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Emotion regulation flexibility: EEG/EMG predictors and consequences of switching between reappraisal and distraction strategies

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Abstract

Flexible use of emotion regulation (ER) strategies is central to mental health. To advance our understanding of what drives adaptive strategy-switching decisions, in this preregistered study, we used event-related potentials (late positive potential, LPP and stimulus preceding negativity, SPN) and facial electromyography (EMG corrugator activity) to test the antecedents and consequences of switching to an alternative ER strategy. Participants ($N = 63$, $M_{age} = 24.8$ years, all female) passively watched and then implemented an instructed ER strategy (reappraisal or distraction) in response to high-intensity negative pictures that were either easy or difficult to reinterpret (high or low reappraisal affordance, respectively). Next, they decided to "switch from" or "maintain" the instructed strategy and subsequently implemented the chosen strategy. Reappraisal affordance manipulations successfully induced switching. Regarding antecedents, switching was predicted by the reduced ER efficacy of the current strategy (corrugator, but not LPP). Switching to distraction was additionally predicted by increased responses to the stimulus during passive viewing (corrugator and LPP) and increased anticipatory effort in implementing reappraisal (SPN). Concerning consequences, switching to distraction *improved*, whereas switching to reappraisal *impaired* post-choice ER effects (LPP). However, starting with reappraisal was overall more effective than starting with distraction, irrespective of the subsequent decision (corrugator). Our results suggest that switching between ER strategies occurs in accordance with situational demands (stimulus affordances) and is predicted by reduced peripheral physiological ER efficacy. However, only switching to distraction leads to improved regulatory effects. These insights provide neurocognitively grounded starting points for developing interventions targeting ER flexibility.

KEYWORDS

corrugator, late positive potential (LPP), monitoring, reappraisal affordances, regulatory flexibility

1 | INTRODUCTION

Flexibility is a hallmark of adaptive human behavior. Research on emotion regulation (ER) has shown that *ER flexibility*, the ability to adapt regulatory efforts to contextual demands, is central to psychological well-being (see Aldao et al., 2015; Bonanno et al., 2023; Bonanno & Burton, 2013; Kashdan & Rottenberg, 2010; Roelofs et al., 2023 for a review). Whereas high ER flexibility has been related to better mental health, low ER flexibility has been linked to increased psychopathology (Bonanno et al., 2023; Chen & Bonanno, 2021; Conroy et al., 2020; Dougherty et al., 2023; Levin & Rawana, 2022; Levy-Gigi et al., 2016; Nardelli et al., 2023; Sheppes et al., 2015; Socastro et al., 2022; Wang et al., 2021). To develop evidence-based interventions aimed at improving ER flexibility, it is important to understand the psychophysiological predictors and consequences of this adaptive ability.

Previous work showed that stimulus- and situation-related factors can moderate the efficacy of ER strategies and thus motivate switching from an ineffective to a more effective ER strategy (see Matthews et al., 2021 for a review). For example, compared to distraction, reappraisal shows reduced efficacy in response to high-intensity (i.e., unpleasant and arousing) stimuli, as evidenced by increased amplitudes of the late positive potential (LPP) (Adamczyk et al., 2023; Shafir et al., 2015, 2016), an electrocortical marker of emotional arousal and sustained motivated attention (see Hajcak & Foti, 2020; MacNamara et al., 2022 for a review). Implementing reappraisal is also anticipated to be more effortful than implementing distraction in response to high-intensity stimuli (Shafir et al., 2015), as revealed by increased (i.e., more negative) amplitudes of the Stimulus Preceding Negativity (SPN), an electrocortical marker of anticipatory cognitive effort (see Brunia et al., 2012 for a review). Accordingly, people preferentially choose distraction over reappraisal (Sheppes et al., 2014) and decide to switch to distraction after initially implementing reappraisal for high-intensity stimuli (Birk & Bonanno, 2016; Dorman Ilan et al., 2019). These switch decisions might be driven by reduced initial efficacy of reappraisal, indexed by higher self-reported affect and peripheral physiological responses (Birk & Bonanno, 2016). Importantly, switching in accordance with personal and situational demands might have adaptive short-term regulatory consequences, as evidenced by reduced LPP amplitudes when participants switch to distraction for high-intensity stimuli (Dorman Ilan et al., 2019).

Together these studies provide initial evidence that the decision to switch to distraction might be motivated by reduced peripheral physiological ER efficacy of reappraisal toward high-intensity stimuli, which might improve short-term neural regulatory effects after switching. However, it remains unknown whether *switching to reappraisal* can also be predicted by reduced efficacy *of distraction*, and whether switching improves ER effects for *both* strategies. Investigating this is important since reappraisal has been shown to act as a stress resilience factor (Riepenhausen et al., 2022), yet the only situational factor that has been found to induce a switching preference for reappraisal over distraction is low stimulus intensity (Birk & Bonanno, 2016; Dorman Ilan et al., 2019; Sheppes et al., 2014). Still, effective downregulation of high-intensity emotions is one of the crucial aspects of adaptive mental functioning. Hence, our goal was to induce switching decisions *from distraction to reappraisal* for high-intensity stimuli to investigate psychophysiological predictors and consequences of adaptive switching between both strategies across different ER phases. To this end, we used a modified ER strategy switching task (cf. Dorman Ilan et al., 2019) in which we manipulated *reappraisal affordances*–inherent stimulus characteristics that make stimuli easy (high affordance) or difficult (low affordance) to reinterpret (Suri et al., 2018).

Participants passively watched high-intensity negative pictures of high or low reappraisal affordance. Next, they were instructed to downregulate their negative arousal toward the high-intensity stimulus using either reappraisal or distraction. Hereafter, they decided to switch from or maintain the initial (reappraisal or distraction) strategy and implemented the chosen strategy. To measure ER efficacy, we used the LPP, an electrocortical marker of sustained motivated attention and emotional arousal (Hajcak & Foti, 2020; MacNamara et al., 2022), as well as electromyography (EMG) corrugator supercilii activity, a facial expressive marker of negative affect (frown; see e.g., Birk & Bonanno, 2016). Both these measures show *decreased* amplitudes, reflecting downregulation of emotional responses, during implementation of reappraisal and distraction compared to passive viewing (Adamczyk et al., 2023; Dorman Ilan et al., 2019; Schönfelder et al., 2014). In addition, we measured the SPN (indexing anticipatory cognitive effort) during the strategy pre-implementation phase to explore whether increased anticipated effort of implementing an instructed strategy would predict switch decisions (see also Shafir et al., 2015).

We expected that our manipulation of reappraisal affordance would result in more switch-to-reappraisal decisions (H1) and increase reappraisal efficacy (H2) for high affordance pictures specifically. Overall, that is, irrespective of affordance, we expected that distraction would be more effective than reappraisal (H3; Adamczyk et al., 2023; Dorman Ilan et al., 2019; Shafir et al., 2015, 2016). Regarding predictors of switching, we expected that increased psychophysiological responses during initial picture presentation would predict a preference for (switching-to and maintaining) distraction (H4). Furthermore, we expected that reduced efficacy of the initially instructed strategy would predict switching to the alternative strategy (H5), especially for reappraisal in response to low affordance pictures (H6; see Birk & Bonanno, 2016). Regarding the consequences of switch decisions, we expected that switching to distraction would be more effective (i.e., result in more psychophysiological downregulation post-choice) than maintaining reappraisal, and that maintaining distraction would be more effective than switching to reappraisal, as demonstrated previously (H7; Dorman Ilan et al., 2019). That maintaining distraction would be more effective than switching to reappraisal, and that mainitaning distraction would be more effective than maintaining reappraisal, both in response to *low but not high* affordance pictures.

2 | METHODS

2.1 | Participants

Participants were Jagiellonian University students (or recent graduates) and were recruited via an email invitation[1] (data collection in 2022). Based on an a priori sample size calculation (see preregistration for details: https://osf.io/ze8mg), we tested 63 participants ($M_{age} = 24.8$, $SD = 4.2$, range 19–37). All participants were of European descent. Only female participants were recruited to control for gender differences in emotional picture processing (Filkowski et al., 2017) and the use of ER (McRae et al., 2008). All participants had normal or corrected to normal vision and no self-reported history of neurological or psychiatric disorders. In accordance with the Declaration of Helsinki, all procedures were carried out with the adequate understanding and written consent of the participants. Participants received monetary compensation (€15). The investigation was approved by the ethics committee of the Institute of Psychology, Jagiellonian University (approval no. KE/21_2022). Participants reported a similar frequency of use of reappraisal and distraction strategies in their daily life (see Procedure for details).

Due to a technical problem, EMG data were not collected for one participant. There was also a problem with triggers for another participant, who had to be excluded from both the EMG and EEG data sets. Data were thus available for 62 and 61 participants in the ERP and EMG analyses, respectively. As preregistered, in the ERP and EMG analyses, we included only those participants who had enough trials (min. 12 for the ERP and 9 for the EMG) in the relevant conditions to reliably measure ER effects on the LPP (Moran et al., 2013) and corrugator activity (Urry, 2010). The exact numbers of participants included per condition and analysis are reported in Table S1.

2.2 | Stimuli

Two hundred negative ($M_{valence} = 2.7$, $SD_{valence} = 0.8$) and arousing ($M_{arousal} = 6.2$, $SD_{arousal} = 0.8$) pictures derived from standardized pictorial databases (IAPS; Lang et al., 2008, NAPS; Marchewka et al., 2014, EmoPics; Wessa et al., 2010) were used. Pictures were divided into high and low reappraisal affordance categories (see Figure 1a for examples), based on subjective reappraisal difficulty and efficacy ratings (i.e., how easy/difficult it was to reinterpret the picture and how effective/ineffective the reinterpretation was), which was determined in a two-part online pilot study (part 1: $N_{subject} = 61$; part 2: $N_{subject} = 52$) with different participants (see preregistration for details). The content of high affordance pictures included predominantly sad, angry, or suffering people, weapon attacks, dangerous/predatory animals, surgical procedures, and minor accidents/wounds. The content of low affordance pictures included mostly mutilated bodies, animal abuse, deadly accidents, and catastrophes. The two picture categories were further divided into two equal sets ($n = 50$ pictures per set), one for each instructed strategy. Between categories all sets were equated for normative arousal, and within each category additionally for reappraisal difficulty and efficacy. Results of our behavioral pilot study ($N_{subject} = 22$, see preregistration) showed that these reappraisal affordance categories induced switch decisions in the intended direction, that is, from reappraisal to distraction for low affordance and from distraction to reappraisal for high affordance pictures. Picture codes as well as individual affordance ratings of high and low affordance pictures are included in the Supplemental Material (Stimuli, Table S2).

To avoid low-level visual effects on EEG measures, all pictures were resized to 840×640 pixels, and equalized for luminance and contrast using the SHINE toolbox (Willenbockel et al., 2010). The luminance equalization was performed separately for each RGB layer (converted

[1] Because of planned EEG source reconstruction analyses, which will be reported elsewhere, we recruited participants who had an anatomical brain scan from their past participation in an (f)MRI study at Jagiellonian University.

to the LAB color space), after which the layers were recombined to form a RGB color picture. Finally, wavelet analysis (Delplanque et al., 2007) was performed to confirm that picture sets did not differ statistically in high (above 128 cycles/picture) and low (below 32 cycles/picture or less) spatial frequencies.

2.3 | Emotion regulation strategy switching task

During this task, participants watched and then down-regulated their emotional responses to high and low affordance pictures using one of two instructed ER

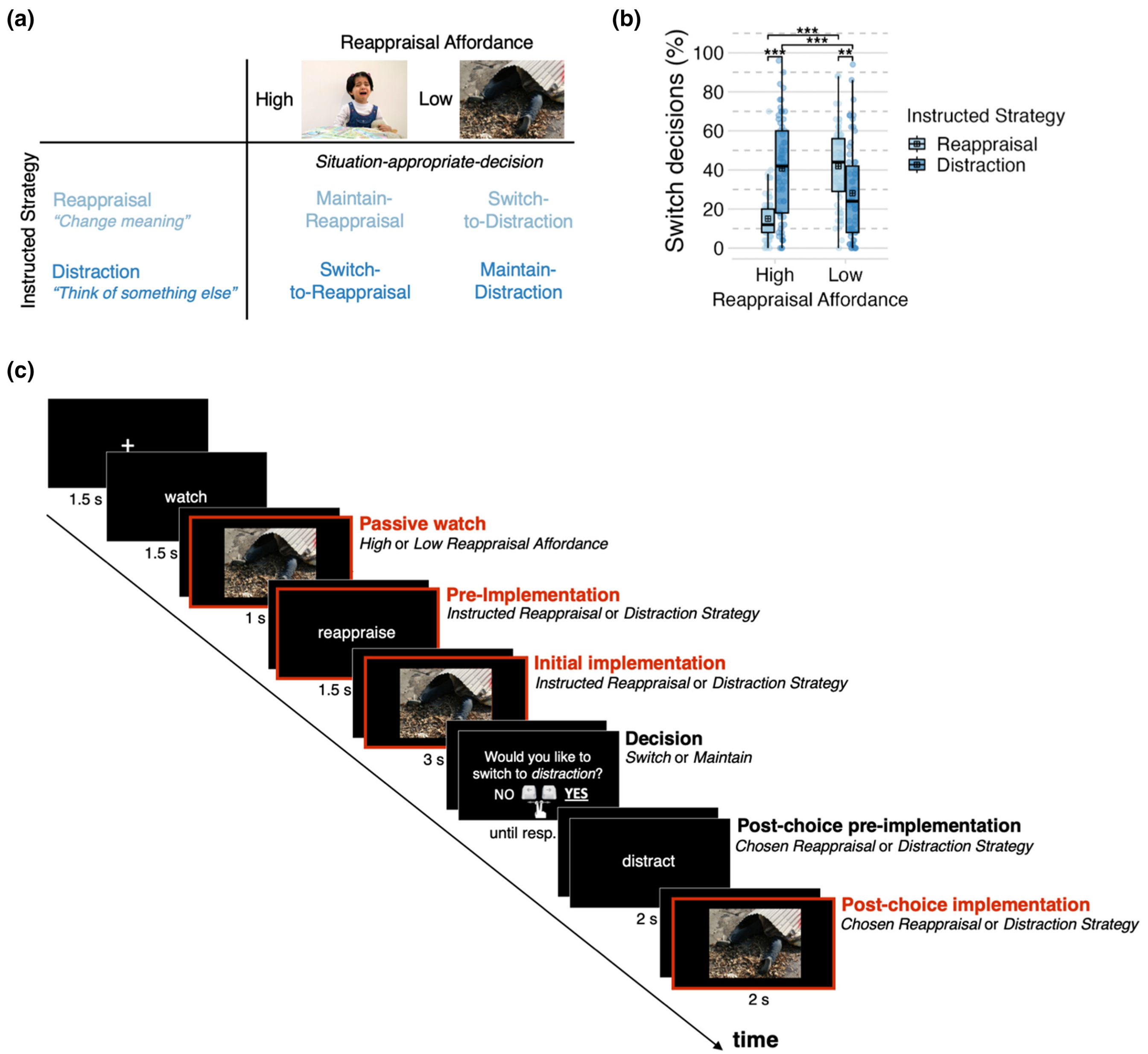

FIGURE 1 Emotion regulation strategy switching task. (a) Manipulation of reappraisal affordances: High affordance pictures were expected to evoke maintain-reappraisal and switch-to-reappraisal decisions, whereas low affordance pictures maintain-distraction and switch-to-distraction decisions. (b) Reappraisal affordance induced the expected switching between ER strategies (see a). Boxplots show the significance of simple effects comprising a significant Instructed Strategy × Reappraisal Affordance interaction. Squares inside the box indicate the mean; individual results are shown as a scatterplot along the whisker. ***$p < .0001$, **$p < .001$. (c) Emotion regulation strategy switching task: A sample trial structure. Presentation duration of the pictures and instruction was fixed. Duration of the fixation cross varied between 1.25–1.75 s ($M = 1.5$ s). Inter-stimulus intervals (blank screen) varied between 0.3 and 0.7 s ($M = 0.5$ s). Red box and font color indicate trial phases used for the calculation of the picture-locked LPP amplitudes (passive watch, initial implementation, and post-choice implementation phases) and the cue-locked SPN amplitudes (pre-implementation phase). In compliance with copyright laws, the pictures used here are similar but not identical to those presented in this study.

strategies: reappraisal or distraction. After that, they decided to *maintain* or *switch* strategies and then they implemented the chosen strategy. Each trial consisted of several phases (Figure 1c): Concretely, the trial started with a fixation cross (1.25–1.75 s), followed by an instruction cue "Watch" (1.5 s), and a picture of high or low reappraisal affordance level (*passive watch phase*; 1 s). Next, an instruction cue was presented ("Reappraise" or "Distract," *pre-implementation phase*; 1.5 s), which instructed participants to prepare for the implementation of the *instructed* strategy. After that, the previously seen picture was presented (*initial implementation phase*; 3 s), and participants' task was to downregulate their emotional response to the picture using the *instructed* (reappraisal or distraction) strategy. This was followed by a decision screen (*decision phase*; until response), where participants decided to either "maintain" the instructed strategy or "switch" to the alternative strategy. Next, an instruction cue was presented ("Reappraise" or "Distract," *post-choice pre-implementation*; 2 s), which depended on their decision. This cue signaled to participants that they should prepare for the implementation of the *chosen* strategy. Finally, the picture was presented a third time (*post-choice implementation phase*; 2 s), and participants' task was to downregulate their emotional response to the picture using the *chosen* (reappraisal or distraction) strategy. Before and after each cue and stimulus, a blank screen was presented (0.3–0.7 s) for baseline measurements.

Importantly, in this task, implicit manipulation of reappraisal affordances was used to induce switch decisions (i.e., participants were not informed whether the stimulus would be of high or low reappraisal affordance). This ensured that participants had to rely on *internal monitoring* of their affective states (and/or their individual assessment of the stimulus features) rather than *external information* about the stimulus that was provided in some previous studies to manipulate ER strategy preferences (see Dorman Ilan et al., 2019; Shafir et al., 2015).

We manipulated two within-subject factors: Instructed Strategy (distraction, reappraisal) and Reappraisal Affordance (high, low). The third factor, Decision (switch, maintain), depended on the participant's choice. One picture set of each affordance category was randomly assigned to each strategy (e.g., sets High-1 and Low-1 to reappraisal, sets High-2 and Low-2 to distraction). Strategy-set assignment was counterbalanced across participants. The order of trials was pseudo-randomized for each participant, with no more than three consecutive trials of the same type (i.e., a combination of Instructed Strategy and Reappraisal Affordance).

2.4 | Procedure

Upon arrival, participants received detailed task instructions on how to downregulate their emotional responses (negative affect and emotional arousal) using reappraisal and distraction. We used a situation-focused reappraisal strategy which involves engaging attention to the pictures to change their affective meaning to a more neutral one (see also Adamczyk et al., 2023; Dorman Ilan et al., 2019; Shafir et al., 2015, 2016). Participants were instructed to think of the depicted situation as being less negative than it initially seemed, or to think that the situation would end well (despite looking bad or dangerous). Participants were asked not to use reality challenge reappraisals (i.e., interpret emotional events as fake; McRae et al., 2012) as this form of reappraisal relies less on the processing content of the stimulus which makes it more similar to distraction (Sheppes et al., 2014). For distraction, participants were instructed to disengage attention by thinking of something neutral and unrelated to the picture, such as walking around the neighborhood or performing neutral daily activities or household chores, while keeping their eyes on the picture. In the passive watch phase, participants were instructed to allow natural thoughts and feelings to arise while looking at the pictures. Instructions were adapted from Sheppes et al. (2014). After these instructions, participants completed several experimenter-guided trials (min. 4, but the exact number depended on each participants' task understanding), during which they implemented each strategy out loud. It was explained to participants that they should try switching to an alternative strategy (after initial implementation of the instructed strategy) if they failed to perform the strategy, or if they felt the current strategy was not effective in downregulating their negative arousal, or if they preferred to use the other strategy. Then, participants performed nine practice trials by themselves to familiarize them with the procedure timing. During the practice trials, participants were asked to monitor the efficacy of reappraisal and distraction and to try out switching from one strategy to another. They were also reminded not to close or avert their eyes away from the screen when viewing the pictures. After that, sensors were attached. Before starting the experimental procedure, we collected a 3D scan of electrode positions. Testing was conducted in a dimly lit, sound-attenuated, air-conditioned EEG cabin. After completion of the experimental task, participants completed a short 6-item version of the Regulation of Emotion Survey (RESS; De France & Hollenstein, 2017), a questionnaire measuring the frequency of use of reappraisal (three items) and distraction (three items) strategies in daily life (Cronbach's Alpha for reappraisal = .78; Cronbach's alpha for distraction = .81). Questionnaire statements were rated on a 5-point Likert scale (1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5 = always) and scores could thus range from 3 (no use) to 15 (very frequent use) for each strategy. Control analyses showed that participants reported habitual use of both reappraisal ($M = 7.7$, $SD = 2.0$) and distraction ($M = 8.2$, $SD = 2.5$) strategies in their daily life, with no significant difference between the two strategies, $t(62) = 1.16$, 95% CI [−0.4, 1.3], $p = .25$, $d = 0.15$. After the RESS, participants were debriefed, compensated, and thanked for their participation in the study.

Several measures were taken to maximize task adherence. First, all participants were informed in advance that the study would involve viewing highly negative and arousing pictures. Second, during training, participants were explicitly instructed not to avert their eyes away from the screen when viewing the pictures, and this was continuously monitored by the research assistants via an online camera. Third, participants were extensively trained in the use of both strategies, and it was verified during the training whether participants found the task feasible within the allotted time (all participants confirmed that it was). Finally, there was a longer break (self-paced) after the completion of the first half of the task. During this break, we verified again whether participants managed to perform the task and rewarded participants with a surprise snack. This gesture aimed to promote task compliance and prolong engagement with the task.

The experimental task lasted ~60 min and consisted of 200 trials, separated by a 1-min break after every 50 trials. The task was administered on a computer equipped with a 61 cm (24 inch) full-HD (i.e., 1920 × 1080 pixels) resolution LED monitor at a viewing distance of approximately 60 cm and 50° of horizontal visual angle. The pictures were presented full screen. PsychoPy software, version v2021.1.4 (Peirce et al., 2019), was used to control the presentation and timing of stimuli.

2.5 | Electrophysiological data recording

EEG and EMG signals were recorded using the BioSemi ActiveTwo system (BioSemi, Amsterdam, the Netherlands) with ActiView software. Continuous EEG was recorded from 64 electrodes based on the extended 10/20 system, using an ECI Electrocap, as well as two electrodes placed on the left and right mastoids. Vertical and horizontal eye movements were recorded with electrodes placed supra- and infra-orbitally at the right eye and on the left versus right orbital rim. The common mode sense active electrode and the driven right leg passive electrode formed the amplifier reference during recording. The EMG signal was recorded from the *Corrugator supercilii* (frown muscles) using Ag/AgCl electrodes with saline-based electrode gel and a bipolar placement according to the guidelines provided by Fridlund and Cacioppo (1986). All signals were sampled at 1024 Hz.

2.6 | EEG: Preprocessing, data reduction, and analysis

The EEG data was processed and analyzed using FieldTrip-based custom routines (Oostenveld et al., 2011). Offline, the signal was re-referenced to the average activity of the two mastoid electrodes. Then, the signal was filtered in a range of 0.1 and 48 Hz with windowed sinc finite impulse filters (high-pass filter order: 8448; low-pass filter order: 33792), downsampled to 256 Hz, and segmented into epochs 200 ms before picture onset until the end of the picture presentation (duration 1000, 3000, or 2000 ms for the passive watch, initial implementation, and post-choice implementation phases, respectively). Baseline correction was performed for each trial using the 200 ms prior to picture onset. Trials containing EOG artifacts (such as eye-movements or blinking) were corrected with the Automated Artifact Removal (AAR) toolbox (Gomez, 2007). Bad channels were detected using IQR-based extreme outliers rejection algorithm (threshold for channel variance set to Q1/Q3 ± 5 IQR), calculated from EOG-corrected signals. If noisy channels were discovered, their signal was estimated by interpolation based on the weighted signal of the neighboring channels. Channel interpolation was allowed for the max. of eight channels per data set. Trial-based artifact rejection consisted of extreme outlier removal based on variance (threshold set to Q1/Q3 ± 3 IQR), maximum voltage difference between any two samples in the epoch (not exceeding 300 μV), and muscle artifact identification (based on elevated spectral power in a 35–47 Hz frequency). If more than one third of all trials were removed, the respective participant would have been excluded from the analysis, but this was never necessary. Grand-averaged waveforms were computed for the passive watch, initial implementation, and post-choice implementation phases as a function of instructed strategy and decision and instructed strategy and reappraisal affordance. For the initial and post-choice implementation phases grand-averaged waveforms were also computed as a function of reappraisal affordance, instructed strategy, and decision. The number of artifact-free trials in the strategy × decision analyses ranged between 29 and 65 per condition, depending on the trial phase. In the strategy × affordance analyses, they ranged between 43 and 46 per condition, and in the strategy × decision × affordance analyses between 24 and 38 per condition (see Tables S3–S5 for details). The LPP was measured from the preregistered centro-parietal electrodes CPz, CP1, and CP2 (see also Dorman Ilan et al., 2019; Shafir et al., 2016; Thiruchselvam et al., 2011). To exclude the P3 from the LPP time-window, the start of the LPP was determined by inspecting the grand average waveform for this electrode cluster during the initial implementation phase (see Figure S1). Specifically, we took the local minimum after the P3-peak and before the LPP-peak as a starting point for the early LPP time-window (Adamczyk et al., 2023). The LPP was quantified as the average activity measured from this starting point (i.e., 450 ms after picture onset) until the end of picture presentation, that is, up to 1000, 3000, or 2000 ms for the passive watch, initial implementation, and post-choice implementation phases, respectively. The SPN was measured from the Pz electrode following a previous study that examined ER anticipatory activity (Shafir et al., 2015) and was quantified as the average activity from 900 ms after strategy instruction onset until the end of the instruction presentation (strategy pre-implementation phase). Topographical maps (see Figure 2d) confirmed that the effect we observed was most evident in parietal electrodes. This is in line with Shafir et al. (2015), as well as with other studies that measured the SPN to instruction cues conveying information about an upcoming task (van Boxtel & Böcker, 2004). It differs from the frontal/−central distribution which is typically observed in the anticipation of affective (vs. non-affective) stimuli (Brunia et al., 2012; van Boxtel & Böcker, 2004), which may be the result of different task demands (van Boxtel & Böcker, 2004).

2.7 | EMG: Pre-processing, data reduction and analysis

The bipolar EMG signal was calculated by taking the difference between the two EMG electrodes. This signal was then filtered in a range of 20–400 Hz with a Butterworth two-pass zero-phase IIR filter (order: 9, window type: Hamming), and a discrete Fourier transform filter (to remove the 50 Hz line noise and 100 and 150 Hz harmonics), rectified (by taking the absolute values), smoothed with a 20-Hz low-pass filter, and downsampled to 512 Hz. These steps were implemented in FieldTrip (Oostenveld et al., 2011). We quantified the amplitude of the corrugator activity as percentage of signal change compared to the mean baseline activity, ([post-stimulus − baseline] × 100/baseline; van Boxtel, 2010). The baseline and post-stimulus time-windows were the same as for the EEG analyses.

2.8 | Statistical analysis

As preregistered, the behavioral and electrophysiological data were analyzed with a frequentist (generalized) linear mixed-effects model approach (G/LMM), using lmer (for continuous dependent variables [DV] and glmer [for model diagnostics for binary DV]) functions of the lme4 package, version 1.1.31 (Bates et al., 2015), and the function mixed of the afex package, version 1.2.0 (for Type III Likelihood Ratio Tests for the binary DV; Singmann et al., 2022) implemented in R, version 4.2.2 (R Core Team, 2021). Because the psychophysiological data were aggregated over trials to increase the signal-to-noise ratio, the averaged LPP and corrugator amplitudes per condition were included as *dependent variables* in the analyses, and the conditions (Instructed Strategy × Decision) as *predictors*. Hence, if LPP and corrugator amplitudes (in the phases preceding the decision: passive watch, pre-implementation, or initial strategy implementation) predict switch decisions, this is reflected in the amplitude differences between switch versus maintain trials.

We followed the approach of fitting maximal models (Barr et al., 2013), that is, including all random intercepts, slopes, and correlations justified by the experimental design (model descriptions are provided in the results below). Although all models converged, for some models, there was a "singular fit" warning, indicating that these models might have been overfitted (see Table 1 for details). It is important to note, however, that the lmer4 package might yield more *false positive* singularity warnings than other multilevel modeling packages (McCoach et al., 2018). Nonetheless, as a robustness check, we also report results for Bayesian full-random effect (G)LMMs, calculated with the function brm of the package brms, version 2.18.0 (Bürkner, 2018) implemented in R (R Core Team, 2021). The critical alpha level for determining statistical significance for a frequentist (G)LMM effect was $p < .05$ (corrected for multiple comparisons for post hoc tests using FDR correction). 95% credible intervals (CIs) not containing zero were used to determine significance of Bayesian (G)LMM effects. Cohen's *d* and parameter estimates are reported to present the magnitude of effects. Details concerning packages and functions used are included in the Supplemental Material. We report results for full-random effect (G)LMMs, excluding outliers identified with df betas and cooks' distances (as preregistered). Data and analysis code have been made publicly available at the OSF and can be accessed at https://osf.io/uz2g9/.

3 | RESULTS

3.1 | Manipulation check

3.1.1 | Reappraisal affordances: Effects on switch decisions and strategy efficacy

The mean percentage of switch decisions was 31.5% (*SD* = 13.3%). As predicted (H1), switch decisions were influenced by reappraisal affordance: Participants switched more often to distraction and less often to reappraisal for low (vs. high) affordance pictures. In line with H2, distraction was more effective than reappraisal at the neural and peripheral physiological level, regardless of picture affordance (contrasting H3; see Table S6 and Figure S2 and Figure 1a,b in the main text). Taken together, our manipulation of reappraisal affordance successfully induced adaptive switch decisions, independent of initial psychophysiological strategy efficacy.

3.2 | Psychophysiological predictors of switching

3.2.1 | Passive watch phase: Initial response to the stimulus

We next tested whether increased psychophysiological responses to initial picture presentation predict distraction choices (i.e., switching and maintaining distraction; H4).

Late positive potential

In line with H4, the Instructed Strategy × Decision interaction for the LPP amplitude was significant, $F(1, 55.7) = 5.08$, $p = .028$, $d = 0.62$. Post hoc comparisons by Strategy showed that the initial LPP in response to the pictures was enhanced in trials where participants decided to switch to distraction (vs. maintain reappraisal), $b = 1.17$, $SE = 0.39$, $t(98.6) = 3.02$, $p_{FDR} = .019$, $d = 0.66$, 95% CI [0.22, 1.10]. On the other hand, when the instructed strategy was distraction, initial LPP amplitudes did *not* predict switch decisions to reappraisal (vs. maintain distraction), $b = 0.03$, $SE = 0.40$, $t(107) = 0.08$, $p_{FDR} = .94$, $d = 0.02$, 95% CI [−0.43, 0.47] (see Table 1 and Figure 2a,b).

Corrugator supercilii

There was a significant Instructed Strategy × Decision interaction on the corrugator amplitude, $F(1, 54.4) = 14.9$, $p < .0004$, $d = 0.78$ (Table 1 and Figure 2c). Post hoc comparisons showed that, in line with LPP results, corrugator activity in response to the pictures was enhanced in trials where participants decided to switch to distraction (vs. maintain reappraisal), $b = 1.92$, $SE = 0.57$, $t(101) = 3.36$, $p_{FDR} = .003$, $d = 0.65$, 95% CI [0.26, 1.04]. When the instructed strategy was distraction, switching to reappraisal (vs. maintaining distraction) was not associated with significantly increased corrugator activity, $b = -1.27$, $SE = 0.61$, $t(109.1) = -2.08$, $p_{FDR} = .079$, $d = -0.43$, 95% CI [−0.84, −0.02].

Summary

Switching *from reappraisal to distraction* was predicted by an increased psychophysiological response to the stimulus when viewing the stimulus for the first time.

3.2.2 | Pre-implementation phase: Anticipatory regulatory effort

We next explored whether increased anticipatory effort (SPN and corrugator) during the pre-implementation phase predict switch decisions.

Stimulus preceding negativity

There was a significant Instructed Strategy × Decision interaction, $F(1, 55.9) = 5.11$, $p = .028$, $d = -0.44$. Post hoc pairwise comparisons showed that more negative SPN amplitudes (i.e., more anticipatory regulatory effort) were predictive of switching to distraction (vs. maintaining reappraisal), $b = -0.99$, $SE = 0.40$, $t(99.8) = -2.51$, $p_{FDR} = .020$, $d = -0.50$, 95% CI [−0.90, −0.10], but not of switching to reappraisal (vs. maintaining distraction), $b = 0.28$, $SE = 0.41$, $t(108.5) = 0.67$, $p_{FDR} = .51$, $d = 0.14$, 95% CI [−0.27, 0.55]. Furthermore, there was also a significant main effect of Instructed Strategy, $F(1, 59.4) = 22.6$, $p < .00002$, $d = -1.19$, showing overall more negative SPN amplitudes before implementing reappraisal versus distraction (see Table 1 and Figure 2d,e).

Corrugator supercilii

There were no significant effects of instructed strategy and decision on the corrugator activity (see Table 1 and Figure 2f).

Summary

Overall, anticipated implementation of reappraisal was associated with more negative SPN amplitudes than anticipated distraction. Furthermore, more negative SPN amplitudes were predictive of the decision to switch to distraction (vs. maintain reappraisal).

3.2.3 | Initial implementation phase: Strategy efficacy

We tested our main hypothesis of interest, namely that relatively reduced strategy efficacy during initial strategy implementation would predict switch decisions (H5), especially for reappraisal (H6).

Late positive potential

In contrast to H5, the main effect of Decision was not significant, $F(1, 55.5) = 0.08$, $p = .77$, $d = 0.06$. In line with H6, we observed a significant Instructed Strategy × Decision interaction, $F(1, 56.1) = 5.06$, $p = .028$, $d = -0.43$ (see Table 1 and Figure 2g,h). Pairwise comparisons by decision showed an overall advantage of distraction over reappraisal: The LPP amplitudes were downregulated more strongly before participants decided to switch to distraction versus switch to reappraisal, $b = 1.0$, $SE = 0.42$, $t(136) = 2.39$, $p_{FDR} = .027$, $d = 0.56$, 95% CI [0.09, 1.03], and before they decided to maintain distraction versus maintain reappraisal, $b = 2.13$, $SE = 0.37$, $t(117) = 5.72$, $p_{FDR} < .0001$, $d = 1.20$, 95% CI [0.77, 1.63]. However, there were no significant differences in the LPP amplitudes between switch versus maintain decisions by instructed strategy: For reappraisal, $b = -0.48$, $SE = 0.35$, $t(102) = -1.40$, $p_{FDR} = .17$, $d = -0.27$, 95% CI [−0.66, 0.12], or distraction, $b = 0.65$, $SE = 0.36$, $t(110) = 1.81$, $p_{FDR} = .087$, $d = 0.37$, 95% CI [−0.04, 0.77]. This indicates that switch decisions were not predicted by a reduced neural efficacy of the implemented strategy.

Corrugator supercilii

In line with H5, but in contrast to the LPP results above, we did observe a significant main effect of Decision on corrugator activity, $F(1, 56.8) = 6.45$, $p = .014$, $d = 0.62$. Switch (vs. maintain) decisions were predicted by increased peripheral physiological responses (i.e., less effective emotional downregulation), independent of the instructed strategy. Instructed Strategy × Decision interaction was not significant, $F(1, 56.3) = 2.48$, $p = .12$, $d = 0.31$ (see Table 1 and Figure 2i).

Summary

Switching was predicted by reduced efficacy of the instructed strategies in downregulating peripheral physiological (but not neural) responses.

3.3 | Psychophysiological consequences of switching

3.3.1 | Post-choice versus initial implementation: Effects by decision and strategy

Finally, we investigated the psychophysiological (LPP and corrugator) consequences of switch decisions. To this end, we fitted a model including the Instructed Strategy and Decision as predictors of the *difference* in the LPP and corrugator amplitudes between the post-choice and initial implementation phases (i.e., Δ LPP or Δ corrugator). A negative value of this difference indicates a lower amplitude (more downregulation) of the LPP or corrugator post-choice.

Δ Late positive potential

In line with H7, we observed a significant Instructed Strategy × Decision interaction on the Δ LPP, $F(1, 57.4) = 39.1$, $p < .00001$, $d = -1.18$ (see Table 1 and Figure 2j,k). Post hoc comparisons of decision by strategy showed that switching from reappraisal to distraction resulted in a *lower* Δ LPP, that is, *more downregulation*, than maintaining reappraisal (−3.17 vs. −0.75 μV), $b = -2.33$, $SE = 0.44$, $t(102.7) = -5.27$, $p_{FDR} < .0001$, $d = -1.04$, 95% CI [−1.44, −0.63]. In contrast, switching from distraction to reappraisal resulted in a *higher* Δ LPP, that is, *less downregulation*, than maintaining distraction (1.09 vs. −0.63 μV), $b = 1.65$, $SE = 0.47$, $t(107.8) = 3.56$, $p_{FDR} = .0007$, $d = 0.73$, 95% CI [0.32, 1.15]. Interestingly, maintaining reappraisal and maintaining distraction both resulted in a negative Δ LPP, that is, stronger downregulation post-choice compared to initial implementation, with *no* significant difference between the two strategies, $b = -0.14$, $SE = 0.42$, $t(98.3) = -0.32$, $p_{FDR} = .75$, $d = -0.06$, 95% CI [−0.43, 0.31]. Finally, switching to distraction resulted in a *lower* Δ LPP, that is, *more downregulation*, than switching to reappraisal (−3.17 vs. 1.09 μV), $b = -4.12$, $SE = 0.49$, $t(119.6) = -8.45$, $p_{FDR} < .0001$, $d = -1.83$, 95% CI [−2.29, −1.36].

Δ Corrugator

In contrast to H7, the Instructed Strategy × Decision interaction was not significant for the Δ corrugator, $F(1, 56.7) = 1.11$, $p = .30$, $d = -0.20$ (see Table 1 and Figure 2l). However, we observed a significant main effect of Instructed Strategy, $F(1, 57.2) = 12.9$, $p < .0007$,

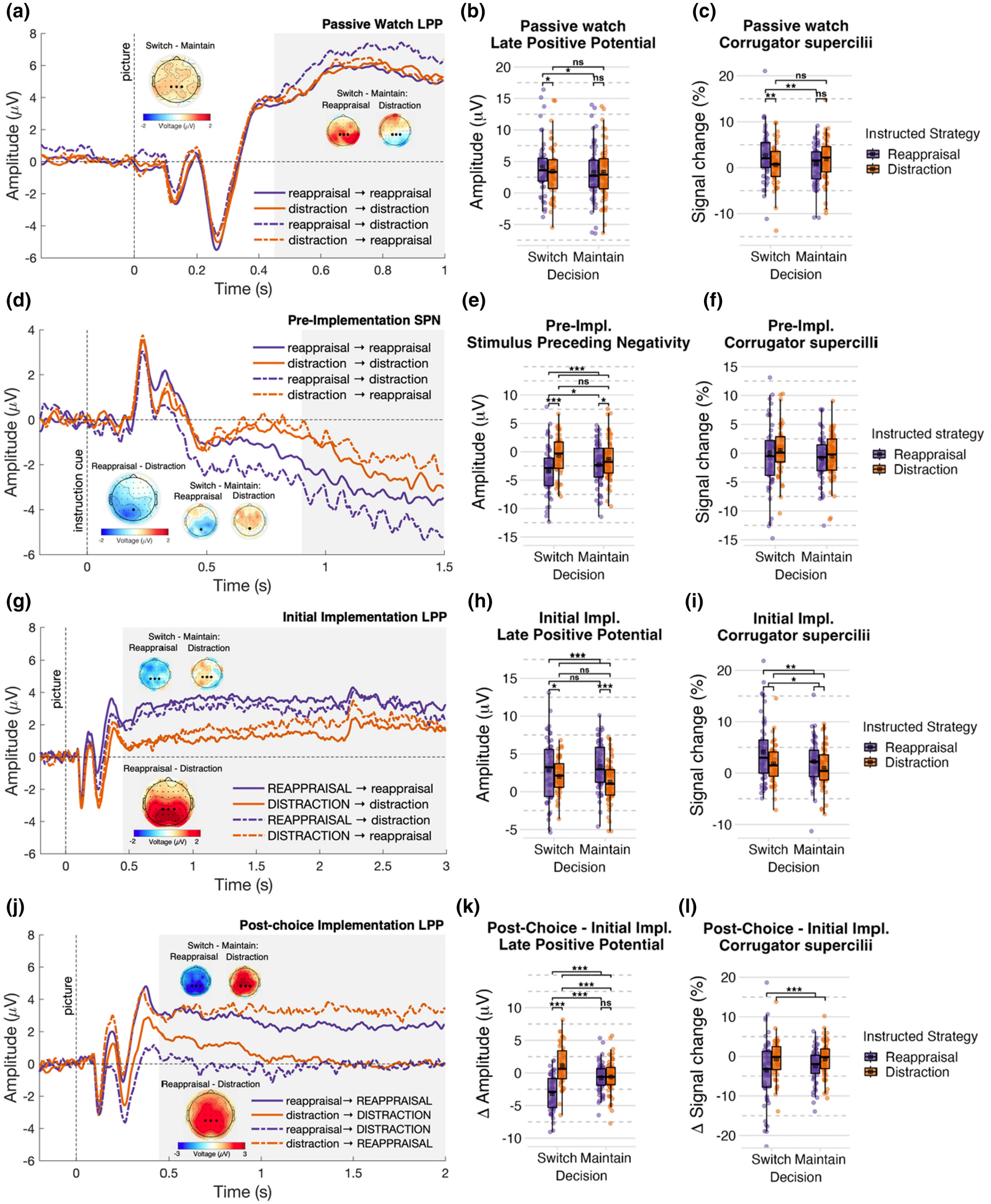
(a)
Passive Watch LPP
Switch - Maintain
picture
Switch - Maintain:
Reappraisal Distraction
reappraisal → reappraisal
distraction → distraction
reappraisal → distraction
distraction → reappraisal
Amplitude (μV)
Time (s)
(b)
Passive watch
Late Positive Potential
Amplitude (μV)
Switch Maintain
Decision
(c)
Passive watch
Corrugator supercilii
Signal change (%)
Switch Maintain
Decision
Instructed Strategy
Reappraisal
Distraction
(d)
Pre-Implementation SPN
reappraisal → reappraisal
distraction → distraction
reappraisal → distraction
distraction → reappraisal
instruction cue
Reappraisal - Distraction
Switch - Maintain:
Reappraisal Distraction
Amplitude (μV)
Time (s)
(e)
Pre-Impl.
Stimulus Preceding Negativity
Amplitude (μV)
Switch Maintain
Decision
(f)
Pre-Impl.
Corrugator supercilii
Signal change (%)
Switch Maintain
Decision
Instructed strategy
Reappraisal
Distraction
(g)
Initial Implementation LPP
Switch - Maintain:
Reappraisal Distraction
picture
Reappraisal - Distraction
REAPPRAISAL → reappraisal
DISTRACTION → distraction
REAPPRAISAL → distraction
DISTRACTION → reappraisal
Amplitude (μV)
Time (s)
(h)
Initial Impl.
Late Positive Potential
Amplitude (μV)
Switch Maintain
Decision
(i)
Initial Impl.
Corrugator supercilii
Signal change (%)
Switch Maintain
Decision
Instructed Strategy
Reappraisal
Distraction
(j)
Post-choice Implementation LPP
Switch - Maintain:
Reappraisal Distraction
picture
Reappraisal - Distraction
reappraisal→ REAPPRAISAL
distraction → DISTRACTION
reappraisal→ DISTRACTION
distraction → REAPPRAISAL
Amplitude (μV)
Time (s)
(k)
Post-Choice - Initial Impl.
Late Positive Potential
Δ Amplitude (μV)
Switch Maintain
Decision
(l)
Post-Choice - Initial Impl.
Corrugator supercilii
Δ Signal change (%)
Switch Maintain
Decision
Instructed Strategy
Reappraisal
Distraction

FIGURE 2 Psychophysiological predictors and consequences of switching: Instructed Strategy × Decision effects. Grand average waveforms, topographical maps, and boxplots as a function of Instructed Strategy and Decision. In the grand average waveforms, line type indicates decision (Solid = Maintain; Dashed = Switch), and colors (Purple = Reappraisal; Orange = Distraction) as well as uppercase letters in the legend indicate the strategy used in the depicted trial phase. The *x*-axis runs from 200 ms prior to picture (or instruction cue) onset to the end of the end of the picture (or instruction cue) presentation. Shaded gray areas indicate the time-windows used for statistical analyses. In the topographical maps, electrode clusters used for calculating mean amplitudes are marked in black. Note that waveforms in J represent post-choice implementation LPP amplitudes *without* subtracted initial implementation LPP amplitudes. Boxplots show the amplitudes used for statistical analysis. Squares inside the box indicate the mean, individual results are shown as a scatterplot along the whisker. Note that boxplots K and L display the *difference* between post-choice and initial implementation phases (Δ), such that negative scores mean that the LPP or corrugator activity *decreased* in the post-choice compared to initial implementation phase, suggesting *more downregulation* of the affective response. ***$p < .001$, **$p < .01$, and *$p < .05$, ns, non-significant.

TABLE 1 Psychophysiological predictors and consequences of switching: Instructed Strategy × Decision effects.

		Frequentist LMM				Bayesian LMM		
Measure	**Fixed effect**	***dfs***	***F***	***p***	***d***	***B***	***SE***	**95%CI**
Passive Watch LPP	Strategy	1, 58.2	2.89	.094	0.43	0.24	0.14	−0.04, 0.51
	Decision	1, 55.8	3.93	.052	0.53	0.30	0.15	−0.00, 0.60
	Strategy × Decision	1, 55.7	5.08	**.028**	0.62	0.28	0.14	**0.02, 0.55**
Passive Watch corrugator[a]	Strategy	1, 54.6	1.65	.20	0.23	0.27	0.22	−0.16, 0.69
	Decision	1, 54.6	0.60	.44	0.17	0.17	0.22	−0.26, 0.59
	Strategy × Decision	1, 54.4	14.9	**<.0004**	0.78	0.79	0.21	**0.39, 1.21**
Pre-Implementation SPN[a]	Strategy	1, 59.4	22.6	**<.00002**	−1.19	−0.82	0.17	**−1.15, −0.49**
	Decision	1, 55	1.55	.22	−0.25	−0.19	0.15	−0.48, 0.11
	Strategy × Decision	1, 55.9	5.11	**.028**	−0.44	−0.32	0.15	**−0.60, −0.03**
Pre-Implementation corrugator[a]	Strategy	1, 57.3	0.45	.50	−0.17	−0.19	0.28	−0.75, 0.37
	Decision	1, 57	2.70	.11	0.39	0.44	0.28	−0.11, 0.96
	Strategy × Decision	1, 56.3	0.00	1.0	−0.00	−0.00	0.23	−0.47, 0.45
Initial Implementation LPP[a]	Strategy	1, 59.6	26.4	**<.0001**	1.30	0.78	0.15	**0.48, 1.09**
	Decision	1, 55.5	0.08	.77	0.06	0.04	0.13	−0.20, 0.29
	Strategy × Decision	1, 56.1	5.06	**.028**	−0.43	−0.28	0.13	**−0.54, −0.04**
Initial Implementation corrugator[a]	Strategy	1, 57.4	12.3	**<.001**	0.88	1.01	0.29	**0.44, 1.58**
	Decision	1, 56.8	6.45	**.014**	0.62	0.69	0.28	**0.14, 1.23**
	Strategy × Decision	1, 56.3	2.48	.12	0.31	0.34	0.23	−0.12, 0.80
Δ LPP[a]	Strategy	1, 58.1	43.6	**<.00001**	−1.39	−1.07	0.17	**−1.40, −0.74**
	Decision	1, 55.1	1.12	.29	−0.19	−0.17	0.17	−0.50, 0.15
	Strategy × Decision	1, 57.4	39.1	**<.00001**	−1.18	−1.00	0.16	**−1.31, −0.69**
Δ corrugator[a]	Strategy	1, 57.2	12.9	**<.0007**	−0.83	−1.22	0.35	**−1.92, −0.51**
	Decision	1, 57	0.69	.41	−0.19	−0.29	0.35	−0.98, 0.41
	Strategy × Decision	1, 56.7	1.11	.30	−0.20	−0.30	0.30	−0.90, 0.29

Note: Factors were coded using sum-to-zero contrast coding: Instructed Strategy: Reappraisal/Distraction = 1/−1; Decision: Switch/Maintain = 1/−1. Δ: Post-Choice minus Initial Implementation. Bolded font indicates statistically significant results.

[a] Models for which there was a "singular fit" warning.

$d = -0.83$, showing that starting with reappraisal (vs. distraction) as an instructed strategy was associated with a *lower* Δ corrugator, that is, more downregulation post-choice compared to initial implementation, regardless of the subsequent (switch-to-distraction or maintain-reappraisal) decision.

Summary

These results show that, for the LPP, *switching to distraction improved*, whereas *switching to reappraisal impaired* post-choice regulatory effects compared to maintaining reappraisal and maintaining distraction, respectively. For the corrugator, however, starting with reappraisal was overall more effective than starting with distraction, irrespective of subsequent decision.

3.3.2 | Moderation by reappraisal affordances

In contrast to H8, the psychophysiological consequences of switching were not moderated by reappraisal affordances (see Supplemental material, pp. 18–21). Specifically, maintaining distraction was more effective in downregulating post-choice compared to initial implementation amplitudes than switching from distraction to reappraisal, regardless of the picture reappraisal affordance (H8a). Moreover, maintaining distraction did *not* improve post-choice ER effects for low affordance pictures compared to maintaining reappraisal. In line with the results reported above, maintaining reappraisal *did* improve post-choice regulatory effects for the corrugator compared to maintaining distraction regardless of the picture category (H8b; see Table S7 and Figure S3).

4 | DISCUSSION

This study investigated the neural (LPP and SPN) and peripheral physiological (EMG corrugator activity) predictors and consequences of switching between reappraisal and distraction strategies. To induce adaptive switch decisions, we manipulated reappraisal affordances of high-intensity emotional stimuli (subjective reappraisal difficulty). We found that switch decisions were made in accordance with situational demands (reappraisal affordances) and were predicted by reduced peripheral physiological ER efficacy, which could be improved when participants switch to distraction. Below, we discuss the results in more detail.

Regarding psychophysiological *predictors* of switching, our results showed that switching was predicted by reduced efficacy in downregulating corrugator activity during initial implementation of the instructed strategy. This is partially in line with the extended process model of ER by Gross (2015), which suggests that participants monitor the effectiveness of their regulation attempt and alter their strategy if it does not yield the desired outcome. Our corrugator results replicate those by Birk and Bonanno (2016), who showed that reduced regulatory efficacy predicts switching from reappraisal *to distraction*. Moreover, we extend these results by showing that reduced ER efficacy can also predict switching from distraction *to reappraisal*. This novel finding suggests that when the strategy is less effective, which might be because it is situationally inappropriate, nonoptimal, or non-preferred (see Aldao et al., 2015; Bonanno & Burton, 2013), people might choose to change this strategy to a potentially more effective, optimal, or preferred strategy. In contrast to expectations, switching was not predicted by the neural strategy efficacy as indexed by the LPP. Corrugator activity has been proposed to reflect emotional *unpleasantness* (Urry, 2010), an interpretation that is further supported by our finding showing that low (vs. high) affordance pictures, which were equally arousing but happened to be *more unpleasant*, evoked stronger passive-watch corrugator (but not LPP) responses (see Table S6 and Figure S2a–c). In contrast, the LPP is thought to primarily reflect emotional *arousal* (Adamczyk et al., 2023; Hajcak & Foti, 2020). Although it is difficult to disentangle arousal from valence (as both are typically highly correlated), these results tentatively suggest that switching might have been predominantly motivated by reduced efficacy in downregulating negative affect.

In this study, switch decisions *from reappraisal to distraction* were also predicted by higher psychophysiological (LPP and corrugator) responses when passively watching the pictures for the first time, reflecting stronger emotional intensity, and by stronger anticipatory effort (SPN) for implementing reappraisal. These results extend the findings of Shafir et al. (2016) and Shafir et al. (2015), who showed that pre-implementation neural responses predict preferential *choices* for distraction over reappraisal. We show that these neural responses can also predict the *decision to switch* to distraction, after initial (instructed) reappraisal.

Notably, neither the passive-watch LPP nor the strategy pre-implementation SPN responses were predictive of switching *from distraction to reappraisal*. This suggests that switching to reappraisal was *not* motivated by emotional intensity or anticipated effort of implementing distraction. Possibly, switching to reappraisal was driven primarily by reappraisal affordance in this study, as shown by the reappraisal affordance by instructed strategy effects on switching. Furthermore, distraction was anticipated to be *overall less effortful* than reappraisal as shown by the main effect of strategy on the SPN and was *more effective* than reappraisal in downregulating both LPP and corrugator amplitudes during initial strategy implementation. Lower anticipated effort of implementing distraction and higher efficacy of distraction over reappraisal might explain why none of these neural responses predicted switch (vs. maintain) decisions for this strategy.

Moving to the psychophysiological *consequences* of switching: Replicating findings by Dorman Ilan et al. (2019), *switching to distraction improved*, whereas *switching to reappraisal impaired* post-choice regulatory effects compared to maintaining reappraisal and maintaining distraction, respectively. This reduced efficacy of reappraisal after switching might have been due to paradoxical effects of distraction, which prevents habituation to the stimulus and has been shown not only to *increase* the LPP amplitude upon stimulus re-encounter, as compared to reappraisal, but also to the passive watch condition (Paul et al., 2016; Thiruchselvam et al., 2011). For the corrugator, however, starting with reappraisal (i.e., maintaining reappraisal or switching to distraction) was overall more effective than starting with distraction, irrespective of the subsequent decision. Compared to distraction, reappraisal might be especially effective in downregulating *unpleasantness* (i.e., corrugator) rather than emotional arousal (i.e., the LPP). Indeed, in our previous study, reappraisal was more effective than distraction in downregulating (subjective) unpleasantness despite *weaker* and *later* downregulation of the LPP amplitudes (Adamczyk et al., 2023). Furthermore, previous evidence showed that reappraisal downregulated (subjective) unpleasantness more than (physiological) arousal, as measured with skin conductance response (Troy et al., 2018). This novel result suggests that first reappraising (or trying to reappraise—by engaging attention to and elaborating the content of) an emotional stimulus can boost the subsequent downregulation effects at the peripheral physiological level. Taken together, these findings suggest that switching can either *improve* (switching to distraction; LPP), *worsen* (switching to reappraisal; LPP), or *fail to change* (switching to reappraisal/distraction; corrugator) short-term ER effects, depending on the strategy and the types of outcomes assessed.

In line with the results reported above, maintaining reappraisal *improved* post-choice ER effects compared to maintaining distraction at the peripheral physiological level. Since distraction exerts early and strong ER effects (Adamczyk et al., 2023; Schönfelder et al., 2014; Shafir et al., 2015), there is less room for ER improvement when distracting from the stimulus a second time. On the contrary, since reappraisal exerts later and weaker ER effects, there is more room for improvement when reappraising the stimulus a second time. This immediate and stronger efficacy of distraction may explain why people motivated to obtain instantaneous (ER) benefits tend to overuse disengagement strategies such as distraction (King et al., 2018; Yoon & Rottenberg, 2020). Interestingly, our results showing stronger downregulation of corrugator activity post-choice when maintaining reappraisal (vs. maintaining distraction) provide new evidence that reappraisal efficacy might *improve* over time for high-intensity stimuli (for which reappraisal is generally *less* preferred; Sheppes et al., 2014). Future studies could test whether reappraisal could become as effective as distraction when more time is allotted for implementing each of these strategies.

Reappraisal affordance predicted adaptive switching between ER strategies (i.e., switch decisions to reappraisal for high affordance and to distraction for low affordance pictures). This supports the validity of our novel ER switching task. In contrast to our expectations, however, reappraisal affordance did *not* modulate the efficacy of reappraisal (nor distraction) at the psychophysiological level. Since the categorization of pictures as high/low in reappraisal affordance came from an independent sample of participants, it is possible that in the current sample, there was variability in the difficulty of reappraisal (between pictures) that was not fully captured by the affordance manipulation. Second, previous studies suggested that reappraisal effects reflect a joint influence of cognitive change (reinterpretation) and nonspecific cognitive factors (such as cognitive demand; Adamczyk et al., 2020, 2022; Wyczesany et al., 2022, 2024; Wyczesany & Ligeza, 2017). Since these nonspecific factors can reduce the LPP amplitudes irrespective of cognitive change (Adamczyk et al., 2022; Wyczesany & Ligeza, 2017), it is also possible that psychophysiological (LPP and corrugator) responses to low affordance pictures were downregulated during initial strategy implementation due to high cognitive demand associated with the generation of alternative interpretations of their meaning. To resolve these ambiguities, future studies could include reappraisal difficulty ratings measured on a trial-by-trial basis or use a description-based reappraisal task (Adamczyk et al., 2022; MacNamara et al., 2009, 2011), which allows the independent manipulation of cognitive demand and cognitive change.

In line with the extended process model of ER (Gross, 2015; Pruessner et al., 2020; Sheppes, 2020; Sheppes et al., 2015), our participants choose to switch (vs. maintain) strategies that show reduced ER efficacy at an initial regulation attempt (indicated by increased corrugator activity). Additionally, we observed that participants sometimes decide to switch strategies that are generally effective in achieving the desired ER goal (such as distraction). Specifically, participants switched to reappraisal for high-intensity (high affordance) pictures, for which distraction is generally more effective and preferred (Sheppes et al., 2014). This may suggest that factors beyond immediate strategy efficacy may contribute to the decision to switch strategies. On the other hand, it is possible that participants would have switched to another ER strategy, had more strategies been available. Future studies could probe participants about their motivations for switching to a particular ER strategy and include more than two strategies.

Some strengths and limitations of our study should be considered. As far as the strengths, we have developed and validated a novel ER strategy switching task. In contrast to previous studies which showed that people prefer distraction for high-intensity situations, by manipulating reappraisal affordances, we show that when the situation allows, people might prefer to *switch from distraction to reappraisal* (Birk & Bonanno, 2016; Dorman Ilan et al., 2019). Moreover, since we used high-intensity stimuli only, we minimized the risk of floor effects (i.e., the inability to downregulate psychophysiological responses to low-intensity stimuli), which could have limited the ability to draw conclusions about the ER efficacy as a predictor of switching decisions (especially from distraction to reappraisal, which typically occurs in response to *low-intensity* stimuli; Sheppes et al., 2014). Finally, we were the first to investigate dynamic changes in psychophysiological responding across different ER phases using multimodal (EMG and EEG) measures. This provided comprehensive insights into how different processing phases and ER efficacy measured at different levels influence switch decisions. As far as the limitations, we only piloted how difficult it was to reappraise, but not how difficult it was to distract from the high and low affordance pictures. Although we believe that switching to reappraisal for high affordance pictures was motivated by seeing an opportunity to reappraise its content, we cannot exclude the possibility that it was motivated by the increased difficulty of implementing distraction. It is important to note that in our study, participants had anticipatory knowledge about the *strategy* they were going to implement, and about the *stimulus* to which they had to regulate their emotional responses, as this stimulus had already been seen in the passive watch phase (see Figure 1c). Although this allowed us to investigate the impact of anticipatory knowledge on switching, it also allowed participants to start implementing strategies already during the pre-implementation phase. Thus, although our SPN results can be explained by *anticipated* regulation effort (in line with Shafir et al., 2015), we cannot rule out potential additional effects of the *actual* effort associated with the implementation of the strategies. Second, we matched high and low affordance pictures for arousal but not unpleasantness. The question thus arises whether reappraisal affordance is not simply a matter of the unpleasantness of pictures (i.e., more unpleasant pictures are more difficult to reappraise). Although we would speculate that the inherent difference between high and low affordance pictures is related primarily to their *content* (see also Horner et al., 2023), in particular whether they depict the end state of a situation (low affordance, e.g., the death of an accident victim) or a situation that is ongoing and thus leaves room for a “happy ending” interpretation (high affordance, e.g., a rescue operation), affordance and unpleasantness may be inextricably linked. Future studies could try to disentangle these two aspects, for instance, by investigating how an individual assessment (or experimental manipulation) of the stimulus unpleasantness affects the evaluation of subjective reappraisal difficulty. Third, we trained participants in situation-focused/reinterpretation reappraisal (Dorman Ilan et al., 2019; Ochsner et al., 2004; Shafir et al., 2015, 2016). However, this form of reappraisal is one of the most cognitively complex and effortful forms of ER (Ochsner et al., 2012), whose efficacy strongly depends on the stimulus content (Sheppes, 2020). This might have contributed to the lower efficacy of reappraisal versus distraction (pre- and post-switch) as well as the increased SPN for reappraisal before switching to distraction. Future studies could thus try to replicate our results using less effortful (and potentially more effective; Qi et al., 2017) reappraisal strategies, such as distancing (Denny et al., 2023; Hermann et al., 2021). Fourth, our results showed that switching to distraction was more effective than switching to reappraisal. However, reappraisal may provide longer lasting benefits than distraction (MacNamara et al., 2011; Paul et al., 2016; Thiruchselvam et al., 2011). Thus, it would be interesting to extend this study by examining longer term consequences of switching. Fifth, it would be also valuable to explore how psychopathology affects switch/maintain decisions, particularly because switching may be more effortful than maintaining the recently or frequently employed ER strategy (Ghafur et al., 2018) and our study shows that it does not always improve ER effects. Effort-aversion as well as fear of a potential ER failure could explain the reduced flexibility in affective psychopathologies (Bonanno & Burton, 2013; Kashdan & Rottenberg, 2010; Sheppes et al., 2015). Relatedly, because excessively high (or context-insensitive) flexibility may also be maladaptive (Aldao et al., 2015; Pruessner et al., 2020), it would be interesting to examine how the frequency of switching (especially of adaptive, context-sensitive switching to reappraisal for high affordance and to distraction for low affordance stimuli) links to mental health.

To conclude, ER switch decisions may indeed be motivated by reduced ER efficacy, as reflected by higher peripheral physiological (EMG corrugator activity) responses during initial strategy implementation. In addition, switching from reappraisal to distraction may be motivated by the strength of an initial response to the stimulus as well as anticipated effort of implementing reappraisal. Switching to distraction can improve, whereas switching to reappraisal may worsen short-term ER effects. These insights could inspire future work on evidence-based interventions aimed at increasing flexible ER, which is especially important given the relationship between ER flexibility and mental health.

AUTHOR CONTRIBUTIONS

Agnieszka K. Adamczyk: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources;

software; validation; visualization; writing – original draft; writing – review and editing. **Saskia B. J. Koch:** Conceptualization; methodology; writing – review and editing. **Miroslaw Wyczesany:** Software; writing – review and editing. **Karin Roelofs:** Conceptualization; methodology; writing – review and editing. **Jacobien M. van Peer:** Conceptualization; methodology; supervision; writing – review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data and analysis scripts necessary to reproduce results reported in this article have been made publicly available at the OSF and can be accessed at https://osf.io/uz2g9/.

ETHICS STATEMENT

The study procedures were in compliance with the Helsinki Declaration of 1975 (as revised in 1983) and were approved by the ethics committee of the Institute of Psychology, Jagiellonian University (approval no. KE/21_2022).

PREREGISTRATION

This study's design, hypotheses, and analysis plan were preregistered in accordance with the APA Preregistration for Quantitative Research in Psychology (PRP-QUANT) Template (Bosnjak et al., 2022) and can be accessed at https://osf.io/ze8mg.

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SUPPORTING INFORMATION

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

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