO4, Fz, Cz, Pz, Oz, and referred to Cz. Two additional electrodes were placed on the skin near the lateral cantus of the left eye and in correspondence with the left orbital ridge to detect eye movements. Another electrode, referred to as Cz, was placed in proximity of the left shoulder for an ECG signal. All impedances were kept below 5 kΩ.

The ECG signal was analyzed with Kubios HRV (Tarvainen et al., 2014). First, the RR series were extracted from the ECG using the well-known Pan-Tompkins algorithm (Pan & Tompkins, 1985), and a cubic spline interpolation method was used to correct algorithm-related peak-detection artifacts. The obtained RR series were then interpolated to 4 Hz to derive the HRV signal (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Starting from the HRV, we extracted several features in the frequency and time domains. Specifically, we computed the mean RR interval duration (RR, ms), the total RR variability (SD), the square root of the mean squared differences of successive normal-to-normal (NN) intervals (RMSSD), the power expressed as a percentage of total power in the low-frequency (LF, 0.04–0.15 Hz) and high frequency (HF, 0.15–0.40 Hz) ranges, and the ratio of LF to HF power (LF/HF ratio). R peaks markers were saved for subsequent HEP analysis.

EEG signals were analyzed using EEGLAB (Delorme & Makeig, 2004) and MATLAB 2020b (The Math Works, Inc, 2020) custom scripts. All EEG signals were downsampled to a sampling frequency of 125 Hz after applying a proper low-pass anti-aliasing filter. Then, a high-pass filter of 0.1 Hz was applied. Bad channels were removed through a semi-automatic procedure. First, the channels whose correlation coefficient with their neighbors was lower than a predefined threshold were discarded (here set to 0.8; Mullen et al., 2013). Then, an expert visually inspected the data to eventually identify and remove those bad channels not captured by the correlation criterion. Afterward, the removed channels were recovered using a spline-spherical interpolation method. The obtained signals were re-referenced to the numeric average of all channels before undergoing independent component analysis (ICA; Makeig et al., 1995). ICA decomposes the signals into sets of maximally statistically independent components that represent both brain sources and different types of artifacts (e.g., muscular, ocular; Onton et al., 2006). Artifact-related ICs were identified through visual inspection of their maps, spectra, and time-course (Delorme et al., 2012). Each independent component was additionally described through its associated equivalent current dipole (Oostenveld et al., 2011). Finally, the EEG signals were reconstructed without the contribution of artifact-related ICs (i.e., ocular, muscular, cardiac, channel noise, and other sources of artifacts). The HEP amplitude was obtained by averaging the EEG signals synchronized the R-peaks previously obtained with Kubios (Tarvainen et al., 2014). More specifically, we extracted EEG epochs from −200 to 600 ms around each R-peak followed by a subtractive baseline correction estimated in 200 ms preceding the R-peak. The epochs contaminated by abrupt

signal changes in the ECG or EEG signal were also discarded from the analysis. At the end of this procedure, we obtained a collection of EEG epochs for each condition for each subject (% of retained epochs >95%).

2.4 | Variables

2.4.1 | Self-reports

TAS scores, last night sleep satisfaction, experienced change in the state of consciousness; *ECG*: RR, SD, RMSSD, LF/HF; *EEG*: point-by-point HEP amplitude across the 200–600 ms time interval following the R peak of ECG.

2.5 | Statistical analysis

The Kolmogorov–Smirnov test was used to study the variable distribution. Then, (1) self-reports scores of highs and lows were compared through separate univariate ANOVAs; (2) RR, SD, RMSSD, and LF/HF were analyzed by repeated measures ANOVAs with a 2 groups (highs, lows) x 6 Conditions (B, R, IND1, IND2, NH, P) design. Gender was not included as a between-subjects factor owing to the limited number of females and males enrolled in each hypnotizability group. Bonferroni correction was applied for multiple comparisons; (3) the HEP amplitude was analyzed through repeated measures ANOVA with hypnotizability (highs, lows) as the between-subject factor and Condition (B, R, IND1, IND2, NH, Post) as the within-subject factor, using the Factorial Mass Univariate Toolbox (Fields & Kuperberg, 2020). Particularly, we used a permutation-bootstrap approach with 2000 permutations to test for significant condition, group, and interaction effects. The analysis was performed for each time-point in (200–600) ms time interval. The time interval from 0 to 200 ms was excluded from analysis because of the potential presence of residual cardiac artifacts on EEG signals. Multiple hypothesis testing was controlled with the cluster correction method (Oostenveld et al., 2011). Post hoc analyses were carried out by means of paired *t*-tests for condition main effect, an unpaired *t*-test for group main effect, and paired *t*-tests (for within factor) and unpaired *t*-tests (for between factor) for interaction and main effect. All tests were carried out with a significance level set at $\alpha = .05$.

3 | RESULTS

3.1 | Self-reports

TAS scores were significantly higher ($F(1, 25) = 5.547$, $p = .027$, $\eta^2 = .188$, $\alpha = .618$) in highs (mean ± SD; 22.82 ± 7.86) than in lows (14.20 ± 7.16). The experience of change (Δ) in the state of consciousness was significantly more intense ($F(1, 25) = 67.27$, $p = .0001$, $\eta^2 = .714$, $\alpha = 1.00$) in highs (Δ: 6.90 ± 1.17) than in lows (Δ:1.57 ± 2.21).The last night's sleep satisfaction was not different between highs (mean ± SD; 7.34 ± 1.35) and lows (7.03 ± 2.15).

3.2 | ECG

None of the variables exhibited significant Group and Condition effects and interactions. RR and LF/HF mean values are illustrated in Figure 1a,b. The SD mean values were 0.052 ± 0.008 s (mean ± SD) for highs and 0.058 ± 0.006 s for lows. The RMSSD mean values were 0.37 ± 0.003 s^2 for highs and 0.052 ± 0.001 s^2 for lows.

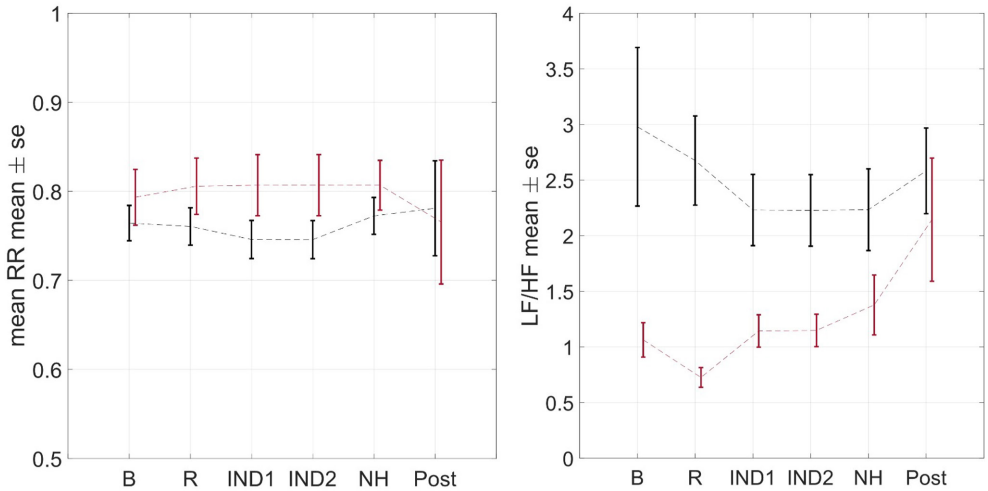

FIGURE 1 RR duration (left) and LF/HF (right) (mean, SE). B, baseline; R, closed-eyes relaxation; IND1 and IND2, earlier and later 3 min of hypnotic induction; NH, neutral hypnosis; Post, open-eyes baseline. Black, highs; red, lows.

3.3 | EEG

HEP amplitude. Upward and downward directed HEP indicates positive and negative brain potentials, respectively (Figure a Suppl El Mat).

Highs and lows exhibited similar HEP amplitudes (Figure 2, averaged conditions) all over the brain—with the highs' HEP sometimes slightly more positive than lows'—except for the right parietal site (P4). At this site (Table a Suppl El Mat), a significant Group effect ($p < .045$) was observed in a time window ranging from 256 ms to 312 ms, with a significantly lower HEP amplitude in highs than in lows (Table b Suppl El Mat) in B, R, IND1, and Post. Moreover, quasi significantly lower values were observed in highs with respect to lows in the time intervals from 424 to 488 ms ($p = .053$) and from 536 ms to 592 ms, as illustrated in Figure 3a.

At P4 (Figure 3b), we also observed a significant Group x Condition interaction ($p < .049$) in the time-range

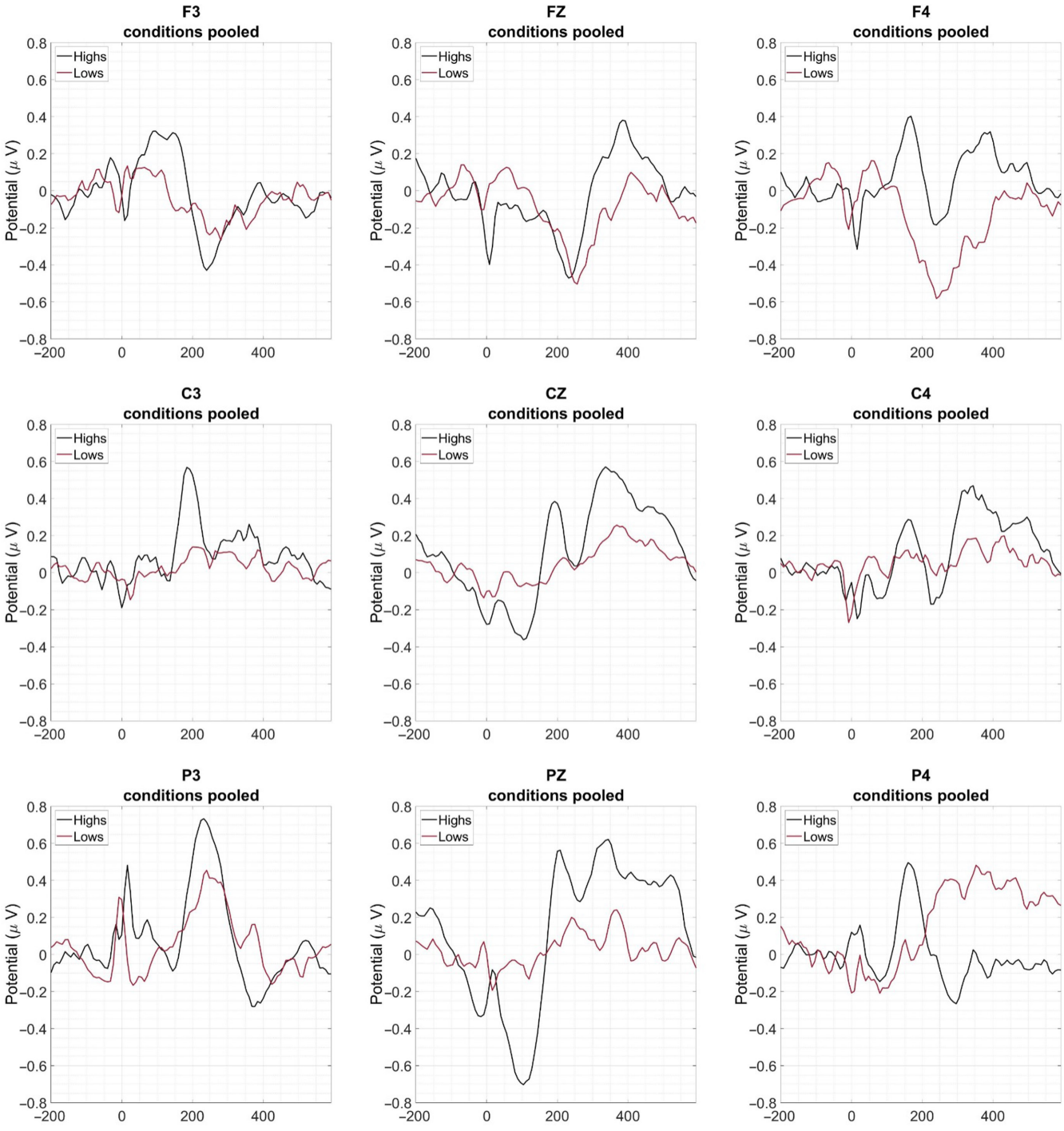

FIGURE 2 HEP amplitude (averaged conditions). Frontal (upper panels), central (middle panels), and parietal (lower panels) HEP. For statistics, see text.

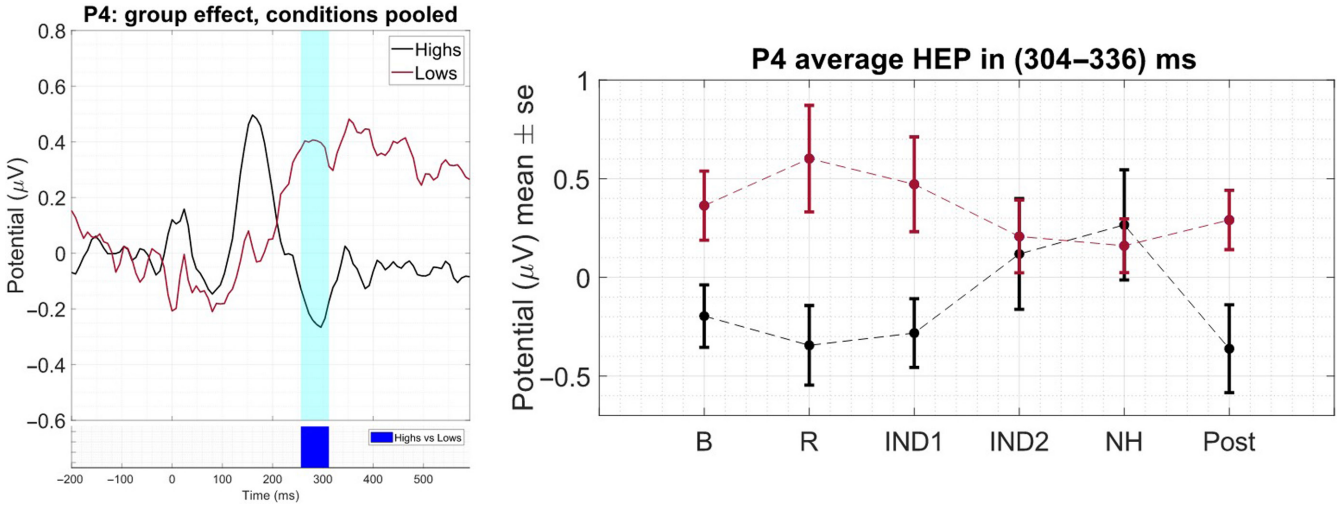

FIGURE 3 Group effect and Condition × Group interaction at P4. Left panel: for each group, the conditions-pooled HEP amplitude is reported. The vertical area highlighted in cyan corresponds to the time points in which there was a significant main effect for the group ($p < .05$, cluster corrected). Right panel: HEP amplitude (mean ± standard error). Group × Condition interaction at P4 for the time-points in the (304–336) ms range.

covering from 304 to 336 ms (Table a Suppl El Mat). Its decomposition revealed significant differences between conditions (Table c Suppl El Mat) in highs (NH > R and Post) who increased their HEP amplitude and in lows (Post < R and IND1) who decreased it.

Moreover, we observed a significant Condition effect ($p < .004$) regarding both groups (Figure 4, Table a Suppl El Mat) at Cz (Figure 4) in a time-window ranging from 288 to 360 ms after R-peak. The most extreme differences between the HEPs were between the R and IND2 conditions, with R exhibiting the higher values of HEP and IND2 the lower ones. Among the other conditions, NH significantly differed from the R (288–346) ms range and from B (352–360) ms range. Interestingly, the first and the second halves of the induction (IND1 and IND2) differed from B in different time windows: that is, (296–320) ms for IND1 and (328–353) ms for IND2.

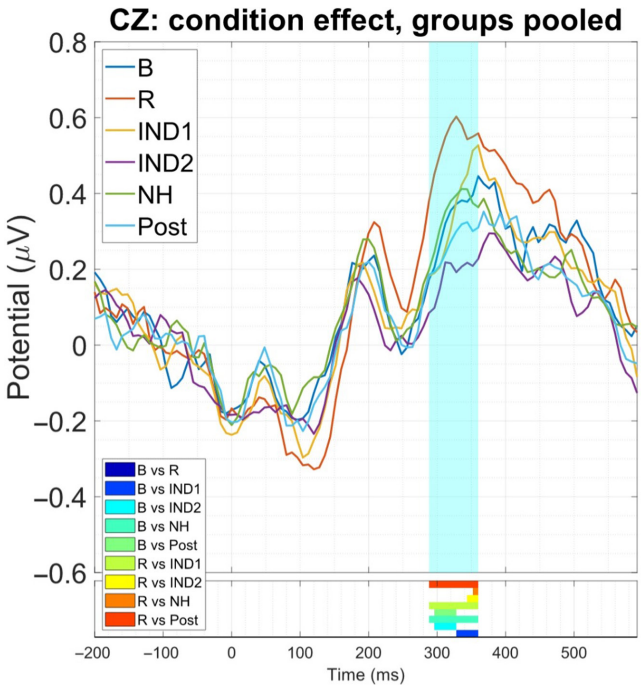

FIGURE 4 For each condition, the group-pooled HEP is reported. The vertical area highlighted in cyan corresponds to the time points at which there was a significant main effect for the condition ($p < .05$, cluster corrected). Post-hoc comparisons for which we observed a significant effect are reported below the results of the ANOVA and highlighted in different colors for each comparison.

4 | DISCUSSION

Interoception represents some of the most important information conveyed to the cerebral cortex, as it also influences somatosensory perception and its neural correlates (Al et al., 2020). The present study was aimed at investigating the relation between the HEP amplitude, considered an index of interoceptive accuracy, hypnotizability, which is associated with variations of interoceptive brain regions (Landry et al., 2017), and the state of consciousness, which changes during hypnosis in highs but not in lows (Elkins et al., 2015; Pekala et al., 2017). Interoceptive signals (and thus, the HEP), in fact, are influenced by the state of consciousness differently from exteroceptive information (Baranauskas et al., 2021), and during wakefulness, highs display lower interoceptive accuracy than lows, according to the heartbeat counting task.

In the present study, self-reports indicate that hypnotizability related differences were not biased by sleepiness and that only highs experienced a change in their state of consciousness, possibly facilitated by their greater attentional abilities, enabling them to be deeply absorbed in the induction procedure.

4.1 | ECG

No significant difference was observed in the autonomic state between groups and within conditions. Seemingly different findings with respect to other studies can be accounted for by differences in the experimental design. The absence of significant differences between groups in the closed-eyes awake condition (R) lasting 3 min accords with the observation that significant differences between highs and lows appear during longer lasting relaxation (15 min; Santarcangelo et al., 2012). Moreover, a decrease in the absolute LF power and an increase in the absolute HF power have been observed during a 20–min neutral hypnosis, with a consequent reduction of the LF/HF ratio (Santarcangelo et al., 1992). Finally, in other studies (De Benedittis et al., 1994), decreasing normalized LF and increased normalized HF have been observed during the second 10 min of a 20-min neutral hypnosis including imaginative suggestions promoting relaxation.

4.2 | EEG

The absence of relevant group differences in the autonomic state allows to exclude that the HEP amplitude was influenced in highs and lows differentially, although the modulation of heart rate and heart rate variability is not necessarily associated with HEP modulation (Park & Blanke, 2019b).

No significant group difference in the HEP amplitude was observed over the scalp except for the right parietal site (P4). Earlier findings in the general population (Baranauskas et al., 2021; Luft & Bhattacharya, 2015) indicate that the right hemisphere is more involved than the left one in the heartbeat detection task (Katkin & Reed, 1988). The highs' lower HEP amplitude at P4, with respect to the lows, accords with their lower performance at the heartbeat detection test (Rosati et al., 2021). In this respect, a limitation of the study is the absence of medium hypnotizable participants, which prevents associating high or low hypnotizability with the performance of the general population (Jensen et al., 2017). The significant difference between highs' and lows' HEP observed in correspondence of sensorimotor areas (P4) is produced by negative and positive potentials in highs and lows, respectively. A possible interpretation of this finding, based on the bilateral connections of the posterior insula with the parietal cortex (Dionisio et al., 2019), is that the activation of the highs' right parietal cortex by insular volleys may be reduced by a diminished contribution of the left insula. The gray matter volume (GMV) of the left posterior (Huber et al., 2014) or entire insula (Picerni et al., 2019), in fact, is negatively correlated with hypnotizability.

The increase in HEP amplitude occurring at P4 in highs during hypnosis supports the view of hypnosis as a state of consciousness associated with enhanced attention to internal signals (Demertzi et al., 2015). In the general population, indeed, the HEP is higher during interoceptive than exteroceptive attention (Petzschner et al., 2019). The same mechanism could be involved in the maintenance of HEP amplitudes during REM sleep in the general population (Baranauskas et al., 2021). On the other hand, disengagement from environmental information during hypnosis (Kramer et al., 2014) could be responsible for a larger interoceptive representation (Luft & Bhattacharya, 2015). The lows, in contrast, might decrease their HEP amplitude during the session owing to distraction due to their low absorption abilities.

The absence of a significant difference in the HEP amplitude between the second part of the hypnotic induction (IND2) and neutral hypnosis can be due to the highs' spontaneously entering the hypnotic state even independently from induction procedures. Unfortunately, an objective, discriminant index of hypnosis is not yet available.

The HEP amplitude at midline Cz (Condition effect) was lower during neutral hypnosis than in baseline and relaxation, independently from the group. Cz roughly corresponds to the dorsal anterior cingulate, which is deactivated during hypnosis (Deeley et al., 2012; Demertzi et al., 2011; Jiang et al., 2017; McGeown et al., 2009). Thus, in highs, the HEP reduction could be accounted for by reduced excitability of this region. In lows, who did not experience hypnosis, the HEP decrease could be accounted for by the reduced arousal due to relaxation. In this respect, a limitation of the study is that the experience of relaxation was not scored.

4.3 | Limitations and conclusions

A limitation of the study is the absence of mediums (Jensen et al., 2017; Perri, 2021). On the one hand, this allowed to better highlight differences between the extremes of the hypnotizability distribution, but on the other hand, it prevented comparing highs and lows with the largest part of the general population represented by mediums (De Pascalis et al., 2000; Elkins et al., 2015). Moreover, we did not include gender in our experimental design owing to

the low number of females and males, despite the males' greater interoceptive accuracy compared to females (Bornemann & Singer, 2017; Grabauskaitė et al., 2017).

Another limitation, which may reduce the repeatability of the study, is that the relation between HEP amplitude and behavioral measures of interoceptive accuracy is influenced by several factors, including the experimental protocol, the participants' level of arousal, attention, and their clinical condition (Coll et al., 2021). In our study, we did not correlate the HEP amplitude with the performance at the heartbeat counting task, which was not performed to prevent the effects of hypnotizability related attentional abilities on the HEP amplitude (Raz, 2005).

In summary, in highs, who display lower behaviorally assessed interoceptive accuracy than lows (Rosati et al., 2021), the HEP amplitude at parietal sites receiving insular information is lower than in lows. It increases in highs during hypnosis, which is associated with pre-eminent internally directed attention (Demertzi et al., 2015) and reduced activity of the anterior cingulate cortex (Deeley et al., 2012; Demertzi et al., 2011; Jiang et al., 2017; McGeown et al., 2009). In contrast, lows decrease their HEP amplitude, possibly due to disengagement from the hypnosis task. The absence of a significant difference in other studied variables during hypnosis with respect to baseline supports the view that hypnotic induction is not greatly relevant to the experience of trance, in line with the socio-cognitive theories of hypnosis (Lynn & Green, 2011).

The reported findings provide further support to the view that hypnotizability is relevant to general aspects of life rather than merely to the proneness to accept suggestions (Diolaiuti et al., 2020; Ibáñez-Marcelo et al., 2019; Santarcangelo & Carli, 2021; Santarcangelo & Scattina, 2016; Spina et al., 2020). Interoception, in fact, influences exteroceptive perception, contributes to self-consciousness, which includes bodily awareness, ownership, and the experience of self as a global unity stable in time (Park & Blanke, 2019a), and could influence emotional experience and behavior (Parrinello et al., 2022).

AUTHOR CONTRIBUTIONS

Alejandro L Callara: Formal analysis; methodology; software; visualization; writing – review and editing. **Lorenzo Fontanelli:** Data curation; investigation. **Iacopo Belcari:** Data curation; investigation. **Gianluca Rho:** Formal analysis; software. **Alberto Greco:** Formal analysis; methodology; resources; software; writing – review and editing. **Žan Zelič:** Writing – original draft; writing – review and editing. **LAURA SEBASTIANI:** Conceptualization; funding acquisition; resources; writing – original draft; writing – review and editing. **Enrica Laura Santarcangelo:** Conceptualization; funding acquisition; project administration; resources; supervision; writing – original draft; writing – review and editing.

ACKNOWLEDGMENT

The study was co-funded by Pisa University (Fondi di Ateneo), by the European Research Council (ERC) under the European Union's Horizon 2020 Research and Innovation Program (Grant No. 801715-PUPILTRAITS), by the European Commission under the NextGeneration EU Programme (PNRR-M4C2-Investment 1.3, PE00000013-"FAIR-Future Artificial Intelligence Research"-Spoke 1 "Human-centered AI" and PNRR-Investment 1.5 Ecosystems of Innovation, Project Tuscany Health Ecosystem (THE), Spoke 3 "Advanced technologies, methods, materials and heath analytics" CUP: I53C22000780001). Open Access Funding provided by Universita degli Studi di Pisa within the CRUI-CARE Agreement.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest. The Bioethics Committee of the University of Pisa approved the study (n.17/2021).

DATA AVAILABILITY STATEMENT

Data are available upon request after the paper acceptance.

ORCID

Alejandro Luis Callara https://orcid.org/0000-0003-2767-0699
Laura Sebastiani https://orcid.org/0000-0001-8279-5238

REFERENCES

Al, E., Iliopoulos, F., Forschack, N., Nierhaus, T., Grund, M., Motyka, P., Gaebler, M., Nikulin, V. V., & Villringer, A. (2020). Heart–brain interactions shape somatosensory perception and evoked potentials. *Proceedings of the National Academy of Sciences*, *117*(19), 10575–10584. https://doi.org/10.1073/pnas.1915629117

Baghdadi, G., & Nasrabadi, A. M. (2012). EEG phase synchronization during hypnosis induction. *Journal of Medical Engineering & Technology*, *36*(4), 222–229. https://doi.org/10.3109/03091902.2012.668262

Baranauskas, M., Grabauskaitė, A., Griškova-Bulanova, I., Lataitytė-Šimkevičienė, B., & Stanikūnas, R. (2021). Heartbeat evoked potentials (HEP) capture brain activity affecting subsequent heartbeat. *Biomedical Signal Processing and Control*, *68*, 102731. https://doi.org/10.1016/j.bspc.2021.102731

Billeci, L., Faraguna, U., Santarcangelo, E. L., d'Ascanio, P., Varanini, M., & Sebastiani, L. (2021). Heartbeat-evoked cortical potential during sleep and interoceptive sensitivity: A matter of hypnotizability. *Brain Sciences*, *11*(8), 1089. https://doi.org/10.3390/brainsci11081089

Bocci, T., Barloscio, D., Parenti, L., Sartucci, F., Carli, G., & Santarcangelo, E. L. (2017). High hypnotizability impairs the cerebellar control of pain. *The Cerebellum*, *16*(1), 55–61. https://doi.org/10.1007/s12311-016-0764-2

Bornemann, B., & Singer, T. (2017). Taking time to feel our body: Steady increases in heartbeat perception accuracy and decreases in alexithymia over 9 months of contemplative mental training: Contemplative training improves interoception. *Psychophysiology*, *54*(3), 469–482. https://doi.org/10.1111/psyp.12790

Candia-Rivera, D. (2022). Brain-heart interactions in the neurobiology of consciousness. *Current Research in Neurobiology*, *3*, 100050. https://doi.org/10.1016/j.crneur.2022.100050

Coll, M.-P., Hobson, H., Bird, G., & Murphy, J. (2021). Systematic review and meta-analysis of the relationship between the heartbeat-evoked potential and interoception. *Neuroscience & Biobehavioral Reviews*, *122*, 190–200. https://doi.org/10.1016/j.neubiorev.2020.12.012

De Benedittis, G., Cigada, M., Bianchi, A., Signorini, M. G., & Cerutti, S. (1994). Autonomic changes during hypnosis: A heart rate variability power Spectrum analysis as a marker of sympatho-vagal balance. *International Journal of Clinical and Experimental Hypnosis*, *42*(2), 140–152. https://doi.org/10.1080/00207149408409347

De Pascalis, V., Bellusci, A., & Russo, P. M. (2000). Italian norms for the stanford hypnotic susceptibility scale, form C. *International Journal of Clinical and Experimental Hypnosis*, *48*(3), 315–323. https://doi.org/10.1080/00207140008415249

Deeley, Q., Oakley, D. A., Toone, B., Giampietro, V., Brammer, M. J., Williams, S. C. R., & Halligan, P. W. (2012). Modulating the default mode network using hypnosis. *International Journal of Clinical and Experimental Hypnosis*, *60*(2), 206–228. https://doi.org/10.1080/00207144.2012.648070

Delorme, A., & Makeig, S. (2004). EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, *134*(1), 9–21. https://doi.org/10.1016/j.jneumeth.2003.10.009

Delorme, A., Palmer, J., Onton, J., Oostenveld, R., & Makeig, S. (2012). Independent EEG sources are dipolar. *PLoS ONE*, *7*(2), e30135. https://doi.org/10.1371/journal.pone.0030135

Demertzi, A., Antonopoulos, G., Heine, L., Voss, H. U., Crone, J. S., de Los Angeles, C., Bahri, M. A., Di Perri, C., Vanhaudenhuyse, A., Charland-Verville, V., Kronbichler, M., Trinka, E., Phillips, C., Gomez, F., Tshibanda, L., Soddu, A., Schiff, N. D., Whitfield-Gabrieli, S., & Laureys, S. (2015). Intrinsic functional connectivity differentiates minimally conscious from unresponsive patients. *Brain*, *138*(9), 2619–2631. https://doi.org/10.1093/brain/awv169

Demertzi, A., Soddu, A., Faymonville, M.-E., Bahri, M. A., Gosseries, O., Vanhaudenhuyse, A., Phillips, C., Maquet, P., Noirhomme, Q., Luxen, A., & Laureys, S. (2011). Hypnotic modulation of resting state fMRI default mode and extrinsic network connectivity. In *Progress in brain research* (Vol. *193*, pp. 309–322). Elsevier. https://doi.org/10.1016/B978-0-444-53839-0.00020-X

Desmedt, O., Luminet, O., & Corneille, O. (2018). The heartbeat counting task largely involves non-interoceptive processes: Evidence from both the original and an adapted counting task. *Biological Psychology*, *138*, 185–188. https://doi.org/10.1016/j.biopsycho.2018.09.004

Diolaiuti, F., Huber, A., Ciaramella, A., Santarcangelo, E. L., & Sebastiani, L. (2020). Hypnotisability-related interoceptive awareness and inhibitory/activating emotional traits. *Archives Italiennes de Biologie*, *4*, 111–119. https://doi.org/10.12871/00039829202042

Dionisio, S., Mayoglou, L., Cho, S.-M., Prime, D., Flanigan, P. M., Lega, B., Mosher, J., Leahy, R., Gonzalez-Martinez, J., & Nair, D. (2019). Connectivity of the human insula: A cortico-cortical evoked potential (CCEP) study. *Cortex*, *120*, 419–442. https://doi.org/10.1016/j.cortex.2019.05.019

Elkins, G. R., Barabasz, A. F., Council, J. R, & Spiegel, D. (2015). Advancing research and practice: The revised APA division 30 definition of hypnosis. *International Journal of Clinical and Experimental Hypnosis*, *63*(1), 1–9. https://doi.org/10.1080/00207144.2014.961870

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Fields, E. C., & Kuperberg, G. R. (2020). Having your cake and eating it too: Flexibility and power with mass univariate statistics for ERP data. *Psychophysiology*, *57*(2), e13468. https://doi.org/10.1111/psyp.13468

Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (2015). Knowing your own heart: Distinguishing interoceptive accuracy from interoceptive awareness. *Biological Psychology*, *104*, 65–74. https://doi.org/10.1016/j.biopsycho.2014.11.004

Gentsch, A., Sel, A., Marshall, A. C., & Schütz-Bosbach, S. (2019). Affective interoceptive inference: Evidence from heart-beat evoked brain potentials. *Human Brain Mapping*, *40*(1), 20–33. https://doi.org/10.1002/hbm.24352

Grabauskaitė, A., Baranauskas, M., & Griškova-Bulanova, I. (2017). Interoception and gender: What aspects should we pay attention to? *Consciousness and Cognition*, *48*, 129–137. https://doi.org/10.1016/j.concog.2016.11.002

Hiltunen, S., Karevaara, M., Virta, M., Makkonen, T., Kallio, S., & Paavilainen, P. (2021). No evidence for theta power as a marker of hypnotic state in highly hypnotizable subjects. *Heliyon*, *7*(4), e06871. https://doi.org/10.1016/j.heliyon.2021.e06871

Huber, A., Lui, F., Duzzi, D., Pagnoni, G., & Porro, C. A. (2014). Structural and functional cerebral correlates of hypnotic suggestibility. *PLoS ONE*, *9*(3), e93187. https://doi.org/10.1371/journal.pone.0093187

Ibáñez-Marcelo, E., Campioni, L., Phinyomark, A., Petri, G., & Santarcangelo, E. L. (2019). Topology highlights mesoscopic functional equivalence between imagery and perception: The case of hypnotizability. *NeuroImage*, *200*, 437–449. https://doi.org/10.1016/j.neuroimage.2019.06.044

Jensen, M. P., Adachi, T., Tomé-Pires, C., Lee, J., Osman, Z. J., & Miró, J. (2015). Mechanisms of hypnosis: Toward the development of a biopsychosocial model. *International Journal of Clinical and Experimental Hypnosis*, *63*(1), 34–75. https://doi.org/10.1080/00207144.2014.961875

Jensen, M. P., Jamieson, G. A., Lutz, A., Mazzoni, G., McGeown, W. J., Santarcangelo, E. L., Demertzi, A., De Pascalis, V., Bányai, É. I., Rominger, C., Vuilleumier, P., Faymonville, M.-E., & Terhune, D. B. (2017). New directions in hypnosis research: Strategies for advancing the cognitive and clinical neuroscience of hypnosis. *Neuroscience of Consciousness*, *2017*(1), nix004. https://doi.org/10.1093/nc/nix004

Jiang, H., White, M. P., Greicius, M. D., Waelde, L. C., & Spiegel, D. (2017). Brain activity and functional connectivity associated

with hypnosis. *Cerebral Cortex*, *27*(8), 4083–4093. https://doi.org/10.1093/cercor/bhw220

Judah, M. R., Shurkova, E. Y., Hager, N. M., White, E. J., Taylor, D. L., & Grant, D. M. (2018). The relationship between social anxiety and heartbeat evoked potential amplitude. *Biological Psychology*, *139*, 1–7. https://doi.org/10.1016/j.biopsycho.2018.09.013

Katkin, E. S., & Reed, S. D. (1988). Cardiovascular asymmetries and cardiac perception. *International Journal of Neuroscience*, *39*(1–2), 45–52. https://doi.org/10.3109/00207458808985692

Kramer, S., Zims, R., Simang, M., Rüger, L., & Irnich, D. (2014). Hypnotic relaxation results in elevated thresholds of sensory detection but not of pain detection. *BMC Complementary and Alternative Medicine*, *14*, 496. https://doi.org/10.1186/1472-6882-14-496

Kritzman, L., Eidelman-Rothman, M., Keil, A., Freche, D., Sheppes, G., & Levit-Binnun, N. (2022). Steady-state visual evoked potentials differentiate between internally and externally directed attention. *NeuroImage*, *254*, 119133. https://doi.org/10.1016/j.neuroimage.2022.119133

Landry, M., Lifshitz, M., & Raz, A. (2017). Brain correlates of hypnosis: A systematic review and meta-analytic exploration. *Neuroscience & Biobehavioral Reviews*, *81*, 75–98. https://doi.org/10.1016/j.neubiorev.2017.02.020

Lechinger, J., Heib, D. P. J., Gruber, W., Schabus, M., & Klimesch, W. (2015). Heartbeat-related EEG amplitude and phase modulations from wakefulness to deep sleep: Interactions with sleep spindles and slow oscillations: Cardiac activity modulates brain oscillations. *Psychophysiology*, *52*(11), 1441–1450. https://doi.org/10.1111/psyp.12508

Luft, C. D. B., & Bhattacharya, J. (2015). Aroused with heart: Modulation of heartbeat evoked potential by arousal induction and its oscillatory correlates. *Scientific Reports*, *5*(1), 15717. https://doi.org/10.1038/srep15717

Lynn, S. J., & Green, J. P. (2011). The sociocognitive and dissociation theories of hypnosis: Toward a rapprochement. *International Journal of Clinical and Experimental Hypnosis*, *59*(3), 277–293. https://doi.org/10.1080/00207144.2011.570652

Makeig, S., Bell, A. J., Jung, T.-P., & Sejnowski, T. J. (1995). Independent component analysis of electroencephalographic data. In D. Touretzky, M. C. Mozer, & M. Hasselmo (Eds.), *Advances in neural information processing systems 8* (pp. 145–151). MIT Press.

McGeown, W. J., Mazzoni, G., Venneri, A., & Kirsch, I. (2009). Hypnotic induction decreases anterior default mode activity. *Consciousness and Cognition*, *18*(4), 848–855. https://doi.org/10.1016/j.concog.2009.09.001

Mullen, T., Kothe, C., Chi, Y. M., Ojeda, A., Kerth, T., Makeig, S., Cauwenberghs, G., & Jung, T.-P. (2013). Real-time modeling and 3D visualization of source dynamics and connectivity using wearable EEG. In *2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* (pp. 2184–2187). https://doi.org/10.1109/EMBC.2013.6609968

Onton, J., Westerfield, M., Townsend, J., & Makeig, S. (2006). Imaging human EEG dynamics using independent component analysis. *Neuroscience & Biobehavioral Reviews*, *30*(6), 808–822. https://doi.org/10.1016/j.neubiorev.2006.06.007

Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J.-M. (2011). FieldTrip: Open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. *Computational Intelligence and Neuroscience*, *2011*, 1–9. https://doi.org/10.1155/2011/156869

Pan, J., & Tompkins, W. J. (1985). A real-time QRS detection algorithm. *IEEE Transactions on Biomedical Engineering*, *BME-32*(3), 230–236. https://doi.org/10.1109/TBME.1985.325532

Park, H.-D., & Blanke, O. (2019a). Coupling inner and outer body for self-consciousness. *Trends in Cognitive Sciences*, *23*(5), 377–388. https://doi.org/10.1016/j.tics.2019.02.002

Park, H.-D., & Blanke, O. (2019b). Heartbeat-evoked cortical responses: Underlying mechanisms, functional roles, and methodological considerations. *NeuroImage*, *197*, 502–511. https://doi.org/10.1016/j.neuroimage.2019.04.081

Parrinello, N., Napieralski, J., Gerlach, A. L., & Pohl, A. (2022). Embodied feelings—A meta-analysis on the relation of emotion intensity perception and interoceptive accuracy. *Physiology & Behavior*, *254*, 113904. https://doi.org/10.1016/j.physbeh.2022.113904

Pekala, R., Kumar, V. K., Maurer, R., Elliott-Carter, N., & Moon, E. (2006). "How deeply hypnotized did I get?" predicting self-reported hypnotic depth from a phenomenological assessment instrument. *International Journal of Clinical and Experimental Hypnosis*, *54*(3), 316–339. https://doi.org/10.1080/00207140600691344

Pekala, R. J., Baglio, F., Cabinio, M., Lipari, S., Baglio, G., Mendozzi, L., Cecconi, P., Pugnetti, L., & Sciaky, R. (2017). Hypnotism as a function of trance state effects, expectancy, and suggestibility: An Italian replication. *The International Journal of Clinical and Experimental Hypnosis*, *65*(2), 210–240. https://doi.org/10.1080/00207144.2017.1276365

Perri, R. L. (2021). In medio stat virtus: The importance of studying mediums in hypnosis research. *American Journal of Clinical Hypnosis*, *64*(1), 4–11. https://doi.org/10.1080/00029157.2020.1859980

Petzschner, F. H., Weber, L. A., Wellstein, K. V., Paolini, G., Do, C. T., & Stephan, K. E. (2019). Focus of attention modulates the heartbeat evoked potential. *NeuroImage*, *186*, 595–606. https://doi.org/10.1016/j.neuroimage.2018.11.037

Piccione, C., Hilgard, E. R., & Zimbardo, P. G. (1989). On the degree of stability of measured hypnotizability over a 25-year period. *Journal of Personality and Social Psychology*, *56*(2), 289–295. https://doi.org/10.1037/0022-3514.56.2.289

Picerni, E., Santarcangelo, E., Laricchiuta, D., Cutuli, D., Petrosini, L., Spalletta, G., & Piras, F. (2019). Cerebellar structural variations in subjects with different hypnotizability. *The Cerebellum*, *18*(1), 109–118. https://doi.org/10.1007/s12311-018-0965-y

Pollatos, O., Kirsch, W., & Schandry, R. (2005). Brain structures involved in interoceptive awareness and cardioafferent signal processing: A dipole source localization study. *Human Brain Mapping*, *26*(1), 54–64. https://doi.org/10.1002/hbm.20121

Quadt, L., Critchley, H. D., & Garfinkel, S. N. (2018). The neurobiology of interoception in health and disease: Neuroscience of interoception. *Annals of the New York Academy of Sciences*, *1428*(1), 112–128. https://doi.org/10.1111/nyas.13915

Rashid, A., Santarcangelo, E. L., & Roatta, S. (2022). Cerebral blood flow in healthy subjects with different hypnotizability scores. *Brain Sciences*, *12*(5), 558. https://doi.org/10.3390/brainsci12050558

Raz, A. (2005). Attention and hypnosis: Neural substrates and genetic associations of two converging processes. *International*

Journal of Clinical and Experimental Hypnosis, *53*(3), 237–258. https://doi.org/10.1080/00207140590961295

Rho, G., Callara, A. L., Petri, G., Nardelli, M., Scilingo, E. P., Greco, A., & Pascalis, V. D. (2021). Linear and nonlinear quantitative EEG analysis during neutral hypnosis following an opened/closed eye paradigm. *Symmetry*, *13*(8), 1423. https://doi.org/10.3390/sym13081423

Rosati, A., Belcari, I., Santarcangelo, E. L., & Sebastiani, L. (2021). Interoceptive accuracy as a function of hypnotizability. *International Journal of Clinical and Experimental Hypnosis*, *69*(4), 441–452. https://doi.org/10.1080/00207144.2021.1954859

Santarcangelo, E. L., & Carli, G. (2021). Individual traits and pain treatment: The case of hypnotizability. *Frontiers in Neuroscience*, *15*, 683045. https://doi.org/10.3389/fnins.2021.683045

Santarcangelo, E. L., Emdin, M., Picano, E., Raciti, M., Macerata, A., Michelassi, C., Kraft, G., Riva, A., & L'Abbate, A. (1992). Can hypnosis modify the sympathetic-parasympathetic balance at heart level? *Journal of Ambulatory Monitoring*, *5*, 191–196.

Santarcangelo, E. L., Paoletti, G., Balocchi, R., Carli, G., Morizzo, C., Palombo, C., & Varanini, M. (2012). Hypnotizability modulates the cardiovascular correlates of subjective relaxation. *International Journal of Clinical and Experimental Hypnosis*, *60*(4), 383–396. https://doi.org/10.1080/00207144.2012.700609

Santarcangelo, E. L., & Scattina, E. (2016). Complementing the latest APA definition of hypnosis: Sensory-motor and vascular peculiarities involved in hypnotizability. *International Journal of Clinical and Experimental Hypnosis*, *64*(3), 318–330. https://doi.org/10.1080/00207144.2016.1171093

Sheehan, P. W. & McConkey, K. M. (1982). The assessment of hypnosis: A survey of measuring instruments. In P. W. Sheehan & K. M. McConkey (Eds.), *Hypnosis and experience: The exploration of phenomena and process* (pp. 18–74). Lawrence Erlbaum Associates.

Simor, P., Bogdány, T., Bódizs, R., & Perakakis, P. (2021). Cortical monitoring of cardiac activity during rapid eye movement sleep: The heartbeat evoked potential in phasic and tonic rapid-eye-movement microstates. *Sleep*, *44*(9), zsab100. https://doi.org/10.1093/sleep/zsab100

Spina, V., Chisari, C., & Santarcangelo, E. L. (2020). High motor cortex excitability in highly hypnotizable individuals: A favourable factor for neuroplasticity? *Neuroscience*, *430*, 125–130. https://doi.org/10.1016/j.neuroscience.2020.01.042

Suksasilp, C., & Garfinkel, S. N. (2022). Towards a comprehensive assessment of interoception in a multi-dimensional framework. *Biological Psychology*, *168*, 108262. https://doi.org/10.1016/j.biopsycho.2022.108262

Tarvainen, M. P., Niskanen, J.-P., Lipponen, J. A., Ranta-aho, P. O., & Karjalainen, P. A. (2014). Kubios HRV—Heart rate variability analysis software. *Computer Methods and Programs in Biomedicine*, *113*(1), 210–220. https://doi.org/10.1016/j.cmpb.2013.07.024

Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. (1996). Heart rate variability: Standards of measurement, physiological interpretation and clinical use. *Circulation*, *93*(5), 1043–1065.

Tellegen, A. (1981). Practicing the two disciplines for relaxation and enlightenment: Comment on "Role of the feedback signal in electromyograph biofeedback: The relevance of attention" by Qualls and Sheehan. *Journal of Experimental Psychology: General*, *110*(2), 217–226. https://doi.org/10.1037/0096-3445.110.2.217

Tellegen, A., & Atkinson, G. (1974). Openness to absorbing and self-altering experiences ("absorption"), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology*, *83*(3), 268–277. https://doi.org/10.1037/h0036681

The Math Works, Inc. (2020). *MATLAB* (Version 2020b) [computer software]. https://www.mathworks.com/

Weitzenhoffer, A. M., & Hilgard, E. R. (1959). *Scala Stanford di Suscettibilità Ipnotica, forme A e B. Organizzazioni Speciali*. [Stanford Hypnotic Susceptibility Scale, Form A]. Organizzazioni Speciali.

Wolf, T. G., Faerber, K. A., Rummel, C., Halsband, U., & Campus, G. (2022). Functional changes in brain activity using hypnosis: A systematic review. *Brain Sciences*, *12*(1), 108. https://doi.org/10.3390/brainsci12010108

Yargholi, E., & Nasrabadi, A. M. (2015). Chaos–chaos transition of left hemisphere EEGs during standard tasks of Waterloo-Stanford group scale of hypnotic susceptibility. *Journal of Medical Engineering & Technology*, *39*(5), 281–285. https://doi.org/10.3109/03091902.2015.1048317

Zaccaro, A., Perrucci, M. G., Parrotta, E., Costantini, M., & Ferri, F. (2022). Brain-heart interactions are modulated across the respiratory cycle via interoceptive attention. *NeuroImage*, *262*, 119548. https://doi.org/10.1016/j.neuroimage.2022.119548

Zhou, H., Zou, H., Dai, Z., Zhao, S., Hua, L., Xia, Y., Han, Y., Yan, R., Tang, H., Huang, Y., Du, Y., Wang, X., Yao, Z., & Lu, Q. (2022). Interoception dysfunction contributes to the negative emotional bias in major depressive disorder. *Frontiers in Psychiatry*, *13*, 874859. https://doi.org/10.3389/fpsyt.2022.874859

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Figure a HEPs during all conditions at frontal, central, and parietal sites.

Table a. HEP amplitude: repeated measures ANOVA results.

Table b. Group differences at P4.

Table c. Differences between conditions in highs and lows at P4.

How to cite this article: Callara, A. L., Fontanelli, L., Belcari, I., Rho, G., Greco, A., Zelič, Ž., Sebastiani, L., & Santarcangelo, E. L. (2023). Modulation of the heartbeat evoked cortical potential by hypnotizability and hypnosis. *Psychophysiology*, *60*, e14309. https://doi.org/10.1111/psyp.14309