RESEARCH REPORT

Electrophysiological evidence of the differential modulation of approach-related processes toward attractive foods by immersive or mindful viewing conditions

Constanza Baquedano[1,2,3] | Vladimir Lopez[2,3] | Diego Cosmelli[2,3] | Antoine Lutz[1] (iD)

[1]Lyon Neuroscience Research Center, INSERM U1028, CNRS UMR5292, Lyon 1 University, Lyon, France

[2]School of Psychology, Pontifical Catholic University of Chile, Santiago, Chile

[3]Interdisciplinary Center for Neuroscience, Pontifical Catholic University of Chile, Santiago, Chile

Correspondence
Antoine Lutz, Lyon Neuroscience Research Center, Lyon 1 University, Lyon, France.
Email: antoine.lutz@inserm.fr

Abstract

Awareness of mental events as mere representations rather than as accurate depictions of reality, also known as dereification, is one of the key features of mindfulness meditation. Dereification is juxtaposed to subjective realism, the process of being lost or totally immersed in the contents of one's mind. Excessive subjective realism is a hallmark of several psychiatric disorders. Here, we investigated whether a "mindful" (dereified) compared with an "immersed" (highly subjectively real) attitude, induced by instructions, differentially modulates approach-avoidance tendencies when processing visual stimuli. We presented novices and experienced meditators with neutral and attractive food images under both mindful and immersed states. Then, participants performed an approach–avoidance Task (AAT) during which we obtained behavioral data, salivary volume, EEG recordings, and self-report measures. The approach bias toward attractive food was correlated with N2 amplitude, a marker of response inhibition, and the regulation of this bias by the mindful instruction compared to the immersed instruction was associated with a modulation of the visual N1 amplitude, a marker of early selective attention. Individuals with more expertise in mindfulness meditation engaged in less late affective reappraisal during mindfulness than during immersion, as measured by lower amplitude in the late positive potential (LPP). Additionally, the ERPs sensitive to the AAT manipulation was also associated to self-report measures of subjective realism, food bias, and mindfulness meditation expertise but not to salivation measures. These findings provide novel insights into the mechanisms by which mindfulness-based interventions could be effective in a range of psychiatric conditions.

KEYWORDS
approach-avoidance tendencies, dereification, ERPs, food craving, immersion, mindfulness, subjective realism

1 | INTRODUCTION

A thought can seem "subjectively real", interpreted as truly happening at the moment, or it can be "dereified", or interpreted as a mere mental event, which, as such, is not necessarily an accurate depiction of reality. Subjective realism takes place in our daily life with differing degrees of intensity and frequency, and is similar to a fully "immersed" or "experientially fused" state (Dahl, Lutz, & Davidson, 2015). It ranges from salivation when imagining our favorite food, to the exacerbation of psychological distress (Lau et al., 2006), and psychiatric conditions such as depression (Barnhofer et al., 2015) and addictive disorders (Shorey, Brasfield, Anderson, & Stuart, 2013), when it occurs excessively.

Dereification somewhat overlaps with alternative constructs in psychology such as decentering (Bernstein et al., 2015), cognitive defusion (Fletcher & Hayes, 2005), or mindful attention (Papies, Barsalou, & Custers, 2012; Papies, Pronk, Keesman, & Barsalou, 2015), even if the relationship between these constructs and their specificity are still debated (for details see Bernstein et al., 2015; Lutz, Jha, Dunne, & Saron, 2015). The process of dereification can happen spontaneously or can be explicitly learned. This learning can be completed, for instance, through mental training regimes like mindfulness meditation, through which one develops the skill and habits necessary to recognize the mental and transient nature of phenomenal appearances (Papies et al., 2015). Indeed, in contrast with the detrimental effect of excessive subjective realism, mindfulness meditation, a practical way to encourage dereification, can improve outcomes for certain psychiatric conditions, such as depression and anxiety (Hofmann, Sawyer, Witt, & Oh, 2010).

In this work, we explore how the interpretative frameworks of subjective realism (immersion) and dereification (mindful attention) bias our perceptions and actions toward the world. We investigate the effect of engagement with thoughts and perceptions as real (subjective realism) or not (dereification) on automatic tendencies toward these thoughts and perceptions as a function of familiarity with and expertise in mindfulness. To answer our questions, we compared a group of novice meditators with a group of experienced meditators. The methodology and behavioral results (a replication and extension of Papies et al., 2012) of this study were initially published in Baquedano et al. (2017). We adapted an approach—avoidance (AA) food engagement paradigm originally used in Papies et al. (2012) to make it suitable for physiological measures (such as electroencephalography (EEG) and salivation) (Baquedano et al., 2017).

The aforementioned study (Papies et al., 2012) as well as our study (described in Baquedano et al., 2017) applied an approach—avoidance task (AAT), to show that a mindful attention instruction (mindful condition) decreases automatic impulses toward attractive food when compared with an immersion instruction (immersed condition) or a control condition. In our study, we also included the group variable of novice and experienced meditators.

The approach–avoidance task (AAT) paradigm implicitly assesses approach-avoidance tendencies. The difference in reaction times (RT) between incompatible conditions (i.e., avoiding attractive food) and compatible conditions (i.e., approaching attractive food) is referred to as the stimulus-response compatibility (SRC) effect. This is calculated by assessing the different reaction time between an "avoidance" condition, where the participant has to pull a joystick away from an attractive food image (and thus avoid pushing a joystick toward it), compared with an "approach" condition, where he or she has to push a joystick toward an attractive food image as requested by an experimental cue. The SRC, when measured in the context of food attractiveness (attractive vs. neutral images), is labeled as the "Food Attractivity Bias" (FAB). The two instructions manipulated the degree of engagement with mental events as real or not (subjective realness vs. dereification). In the immersion condition (subjective realness) participants were asked to see the food images "in the flesh", and to connect intensely with the sensations generated by each image. Meanwhile, in the mindful condition (dereification), participants were asked to be aware of thoughts, sensations, and reactions while watching each image, and to experience these mental events as mere constructions of the mind that appear and disappear.

Baquedano et al. (2017) replicated the SRC/FAB effect previously described for this task (Papies et al., 2012; Phaf, Mohr, Rotteveel, & Wicherts, 2014) among a number of other relevant findings. The study extended the findings of Papies et al. (2012) to a within-subject design (Baquedano et al., 2017) and demonstrated a reduction of the FAB in the mindful condition as compared to the immersion condition. Down-regulating subjective realism during the mindful condition was associated with a decrease in the standard cephalic phase responses, an autonomic anticipation reflex that prepares the organism to receive food, estimated by salivary flow measurements. Salivary volumes correlated positively with the FAB effect in the immersion condition, suggesting a functional relationship between an autonomic physiological marker of subjective realism toward food cues, and their behavioral affordance. The findings were further supported by the identified relationships between subjective, behavioral, and physiological measures of subjective realism, as measured by self-report post-state questionnaires, FAB effects, and salivary volumes, respectively. Finally, AAT behavioral results indicated that meditation experience influenced trait measures of decentering (which is closely tied to

dereification) and food craving, but did not play a significant role in the capacity for dereification in the context of a brief mindful instruction (Baquedano et al., 2017). In other words, the mindful instructions offset the FAB and cephalic phase responses effects that were observed in the immersed condition.

Despite these promising behavioral results from our previous report, the physiological mechanisms by which the mindful instruction overrides the FAB effect are still unknown. Furthermore, although AA is two highly robust behavioral tendencies that represent appetitive and aversive behaviors to positive and negative stimuli (Carver, 2006), little is known to date about the neural mechanisms underlying AA actions. Some EEG studies support a model of frontal asymmetry of AA processing, with approach tendencies lateralized to the left frontal region and avoidance to the right (Davidson, Ekman, Saron, Senulis, & Friesen, 1990), but this model is still under discussion (Reznik & Allen, 2018). Finally, to our knowledge, only four studies have investigated event-related potentials (ERPs) during the AAT task. None of those four studies have used food images and only two of those used joystick. In this study, we extended this literature by looking at the AAT paradigm with food images using a joystick.

The four ERP studies targeted the N1, N2, P3, and LPP, in addition to the aforementioned SRC effect (Bamford et al., 2015; Ernst et al., 2013; Ernst, Weidner, Ehlis, & Fallgatter, 2012; van Peer et al., 2007). These ERPs and the SRC effect are believed to play different roles in the processing of stimuli. The N1 component is indicative of an early efficient stimulus classification. It is believed that N1 is a manifestation of an essential sensory gating mechanism of attention, as well as an early mechanism that influences the selection of further perceptual features (Vogel & Luck, 2000). The N2 component is usually interpreted as a marker of response inhibition in several cognitive paradigms assessing conflict processing (Folstein & Van Petten, 2008). In other paradigms involving congruent and incongruent stimulus response, such as the Stroop or Flanker tasks, an N2 congruency effect is also repeatedly observed (Yeung, Botvinick, & Cohen, 2004). Enhanced N2 amplitudes in those paradigms are associated with better behavioral regulation (Forster, Carter, Cohen, & Cho, 2011). The P3 component, in general, is thought to reflect the intensity of processing (Polich & Kok, 1995). We focused on the parietal P3, which indicates the allocation of capacity-limited attentional resources toward relevant situations (Hajcak, MacNamara, & Olvet, 2010; Linden, 2005; Nieuwenhuis, Aston-Jones, & Cohen, 2005). P3 has been interpreted as an ERP reflecting the process linking perceptual stimulus analysis and response initiation (Verleger, Jaśkowski, & Wascher, 2005), and the update of response representations and short-term memory after conflict-induced uncertainty (Donchin & Coles, 1988). The LPP is reflective of maintenance of emotional stimulus processing and has a larger amplitude in response to emotional rather than neutral stimuli (for a review see Hajcak et al. (2010)). It seems to be especially important in an active regulation of emotional responses and in the preparation of regulated actions. A reduction in LPP amplitude has been observed following reappraisal (Hajcak & Nieuwenhuis, 2006; Macnamara, Foti, & Hajcak, 2009) and suppression (Moser, Hajcak, Bukay, & Simons, 2006) for negative stimuli, while no such down-regulation (at least for appetitive food) has been found for reappraisal and suppression (Sarlo, Übel, Leutgeb, & Schienle, 2013) for positive stimuli. LPP is sensitive to emotional eating (Blechert, Goltsche, Herbert, & Wilhelm, 2014) and the processing of appetitive food stimuli in different motivational contexts (Blechert, Feige, Hajcak, & Tuschen-Caffier, 2010).

One of the four studies concerning ERPs, Ernst et al. (2013), reported an enhanced N1 and N2 for incompatible conditions (avoid condition) compared with compatible conditions (approach condition) for positive stimuli, but found no SRC effect at the behavioral level. For negative stimuli, they found the inverse; the SRC effect was not present at the electrophysiological level, but clearly present at the behavioral level. This finding suggests that an increase of the N1 and N2 amplitudes reflects a latent process associated with the regulation of the behavioral SRC. No SRC effects were seen on the P3 component. Bamford et al. (2015) also reported LPP results in addition to N1. Significant congruency effects were found on the LPP, where incongruent responses (avoid pleasant/approach unpleasant) had smaller amplitudes than the congruent responses (approach pleasant/avoid unpleasant). The LPP congruency effect reached significance for pleasant stimuli, with a weaker (non-significant) effect for unpleasant stimuli. The authors concluded that, "the neural response to identical stimuli is modulated by the required action" and that the LPP plays a role as a marker for preparing AA actions in response to emotional stimuli. The study also found an SRC effect for both positive and negative stimuli in the behavioral dimension. Contrary to Ernst et al., (2013), the researchers found no congruence effect for N1 for positive or negative stimuli. The final two studies focused on the influence of personality traits on AA responses and their underlying ERP correlates (Ernst et al., 2013; van Peer et al., 2007).

As evidenced by these studies concerning ERPs and AA, there is no consensus in the results, and ERPs and the relationship between subjective realism and appetitive food processing have not yet been investigated. Research concerning this interplay could be of particular value as ERPs are promising markers for the overlap of these two fields. They are not only sensitive to appetence toward food (Toepel, Knebel, Hudry, le Coutre, & Murray, 2009), but also could reveal the impact of induced emotional states over food processing (Blechert, Meule, Busch, & Ohla, 2014).

Given this past research and the existing gaps in the literature, in this study, we focus on the analysis of the EEG data

collected during Baquedano et al. (2017) to isolate ERPs, identify a neural marker of the physiological mechanisms by which the mindful instruction overrides the FAB effect, and further illuminate neurological mechanisms related to AA actions. We focus in particular on how ERPs signal conflict resolution in incompatible conditions. Following the precedent of the prior ERP studies, our study analyzed the N1, N2, P3, and LPP ERP measures, which promise to be sensitive to both appetitive food processing (the paradigm), and subjective realism (our variable of interest). The depletion of the behavioral SRC effects in response to mindful instruction, a replication of Papies et al. (2012), is reported in Baquedano et al. (2017), while this paper discusses the results concerning the aforementioned ERPs.

We first aim to replicate Ernst et al. (2013)'s findings by measuring an enhanced early efficient stimulus classification (N1), in particular during the mindful condition. Secondly, considering the non-replication of this N1 finding by Bamford et al. (2015), their finding concerning ERP correlates of SRC, and the literature on emotion regulation and LPP, we aim to characterize the modulation of the P3 or LPP using our paradigm.

We hypothesize that these later components reflect active emotion regulation (e.g., reappraisal) during the mindfulness instruction, as measured by an enhanced perceptual stimulus classification for an effective response initiation (P3), and a decrease in LPP-ERP amplitude. We anticipate that both the early and late ERP components will be modulated by the provided instructions, as well as meditation life experience, since training in mindfulness is thought to make the practice more automatic.

2 | METHODS

2.1 | Participants and recruitment

The participant cohort and methods were identical to our previous study (Baquedano et al., 2017). In brief, 25 non-meditators and 25 meditators (from 6 months to 6 years of experience in meditation, with an average of $1,415 \pm 1,227$ hrs of practice) participated in the study. We excluded participants with a self-reported history of psychological disorders (depression, anxiety, eating disorders), high body mass index (BMI > 30), or any cardiac condition that could interfere with the aims of this study or put participants' health at risk. The final sample consisted of 50 healthy adults: 25 (13 females) non-meditators of 28.7 ± 7.0 years of age, including 3 vegetarians, and 25 (20 females) meditators of 28.6 ± 5.6 years of age, including 9 vegetarians (see Appendix S1 on Baquedano et al., 2017 for the psychometric descriptions of the two groups). The Institutional Ethics Committee of the School of Psychology at the Pontifical Catholic University of Chile, in accordance with the guidance and regulation from the National Committee of

Science and Technology of Chile (CONICYT) approved all procedures in this study. All participants gave informed consent prior to participation in the study.

2.2 | General design and procedure

All experimental sessions started in the afternoon between 15 and 16 hrs. As a way of controlling variations attributable to the circadian rhythm on food intake and alpha-amylase secretion (Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007), participants were asked to have a regular lunch at least one hour before coming to the laboratory.

Upon arrival at the laboratory, novice and experienced meditators filled out a "pre-state questionnaire" (see below and Appendix S1 for details). The participant then viewed 120 food images under either the mindful or immersed conditions. Each participant took part in two experimental data collection sessions (one condition/session) separated by a washout period.

Each session had the following structure: Participants first completed the "exposure phase", under either immersed or mindful attention instructions, and then completed the AAT phase, where each picture was shown four times (two with an approach cue and two with the avoidance cue). Both the exposure and AAT phases were separated into two blocks (see Figure 1a) to allow the participants to rest between the blocks if necessary. During the AAT, a researcher instructed participants to "maintain their gaze on the screen" and to "respond as quickly as possible to the visual cues." At the end of each session, participants completed open and semi-structured interviews with a researcher. After the interviews, participants filled out a "post-state questionnaire."

Following the first session, participants took a break during which we offered a snack and herbal tea in order to restore them to their initial state. After the break and snack, participants had 45 min of free time as a "psychological washout", to allow physiological levels to return to a comparable baseline. Then, participants filled out a new set of "pre-state questionnaires" and performed the second session (the experimental design counter-balanced the order of the instructions across participants). Overall the experimental session lasted between 3 and 3½ hrs. The participants received a battery of questionnaires by mail to complete at home, including food preference questionnaires, just after the experimental session.

2.3 | Food image stimuli validation and Personal image pool construction

To validate the food stimuli, a group of 100 Chilean participants ranked, via an online questionnaire, 300 items from the

(a) Block structure:
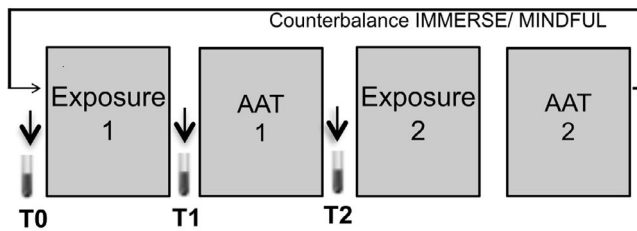
(b) Trial structure:

FIGURE 1 General paradigm design. (a) Participants observed food pictures following either a mindful attention or an immersion instruction (EXPOSURE 1) before performing an approach–avoidance task (AAT). We collected saliva samples before starting the experiment (T0), after the exposure phase (T1), and after the AAT (T2). After a 45-min break, participants repeated this pattern while following the remaining instruction. (b) Trial structure during the AAT: participants were asked to look at the center of the screen. There was first a fixation cross for 350 ms followed by a gray image lasting between 300 and 700 ms, then the food image was presented for up to 2,000 ms until the detection of the motor response. To induce approach or avoidance tendencies toward food images, we overlaid one of two possible cues (a blue circle or square) on the food images, requesting the participants to move a joystick as quickly as possible either toward them or away from them. Moving the joystick toward or away from them prompted the images to grow or shrink, respectively, for 2,000 ms (adapted from Baquedano et al., 2017) [Colour figure can be viewed at wileyonlinelibrary.com]

Food-pics image database (Blechert, Meule, et al., 2014), according to their attractiveness on a 5-point Likert scale. A total of 120 food items were selected: The 60 images having the highest scores for attractiveness constituted the "Attractive food" pool, and the 60 images having the lowest scores for attractiveness constituted the "Neutral food" pool of the experiment. After having performed the exposure phase and AAT with these selected 120 food images in the laboratory, participants were asked to rate the attractiveness each one of these images on a Likert scale at home. Using this information, we computed personalized pools of attractive and neutral food images to use in the RT analysis for each participant.

2.4 | Task

We adapted a protocol of exposure to neutral and attractive food pictures, with either a mindful attention or immersed instruction followed by an approach–avoidance task (AAT) as

described in Papies et al. (2012) and Baquedano et al. (2017) (See Figure 1 for details).

2.4.1 | Instructions and exposure phase

Participants were asked to look at food pictures for 5 s while following two instructions given in randomized order across participants. Half of the participants began with 60 pictures while applying the mindful attention instruction, while the other half of participants began with 60 pictures while applying the immersive instruction. During the mindful condition, participants were asked to "(…) be aware of thoughts, sensations, and reactions while watching each image, and to experience these mental events just as mere constructions of the mind, that appear and disappear (…)". During the immersed condition, participants were asked to "(…) try to connect intensely with the sensations generated by each image and get immersed into each image (…)". (See Appendix S1 for textual instructions).

2.4.2 | Approach–avoidance task (AAT)

In this task, neutral and attractive food images were displayed with either a blue circle or a square centrally overlaid above the food item, which indicated if participants had to approach or avoid the food item. Participants were asked to respond as quickly as possible, by moving a joystick toward them, or by moving it away from them, according to the provided cue. These movements correspond to the conditions of approaching or avoiding the image, respectively. Once the joystick movement was detected (i.e., the participant pushes or a pulls the joystick beyond a chosen threshold), the pictures immediately started to grow or shrink, mimicking approach or avoidance. Participants had a maximum of 2,000 milliseconds (ms) to respond before the next image appeared (Figure 1). The next image was presented between 650 and 1,050 ms after the participant's response, (during which the image stopped growing or shrinking), or alternatively 2,000 ms following the first appearance of the image if the participant did not respond.

To summarize, during one condition type, each of the 120 images was presented 4 times (twice with a circle and twice with a square), resulting in 240 trials per AAT block, and 480 trials per condition. In this way, we managed to present 120 trials for "approach-attractive", 120 trials for "avoid-attractive", 120 attractive trials for "approach-neutral", and 120 trials for "avoid neutral" in each condition type.

2.5 | Post-State questionnaire

After EEG hookup and before starting each session, participants filled out a pre-state questionnaire, consisting of

three Likert scale questions. This pre-state questionnaire assessed the role of hunger and mood in the experimental manipulation. In order to measure the effect of the instructions, participants also filled out a post-state questionnaire after each session (i.e., exposure phase and AAT task). With this questionnaire, we assessed four dimensions that we considered relevant for characterizing the first-person features of subjective realism in this paradigm: the dimensions of "Craving" and "Stickiness" assessed the impulsive and motivational consequences of subjectively perceived food images as real, while the dimensions of "Dereification" and "Meta-awareness" directly assessed self-perceived experience of subjective realism toward food. We computed an overall score of this post-state questionnaire based on the average scores for each sub-scale (more details and further examples along with this questionnaire validation are available in the Appendix S1 of Baquedano et al., 2017).

2.6 | Behavioral measures

2.6.1 | Reaction times acquisition and processing

Reaction times (RT) were obtained from the AAT using the time delay from the moment the food image with the cue appears on the screen to the moment the participant answers. These behavioral results are reported in Baquedano et al. (2017). Nevertheless, in this study we used our developed FAB index to explore the relationship between RT and ERPs. In the FAB index, we reduced the number of within-subject factors related to RT as follows:

$$FAB = \left[\text{Avoidance}_{\text{attractive}} - \text{Approach}_{\text{attractive}} - \text{Avoidance}_{\text{neutral}} - \text{Approach}_{\text{neutral}} \right]$$

where avoidance corresponds to RTs for avoidance responses, approach corresponds to RTs for approach responses, attractive refers to RTs for attractive food type and neutral refers to RTs for neutral food type.

2.7 | Physiological measures

2.7.1 | Electrophysiological signal acquisition and preprocessing

Recordings were obtained during the exposure and AAT under the two experimental conditions (immersed and mindful). We used a 64-channel Biosemi ActiveTwo digital EEG system, with scalp electrodes placed according to the International 10/20-System (Jasper, 1958)(Oostenveld & Praamstra, 2001); We re-referenced the EEG signals to

the average of signals above the left and right mastoids. The sample rate for the continuous data was 2,048 Hz. The recorded EEG was down-sampled to 512 Hz and filtered between 0.1 Hz and 30 Hz (Butterworth filter, fourth order).

All further analysis was completed using the MATLAB toolboxes EEGLAB (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014) (©MatLab version R2011a). We removed the eye movement artefacts (blinks and saccades) using an independent component analysis (ICA). The eye ICA components were removed based on the topographical localization and temporal profile of the ICA components (Delorme, Sejnowski, & Makeig, 2007).

We segmented continuous data into epochs of 900 ms, starting 200 ms before the onset of the picture stimulus. An automatic artifact rejection excluded all segments with amplitudes exceeding $\pm$ 110 μV Epochs were averaged separately for each of the four combinations of picture and response type, and a baseline correction was applied using the first 200 ms as a reference. Sufficient numbers of artifact-free segments remained for all 50 participants in each combination after the artifact rejection. There were no significant differences in the number of available trials after artifact rejection between group, condition, or trial type.

2.7.2 | Event-related potentials (ERPs)

The P1, N1, P2, N2, P3, and LPP (split into three successive time windows) ERPs were assessed based on visual inspection of stimulus-locked grand average ERP waveforms and were quantified at electrode sites selected on the basis of topographical maps, amplitude maps, and previous literature reports (Keil et al., 2014).

We analyzed the P1 ERP in the 70–110 ms window (Cunningham, Bavel, Arbuckle, Packer, & Waggoner, 2012; Di Russo, Martínez, Sereno, Pitzalis, & Hillyard, 2002) and the N1 ERP between 120 and 150 ms, in an occipital region of interest, composed of O1, O2, and Oz (Luck & Hillyard, 1995; Vogel & Luck, 2000) We assessed the P2 ERP between 130 and 180 ms at (Clayson & Larson, 2011; Feng et al., 2012; Keil et al., 2014). The N2 ERP was defined as the most negative data point in a window of 200–250 ms at Cz, and P3 amplitude was defined as the most positive data point in a window of 300–450 ms at Pz (Ernst et al., 2013; Gajewski, Stoerig, & Falkenstein, 2008; van Peer et al., 2007).

The amplitude of each component was calculated as the average amplitude of a window of 10 ms (5 ms per side) for the early components P1 and N1, a window of 20 ms (10 per side) for P2 and N2 and a 50 ms window (25 per side) for P3, around the most negative or positive point, respectively. We individually defined peaks in the respective average data. Finally, we measured the mean amplitude of

a late slow-wave LPP around the spatial peak (see Figure 3a,d,g) within three successive fixed time windows (LPP1 450–550 ms, LPP2 550–650 ms, LPP3 650–750 ms). LPP1 was assessed at the parieto-occipital ROI (PO7, PO3, PO8, and, PO4), LPP2 at the parietal ROI (P1, Pz, and P2), and LPP3 at the Central ROI (C1, Cz, and C2). These ROIs were selected on the basis of amplitude topographical maps and previous literature reports (see Figure 3a,d,g) (see a similar approach in Bamford et al., 2015). Amplitudes (in μV) were calculated relative to the pre-stimulus baseline using an automated, offline computerized routine. We inspected how many participants had an identifiable peak for the P1, N1, P2, N2, and P3 within the time ranges of interest. We detected an identifiable peak for 93, 96, 94, 77, and 89% of participants, for each of these ERPs, respectively (for details see Appendix S1).

2.7.3 | Saliva

Saliva samples were collected through passive drooling three times during the experimental sequence for each condition: before starting the experiment ("T0", baseline sample), after the exposure phase ("T1" sample), and after the following AAT block ("T2" sample). The majority of the results concerning saliva are reported in Baquedano et al., 2017. Nevertheless, here we explore the relationship between salivary volume and ERPs in each condition.

2.8 | Analyses

2.8.1 | Event-related potential analysis

To explore the relationship between the ERP components and other dependent variables, we reduced the number of within-subject factors related to the ERPs. In order to relate the ERP measures to the FAB behavioral measure, we computed the "ERP food attractiveness bias index" (ERP-FAB) as follows:

$$\text{ERP-FAB} = \left[\text{ERP\_Avoidance}_{attractive} - \text{ERP\_Approach}_{attractive}\right] \\ - \left[\text{ERP\_Avoidance}_{neutral} - \text{ERP\_Approach}_{neutral}\right]$$

where avoidance corresponds to the amplitude for the avoidance of the given component, approach corresponds to the amplitude for the approach of the given component, attractive corresponds to the amplitude for the attractive food type and neutral corresponds to the amplitude for the neutral food type. ERP is replaced with the data concerning the specific ERP in question and; therefore, the word "ERP" is also replaced in the results concerning these specific measures, i.e., N2-FAB). The ERP-FAB value expresses the specific difference in amplitudes of a component in avoiding versus approaching attractive food

images for a given person. We modified the sign of this formula when necessary to yield positive ERPs, (i.e., P1 and P3, see Appendix S1). This value, expressed in microvolts (μV), is an EEG counterpart to the FAB behavioral marker.

Finally, the original FAB measure included in other papers, concerning reaction times, is labeled RT-FAB throughout this study, to avoid confusion. Similarly to the RTs within factor reduction (RT-FAB) (Baquedano et al., 2017), we use these ERP indices to explore the relationship between the ERPs and other dependent variables (see Bamford et al., 2015 for a similar approach).

2.8.2 | Electrophysiological data analysis

A mixed repeated analysis of variance (ANOVA) was performed with a 2 (group: non-meditators vs. meditators) × 2 (condition: mindful vs. immersed) × 2 (food type: attractive vs. neutral) × 2 (response type: approach vs. avoidance) × 5 component (P1, N1, P2, N2, P3, and LPP) design.

Subsequently a 2 (condition: mindful vs. immersed) × 2 (food type: attractive vs. neutral) × 2 (response type: approach vs. avoidance) ANOVA was performed for each of the components. Conservative Greenhouse–Geisser Corrections were used for all comparisons with more than two levels. Bonferroni Corrections were applied on all post hoc t tests.

2.8.3 | Integrative analysis

Once we determined how the immersed and mindful condition modulated the ERP components, we conducted Pearson correlations to determine the relationship between the above-mentioned conditions and the components. Specifically, we evaluated whether the post-state questionnaire, RT, and salivary volume predicted ERPs. There was no outlier (±3 SD) detected in the correlation analysis.

3 | RESULTS

3.1 | Electrophysiological results: ERP assessment during the Approach–Avoidance Task

As N1, N2, P3, and LPP amplitudes are modulated during an AAT, we hypothesized that these AAT-related ERP modulations would interact with the type of instructions and with group condition. We tested this hypothesis using a mixed design of repeated analysis of variance (rmANOVA) including 2 (group: non-meditators vs. meditators) × 2 (condition: mindful vs. immersed) × 2 (food type: attractive vs. neutral) × 2 (response type: approach vs. avoidance) × 6

component (N1, N2, P3 LPP1, LPP2, and LPP3). Consistent with our hypothesis, we found a condition by food type by response type by component type interaction ($F(5, 250) = 2.82$, $p = .01$). Based on this interaction, we explored each component separately.

Below we detail only ERPs sensitive to either the condition (mindful vs. immersed) or the meditation expertise group of the participant. In the Appendix S1, we also report ERPs sensitive to the approach/avoidance response type and to the food type (neutral vs. attractive food), as well the exploratory ERP analysis on the P1 and P2 ERPs. These AAT-related findings include significantly greater P1 amplitude for approach than for avoidance in attractive foods, and a positive correlation between N2-dFAB and RT-FAB, suggesting that N2 increases as a function of the difficulty to overcome the AAT conflict (see Appendix S1 for details).

3.1.1 | N1 ERP

At occipital ROI (O1, Oz, and O2), the rmANOVA revealed a condition by food type by response type interaction ($F(1,48) = 4.31$, $\eta^2_G = 0.001$, $p = .014$). In the mindful condition, we found a food type by response type interaction ($F(1,49) = 5.25$, $\eta^2_G = 0.003$, $p = .026$), driven by greater N1 amplitude for avoidance ($M = -4.93$, $SD = 3.03$) than for approach ($M = -4.40$, $SD = 2.97$) during attractive food ($t(49) = 3.07$, $p = .003$) but not during neutral food ($t(49) = 0.45$, $p = .65$). There was no food type by response type interaction ($F(1,49) = 0.97$, $\eta^2_G = 0.0005$, $p = .19$) during the immersed condition (Figure 2a).

3.1.2 | P3 ERP

At the Pz electrode, the rmANOVA revealed a main effect of condition ($F(1,48) = 27.10$, $\eta^2_G = 0.009$, $p = .04$). The P3 amplitude was greater for the mindful ($M = 4.72$, $SD = 2.85$) than for the immersed condition ($M = 4.19$, $SD = 2.70$) ($t(199) = 3.74$, $p < .001$). A main effect of response type ($F(1,48) = 20.05$, $\eta^2_G = 0.007$, $p < .001$) showed that P3 amplitude was greater for the approach ($M = 4.69$, $SD = 2.79$) than for the avoidance responses ($M = 4.21$, $SD = 2.75$) ($t(99) = 4.33$, $p < .001$) (Figure 2b).

3.1.3 | LPP1 ERP (450–550 ms)

At the parieto-occipital ROI (PO7, PO3, PO8, and PO4), the rmANOVA revealed a main effect of response type ($F(1,48) = 12.80$, $\eta^2_G = 0.01$, $p = .001$), where the LPP1 amplitude was greater for approach ($M = 2.41$, $SD = 1.81$) than

avoidance responses ($M = 2.05$, $SD = 1.71$) ($t(199) = 4.95$, $p < .001$). This rmANOVA also revealed a group by response interaction ($F(1,49) = 5.65$, $\eta^2_G = 0.003$, $p = .003$). For the non-meditator group the LPP1 amplitude was greater for approach ($M = 2.5$, $SD = 1.6$) than for avoidance responses ($M = 1.9$, $SD = 1.5$) ($t(99) = 5.54$, $p < .001$) (Figure 3a,b,c). For the meditator group, the LPP1 amplitudes for approach ($M = 2.3$, $SD = 1.9$) and for avoidance ($M = 2.1$, $SD = 1.8$) were not significantly different ($t(99) = 1.5$, $p = .13$). Finally, the rmANOVA revealed a food type by response type interaction ($F(1,48) = 8.59$, $\eta^2_G = 0.002$, $p < .005$), where the amplitude of LPP1 was greater for approach ($M = 2.56$, $SD = 1.83$) than avoidance ($M = 2.02$, $SD = 1.71$) for attractive food ($t(99) = 5.41$, $p < .001$), but not for neutral food ($t(99) = 1.74$, $p = .08$).

3.1.4 | LPP2 ERP (550–650 ms)

At the parietal ROI (P1, Pz, P2), the rmANOVA revealed a main effect of response type ($F(1,48) = 28.62$, $p < .001$, $\eta^2_G = 0.03$), where the LPP 2 amplitude was greater for approach ($M = 1.16$, $SD = 1.29$) than avoidance ($M = 0.66$, $SD = 1.31$) responses ($t(199) = 7.32$, $p < .001$). This rmANOVA also revealed a food type by response type ($F(1,48) = 4.4$, $p = .04$, $\eta^2_G = 0.002$), where the LPP2 amplitude for attractive food was greater for approach ($M = 1.26$, $SD = 1.32$) than for avoidance responses ($M = 0.63$, $SD = 1.32$) ($t(99) = 6.55$, $p < .001$) (Figure 3d,e,f). Approach and avoidance response amplitudes were not different for neutral food (approach, $M = 1.07$, $SD = 1.28$; avoidance, $M = 0.69$, $SD = 1.32$) ($t(99) = 3.88$, $p = .01$).

This rmANOVA also revealed a group by condition by response type interaction ($F(1,48) = 5.24$, $p = .026$, $\eta^2_G = 0.001$). While for the immersed condition there was only a main effect of response type ($F(1,48) = 25.17$, $p < .001$, $\eta^2_G = 0.04$), the LPP2 amplitude was greater for approach ($M = 1.2$, $SD = 1.4$) than for avoidance responses ($M = 0.61$, $SD = 1.3$) ($t(99) = 5.84$, $p < .001$). The mindful condition rmANOVA revealed a main effect of response type ($F(1,48) = 16.17$, $p < .001$, $\eta^2_G = 0.03$). The LPP2 amplitude was greater for approach ($M = 1.16$, $SD = 1.19$) than for avoidance responses ($M = 0.7$, $SD = 1.3$) ($t(99) = 4.54$, $p < .001$), and also revealed a group by response type interaction ($F(1,48) = 5.14$, $p < .05$, $\eta^2_G = 0.01$). For the control group, the LPP2 amplitude for approach responses ($M = 1.25$, $SD = 1.14$) was greater than for avoidance responses ($M = 0.53$, $SD = 1.32$) ($t(49) = 4.99$, $p < .001$). For the meditator group, the LPP2 amplitude for approach responses ($M = 1.0$, $SD = 1.2$) was not greater than for avoidance responses ($M = 0.8$, $SD = 1.2$) ($t(49) = 1.5$, $p = .13$).
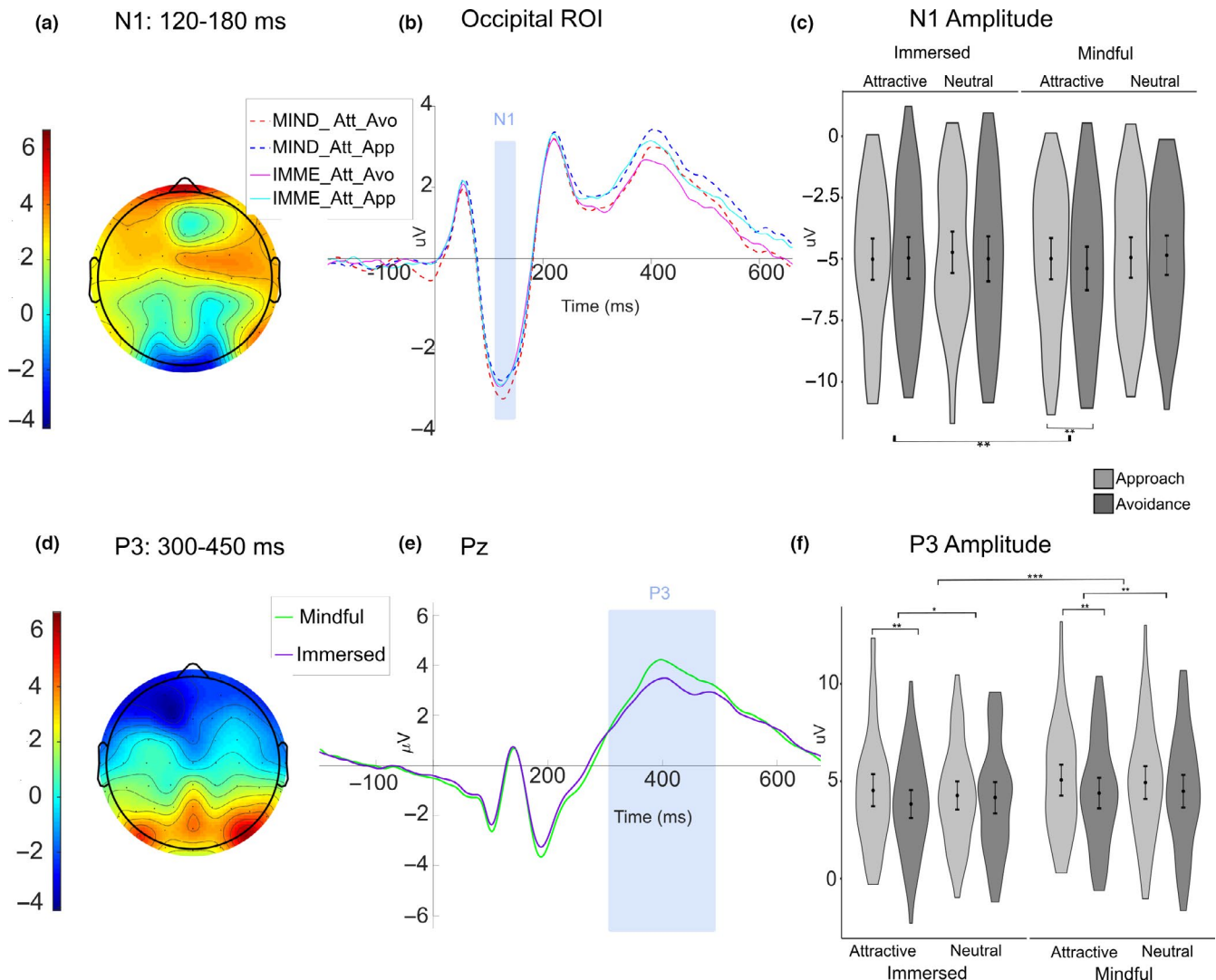
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FIGURE 2 Visual ERPs, elicited by food pictures, during AAT under the two different instructions. (a) Scalp plot from N1. (b) ERP brainwave of N1 in the occipital ROI (O1, Oz O2). (c) Quantification of the N1 ERP amplitude in μV. (d) Scalp plot from P3. (e) ERP brainwave of P3 in Pz. (f) Quantification of the P3 ERP amplitude in μV. Light blue zone indicates statistically evaluated area. Bars denote standard error. *$p < .05$, **$p < .01$, ***$p < .001$ [Colour figure can be viewed at wileyonlinelibrary.com]

3.2 | Integrative analyses

3.2.1 | Relationship between ERP components and salivary volume

We performed Pearson correlations to investigate whether instruction-related changes on ERP-FABs (ERP-FAB = [ERP_Avoidance$_{attractive}$ − ERP_Approach$_{attractive}$] − [ERP_Avoidance$_{neutral}$ − ERP_Approach$_{neutral}$]) predicted condition related changes in salivation. Since N1 and LPP2 in the aforementioned results were the only ERP components for which the AAT factors (food, response, etc.) were sensitive to the condition manipulation, we only tested for their relationship with salivation. First, to further explore the functional role of N1-FAB, we tested whether larger (more negative) N1-FAB values,

which reflect a greater amplitude of N1 for avoiding attractive relative to other food type responses, would be related to decreased salvation amounts. Second, we hypothesized that more negative LPP2-FAB values, which reflect a greater amplitude of LPP for approaching attractive food (relative to other food type responses), would be related to an increase in salivary volume. For these above possibilities, we did not find any correlation with the amount of salivation.

3.2.2 | Relationship between ERP components and behavioral measures

N2 as N2-dFAB index was the only ERP component presenting a positive correlation with the RT-FAB ($R = 0.27$, $p = .029$) (Figure S3). This positive correlation indicates that participants
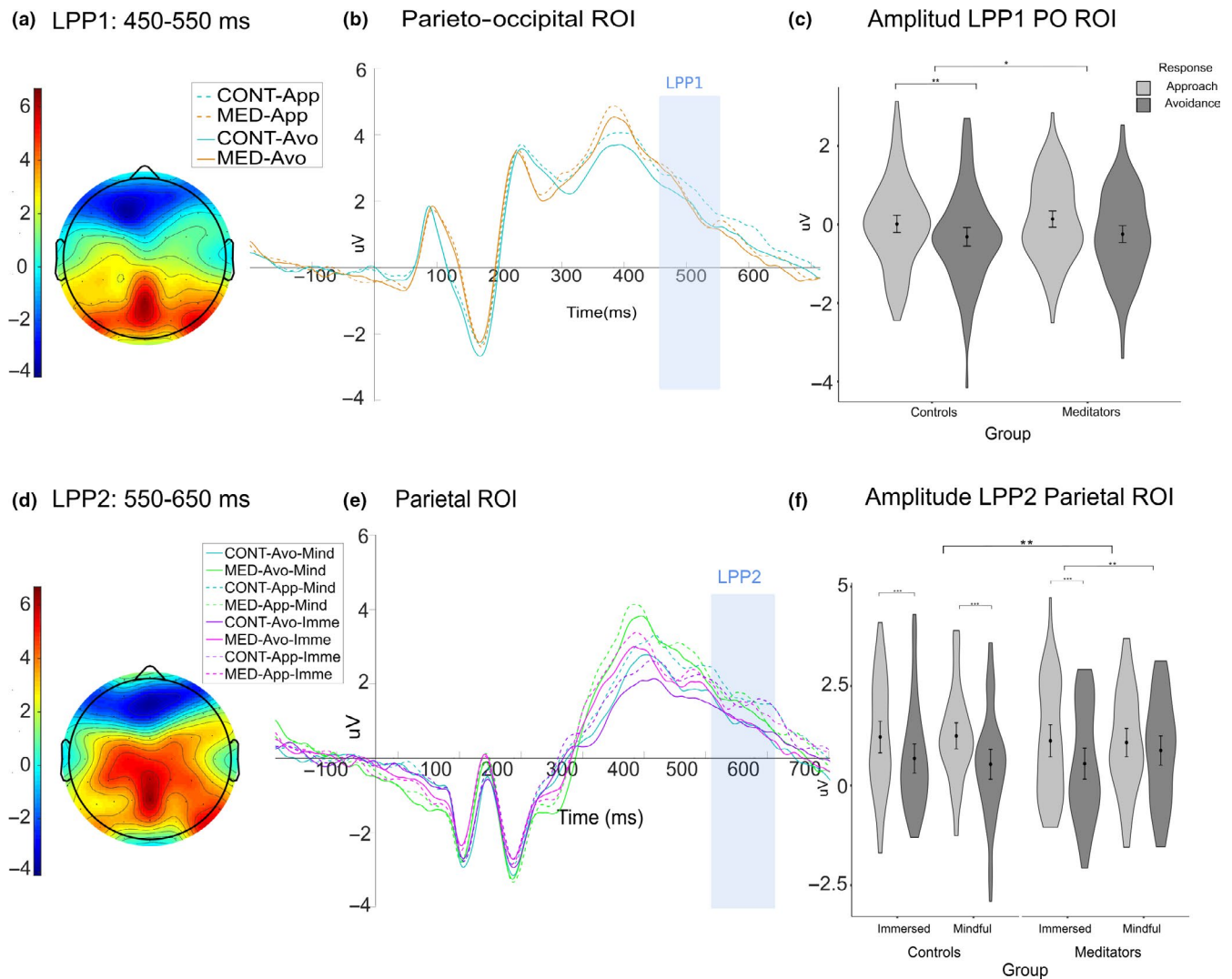
FIGURE 3 Visual LPP ERPs, toward food pictures, during AAT under the two different instructions. (a) Scalp plot from LPP1. (b) ERP brainwave of LPP1 in the parieto-occipital ROI. (c) Quantification of the LPP1 ERP amplitude in uV. (d) Scalp plot from LPP2. (e) ERP brainwave of LPP2 in the parietal ROI. (f) Quantification of the LPP2 ERP amplitude in μV. Light blue zone indicates statistically evaluated area. Bars denote standard error. *$p < .05$, **$p < .01$, ***$p < .001$ [Colour figure can be viewed at wileyonlinelibrary.com]

who presented greater bias toward attractive food (expressed in higher RT-FAB values) also presented greater N2 amplitudes.

To control for the possible contribution of the motor response in some of the LPP findings, we examined the relationship between ERP amplitudes and RTs independently of any factor (group/condition/food/response) using Pearson correlations. As described in the Appendix S1, we found no correlation between RTs and ERPs, with the exception of the P3.

3.2.3 | Relationship between ERP and Self-Report Measures

We performed exploratory correlational analyses between the ERPs sensitive to the AAT manipulation and post-state questionnaires associated with subjective realism, food bias, or mindfulness meditation.

We used Pearson correlations to evaluate whether individuals who reported greater differences in subjective realism between the mindful and immersed conditions during the exposure phase (as measured by the "post-state questionnaire"), showed higher food attractiveness bias in the AAT ERP components.

We found that participants who reported more craving during the immersion condition had greater N1-FAB in response to approach attractive food relative to avoid attractive food ($r = 0.3$, $p = .03$), presenting an enhanced attentional selection toward attractive food (Figure 4a). In the mindful condition, these variables were not related ($r = -0.12$, $p = .2$). These two correlations were significantly different from one another ($p = .03$). To summarize, the N1, a marker of early attentional selection, was the best predictor of successful AAT conflict resolution during the mindfulness condition compared with the immersed condition.

Consistent with these findings, participants who reported less meta-awareness in the immersion condition had greater P1 amplitude in response to approaching attractive food, relative to avoiding it ($r = -0.28$, $p = .04$) (Figure 4b). This finding suggests that participants who had less self-reported meta-awareness in the immersion condition also showed more attentional bias toward attractive food. In the mindful condition, this correlation was not significant ($r = -0.1$, $p = .4$).

Participants who reported more stickiness in the immersion condition showed greater N2 amplitude in response to approaching attractive food trials relative to avoiding attractive food trials ($r = 0.3$, $p = .02$) (Figure 4c), which we interpret as reflecting greater inhibition of preponderant response toward the food.

4 | DISCUSSION

In this study, we aimed to replicate the finding reported by Ernst et al. (2013) concerning the N1 and N2 ERP modulation on the AAT incompatible trials (avoid positive), and the finding by Bamford et al. (2015) concerning the LPP ERP correlates using our AAT paradigm. We hypothesized that these early or late ERP components would be differently modulated by the provided instructions, as well as by the group variable of experience in mindfulness meditation.

The results from the study revealed two main effects of the instructions and the meditation expertise on the ERP EEG. Firstly, RT-FAB regulation by the mindful instruction compared to the immersed instruction was associated with a modulation of the visual N1 amplitude, replicating the results reported by Ernst et al. (2013) for the mindful condition. N1

modulation in the mindful condition also confirmed our hypothesis of the differential modulation of early ERPs by the provided instruction.

Secondly, participants with expertise in mindfulness meditation engaged less in late affective reappraisal regulation during mindfulness, as shown by the lower amplitude in LPP-ERP. This LPP result replicates Bamford et al.'s (2015) LPP findings and is in accordance with our hypothesis regarding the differential modulation of ERP correlates by the AAT depending on mindfulness meditation expertise.

Finally, concerning the findings of Ernst et al. (2013), we did not replicate the modulation of N2 under any of the tested conditions. Nonetheless, in accordance with their findings, we found no P3 ERP modulation on the AAT.

These results extend our previous findings (Baquedano et al., 2017), where we reported a reduction in automatic bias toward attractive food in visual stimuli following the mindful instruction, but no reduction in automatic bias following the immersed instruction, as measured by performances on the ATT. In the above-mentioned study, we also found that the saliva volume was reduced during the mindful condition compared with the immersed one.

4.1 | N1 modulation

N1 is thought to be a manifestation of an early essential sensory gating mechanism of attention that influences further selection of perceptual features (Vogel & Luck, 2000). Therefore, it reflects an efficient allocation of attentional resources (Luck, 2005). In the context of the AAT, findings on N1 have so far been inconsistent. Ernst et al. (2013)
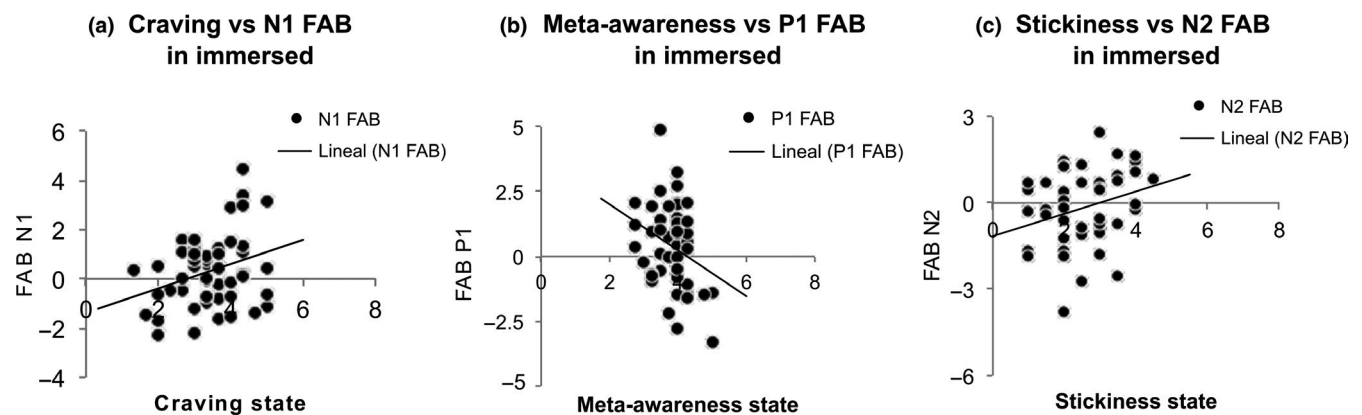
(a) Craving vs N1 FAB in immersed

(b) Meta-awareness vs P1 FAB in immersed

(c) Stickiness vs N2 FAB in immersed

FIGURE 4 FAB index from the ERPs components versus. subscales from the post-state questionnaire. (a) N1-FAB versus. food craving as a state in the immersed condition ($R = 0.3$, $p = .03$). Participants who reported more craving during the immersed condition had a greater amplitude of N1 in response to approaching attractive food trials relative to avoiding attractive food trials. (b) P1-FAB versus. Meta-awareness as a state in the immersed condition ($R = -0.28$, $p = .04$). Participants who reported less meta-awareness had greater P1 amplitudes toward approaching attractive food relative to avoiding attractive food. (c) N2-FAB versus. Stickiness as a state in the immersed condition ($R = 0.3$, $p = .02$). Participants who reported more Stickiness in the immersed condition had a greater N2 amplitude toward approaching attractive food relative to avoiding attractive food

found an enhanced N1 and N2 for incompatible conditions (avoid positive), compared with compatible conditions (approach positive), for positive stimuli and that this neuronal regulation (i.e., electrophysiological SRC effect) was followed by the cessation of the SRC at the behavioral level. For negative stimuli, they found an inverse pattern: The SRC effect was not present at the electrophysiological level, but was clearly present at the behavioral level. The authors concluded, "[t]hese electrophysiological SRC effects indicate efficient regulation of the AAT conflict in response to positive pictures, which seems to have prevented any influence of incompatibility on behavior since there were no behavioral SRC effects." (Ernst et al., 2013, p. 243) Contrary to this finding, Bamford et al. (2015) found no congruence effect for N1 for positive or for negative stimuli.

In our AAT paradigm, we found a condition by food type by response type interaction. The mindful condition was the only condition in which the amplitude of N1 was greater for avoidance than for approach responses toward attractive food, with no difference in responses toward neutral foods. This finding suggests that during the mindful condition the elimination of the RT-FAB (behavioral SRC effect) could be caused by a greater allocation of attention and an effective early selection (Luck, 2005) toward incongruent required responses (i.e., avoiding attractive food). This process may also allow for better subsequent executive processing during the resolution of the AAT conflict. This interpretation is in line with the results of Ernst et al. (2013) and the findings indicating that the N1-ERP is related to the facilitation, through early attention allocation, of effective perceptual processing and classification of stimuli (Luck, 2005; Vogel & Luck, 2000).

4.2 | LPP modulation

The LPP is an ERP component that reflects brain activity involved in emotional processing (Hajcak et al., 2010; Thigpen, Keil, & Freund, 2016). A broad compendium of literature has demonstrated that emotionally arousing pictures typically elicit larger LPPs than neutral pictures (for a review see Hajcak et al., 2010). Affective images that engender high arousal also elicit larger LPPs than less intense pictures (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000). LPP appears to reflect both automatic and controlled modulation during emotional picture viewing (Hajcak, Dunning, & Foti, 2009; Littel & Franken, 2011). In the food-related research field, LPP is used as an index of motivational significance of food stimuli. Accordingly, positive correlations have been found between late positivities (P300, LPP) and self-reported hunger (Nijs, Franken, & Muris, 2008; Sarlo et al., 2013; Stockburger, Weike, Hamm, & Schupp, 2008).

For the AAT, Bamford et al., (2015) found a behavioral SRC effect for both positive and negative stimuli. At the EEG level, the significant congruency effects were reflected in the LPP amplitudes. Incongruent responses (avoid pleasant/approach unpleasant) had smaller amplitudes than congruent responses (approach pleasant/avoid unpleasant). This LPP congruency effect was stronger for pleasant stimuli than for unpleasant stimuli. From these results, the authors postulated the LPP as a congruency effect neural marker of emotion-driven action preparation in an AA paradigm (Bamford et al., 2015).

Our LPP results, for all ROIs and time periods assessed, presented a main response effect, whereby approach responses showed larger amplitudes of LPP in general. Furthermore, we repeatedly found a food by response interaction; attractive food approach responses presented larger amplitudes of LPP when compared with avoid responses. These findings are consistent with existing literature and especially with the results of Bamford et al. (2015). Therefore, consistent with the above-mentioned findings, our results support the congruency effects that show the neural response to identical stimuli at the LPP is modulated by the required action (Bamford et al., 2015). Data supports that LPP responses to affective pictures are modulated both by the intrinsic motivational significance of the image and the evaluative context of picture presentation (Schupp et al., 2000).

In addition to these corroborative results, we found a group by response interaction in the ROI assessed for LPP1. In contrast to the meditators group, for the non-meditator group the LPP1 amplitude was higher in approach than in avoidance responses. More importantly, we also found a group by condition by response interaction in the ROI assessed for LPP2. In the mindful condition, for the meditator group, LPP2 amplitudes were not different for approach or avoidance responses, while LPP2 amplitudes were different for the non-meditator group.

Smaller LPP amplitudes are interpreted as reflecting effectively regulated responses (Hajcak & Nieuwenhuis, 2006; MacNamara et al., 2009; Moser et al., 2006). LPP is also sensitive to the active regulation of emotional responses, where a reduction in LPP amplitude is observed following reappraisal (Hajcak & Nieuwenhuis, 2006; Macnamara et al., 2009), and suppression (Moser et al., 2006) for negative stimuli. In contrast, reappraisal and suppression toward positive stimuli (at least for appetitive food) does not seem to down-regulate the LPP (Sarlo et al., 2013). The results concerning LPP1 suggest that, compared with meditators, non-meditators mobilize more regulatory mechanisms related to LPP modulation to solve the AAT conflict.

4.3 | N2 Modulation

Even though we did not replicate the finding regarding the modulation of N2 reported by Ernst et al. (2013), N2 as

N2-dFAB index was the only ERP component presenting a positive correlation with the RT-FAB. This positive correlation indicates that participants who presented greater bias toward attractive food (expressed in higher RT-FAB values) also presented greater N2 amplitudes. In other words, the amplitude of N2 did not correlate with successful extinction of AA tendencies. Since we did not find any interaction with the condition type in the rmANOVA conducted for N2, we cannot attribute the increase of the N2 amplitude to the specific successful resolution of the RT-FAB during the mindful condition compared to the immersed condition. Rather, this positive correlation between N2-dFAB and RT-dFAB suggests that N2 increases as function of the approach and avoidance bias during the AAT.

In summary, in this paper, we outline the replication of the results concerning N1 in Ernst et al., 2013 and the results concerning LPP in Bamford et al., 2015. The results we have obtained for N2 and P3 (see Appendix S1) are in accordance with the functional role traditionally attributed to these measures in the existing literature, but do not account for the resolution of the behavioral SRC/FAB effect. The correlations of ERP-FABs with the post-state questionnaires (e.g., greater P1 amplitude with lower scores of meta-awareness or greater N2 amplitude related to higher scores in stickiness) are consistent with their functional role. The modulations that ERP-FABs showed through our condition manipulation concur with their functional role reported in the literature. Together, these correlations provide confirmatory evidence for the functional interpretation of these ERPs.

5 | LIMITATIONS

The present study has several limitations. With the current design, it is challenging to separate the effect of immersion and mindful attention. Adding an uninstructed control task, on the other hand, would have made the task too long and therefore susceptible to the confound of participant fatigue.

Concerns about potential motor response as a confound in LPP ERPs and the possible relationship between motor preparation response and the ERP components were raised in the peer review process. In our experimental design, there was no delay between the moment the participant's movement was detected and the onset of the picture movement. The majority of participants' mean reaction time were slower than 500ms (see Figure S1). Therefore, the soonest this change in the visual input could have affected the EEG signals was at 550 ms, which corresponds to the end of window of interest of the LPP1, whose interpretation is thus not problematic.

If there is a possible motor confound in the late ERP induced by this visual change, it would only affect the late portions of LPP (LPP2 and LPP3). However, we do not anticipate this motor or visual confound to affect the late ERP because these visual changes (shrinking or growing of the image) are not locked to the initial visual stimuli but to the motor responses. The trial-by-trial motor or visual EEG confounds after 550 ms are not phase-locked to the onset of the visual stimuli and should thus cancel out on average. As such, we believe that they do not contribute to the late ERP. Nonetheless, it is true that LPP2 was assessed in parieto-occipital regions, while LPP3 was assessed in central electrodes. Therefore, we remain cautious in our interpretation of these LPP3 ERP results and have moved them to the Appendix S1 section.

In our study, we assumed that any effect of condition reflected an SRC effect on behavior induced by the exposure phase only. However, we cannot rule out that the mindful and immersed conditions during the exposure phase differentially impact response preparation or decision making during the AAT task, even if the participants are not instructed to voluntarily maintain these states during the AAT task. This means that it is possible for one participant to be more alert and focused after the mindful condition compared with after the immersed condition.

In our previous reports, we discussed the lack of findings of group in the behavioral and autonomic data (see Baquedano et al., 2017), despite group differences on several self-report measures. We initially hypothesized that meditation experience would improve the AAT performance during the mindful attention instruction. Despite an overall faster behavioral response for meditators compared to novices, we found no interaction between conditions and groups, which indicated that the capacity to sustain mindful attention toward food cues, as requested by a brief instruction, does not require formal training to induce detectable behavioral effects, and that meditation experience does not influence the capacity of self-immersing (discussed in Baquedano et al., 2017). Based on these results, we argued that a more appropriate design with this paradigm to look at meditation expertise could be to do the task without any instruction manipulation. It is possible that experienced meditators will spontaneously engage in mindful attention but not novices. As discussed in the limitation section (from Baquedano et al., 2017), this additional condition was not included in our paradigm.

6 | CONCLUSION

In this follow-up study pursuing the neuronal basis of AA tendencies and their modulation by specific mindset instructions, we found that the two differentially influence the early N1 ERP. We attribute the override of the behavioral

FAB effect in the mindful condition to an enhanced early attentional selection (as expressed in an increased N1) to incongruent stimuli (avoid attractive). Additionally, we found that the late LPP ERP is modulated differently for participants either with or without meditation expertise during AAT. Compared to experienced meditators, participants naïve to meditation tend to regulate automatic approach tendencies through a late affective reappraisal in the mindful condition.

Overall, these findings suggest that a dereified attitude induced by a brief mindful attention instruction de-automatizes the approach bias toward attractive stimuli found during subjective realism. This effect correlates with a modulation at an early stage of stimulus processing during the AA conflict, even though the LPP component is also modulated during the AAT, especially in participants inexperienced in meditation. These novel findings provide important insights into the mechanisms by which mindfulness may promote well-being in healthy individuals and by which mindfulness-based interventions used for a range of psychiatric conditions (such as food or addiction disorders) could strengthen participants cognitive capacities to down-regulate undesirable symptoms.

CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

AUTHOR'S CONTRIBUTION
C.B., A.L., D.C., and V.L. designed the study. V.L. and D.C. contributed the experimental data acquisition setup. C.B. participated in the data collection process. C.B. analyzed and interpreted the data with inputs from A.L., D.C., and V.L. C.B. wrote the manuscript, and V.L., D.C., and A.L. contributed to the writing and editing of the manuscript. All authors reviewed the manuscript critically for content and contributed to the interpretation of the results.

DATA AVAILABILITY STATEMENT
Data are available upon request to the corresponding author.

ORCID
Antoine Lutz https://orcid.org/0000-0002-0258-3233

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.
Appendix S1

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