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Degree project

The Role of the Late Positive Potential in Distraction: A Systematic Review

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Student: Nanna Strid

Supervisor: Pilleriin Sikka

Examiner: Oskar MacGregor

Abstract

The late positive potential (LPP) is increasingly used as an indicator of emotional salience, which can be reduced by effective emotion regulation (ER), thus making LPP differences a practical marker of ER effects. One commonly used ER strategy is that of explicit distraction, a form of distraction that is consciously monitored and directed. Studies have shown that distraction modulates the LPP, and there are theoretical as well as empirical reasons to suspect that distraction occurs at an early stage in the timecourse of the LPP. However, the consistency of these findings have not yet been systematically assessed. This systematic review was conducted to address this gap in the literature. Following a literature search across three databases, nine empirical studies were systematically reviewed to assess the consistency of the effect of distraction on LPP latency and amplitudes. Mean LPP amplitude measurements from 270 healthy young adults, engaging in distraction and passive viewing during exposure to emotional stimuli, were gathered and reviewed. Mean differences were compared to assess the consistency of the LPP during distraction. Results showed consistent early LPP activation at centro-parietal sites, but not at frontal sites. These findings support the predictions of the process model of ER and its conceptualization of distraction as an antecedent strategy. The review was limited by the small number of studies, low mean ages of participants, and lack of diversity in stimuli, among other factors. As additional research is needed to further the scientific understanding of ER and its mechanisms, future directions are suggested.

Keywords: emotion regulation, late positive potential, event-related potential, distraction

The Role of the Late Positive Potential in Distraction

In recent decades, the field of emotion regulation (ER) has flourished into a major, rapidly growing research area in psychology, affective neuroscience, and related fields (Gross, 2015; Hajcak et al., 2010; Koole, 2009; Tamir, 2011). Although ER has garnered research interest for several reasons, among its most obvious merits are its contribution to subjective well-being and its potential utility in helping to treat psychopathology. Successful ER is associated with mental health, increased positive emotions, and reduced negative emotions (Domaradzka & Fajkowska, 2018; Speed et al., 2017), while maladaptive ER is linked to several psychiatric disorders, such as mood, substance abuse, and eating disorders (Aldao et al., 2010). Thus, greater insight into the neurobiological correlates of ER may contribute to more advanced understanding of the mechanisms underlying mental health and illness.

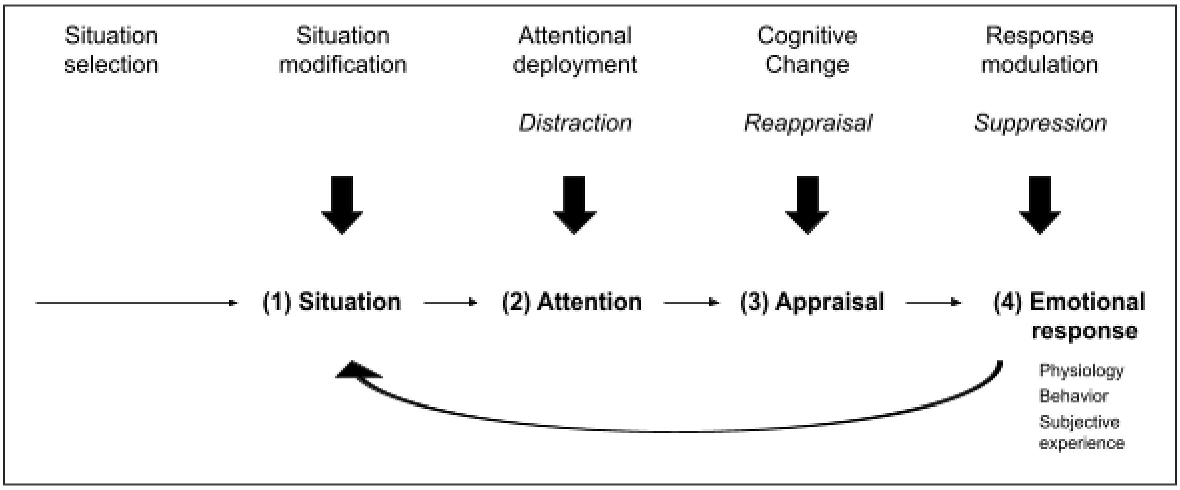
Emotion and Emotion Regulation

Emotions are temporary, situationally bound, and valenced changes in physiology, behavior, and subjective experience that are elicited by motivationally salient and personally significant events (Gross, 2015; McRae & Gross, 2020; Speed et al., 2017). According to the modal model of emotion (Gross, 2014), a commonly used model in affective neuroscience and psychology, emotions are generated via a dynamic process beginning with a specific situation (1), in which features that are relevant to one's current goals are attended to (2), and then appraised (3), which then generates a coordinated, flexible multi-system emotional response (4) that alters the situation (see Figure 1). ER refers to processes by which individuals influence the timing, intensity, and type of their emotions (i.e., physiological responses, behavioral expressions, or subjective experiences) to adaptively meet environmental challenges (Aldao et al., 2010; Gross, 2014). Both positive and negative emotions can be regulated through various methods which, depending on situational demands, are more or less adaptive. For example, when losing a job, one may reappraise the initially upsetting situation as an opportunity to explore new career directions, thereby creating motivation for constructive action (adaptive ER). Conversely, after a painful break-up, one may ruminate over one's negative attributes and mistakes, thereby producing overwhelming apathy that culminates in a depressive episode (maladaptive ER).

The process model of ER (Gross, 1998a) is one of the most commonly used theoretical frameworks against which findings on ER have been contextualized. As such, it was deemed to constitute a suitable theoretical basis also for the present thesis. According to the process model, each step in the emotion generation process can be a target of ER (see Figure 1). Building on the modal model of emotion, the process model divides ER strategies into antecedent and response-focused strategies, which can be further divided into five families of ER processes, distinguished by where in the emotion-generative process they interfere. Antecedent strategies occur before appraisals develop into fully formed expressions of responses and involve situation selection, situation modification, attentional deployment, and cognitive change, whereas response-focused strategies involve response modulation. Among the most studied strategies are *distraction*, which involves directing attention away from the emotional situation before more elaborative mechanisms evolve; *cognitive reappraisal*, which involves alteration of stimulus significance (*distancing*, which involves reformulating emotion-inducing situations into nonaffective terms, is considered to be a form of reappraisal); and *expressive suppression*, in which emotionally expressive behavior is inhibited during emotional arousal (Gross, 1998b, 2014; Webb et al., 2012). These, respectively, correspond to the last three stages of the process model.

Figure 1

The Process Model of Emotion Regulation



Note. Process model of ER. Adapted from “Emotion Regulation: Conceptual and Empirical Foundations,” by J. J. Gross, in J. J. Gross (Ed.), *Handbook of Emotion Regulation* (2nd ed., p. 7), 2014, Guilford Press. Copyright 2014 by Guilford Press.

Emotions may be regulated implicitly and explicitly. Implicit regulation is automatic and nonconscious. Conversely, explicit strategies involve conscious monitoring and direction of emotions (Braunstein et al., 2017). Affective and physiological consequences vary across strategies (Demaree et al., 2006; Webb et al., 2012). Certain strategies, such as reappraisal, have generally been linked to positive health outcomes and protection against psychopathology, while other strategies, such as expressive suppression, have more often been linked to negative health outcomes. Consequently, there has been a tendency in affective science to broadly categorize ER strategies as either adaptive or maladaptive. However, the adaptiveness of particular ER strategies depends on a complexity of factors, including context and the specific use of the strategy in a particular situation (Aldao et al., 2010; Gross, 2002; Webb et al., 2012).

The Late Positive Potential and Emotion Regulation

Among numerous approaches to investigating ER, neuroimaging methods emerge as productive tools for acquiring quantitative data. Highlighting the temporal dynamics of neural processes, event-related potentials (ERPs) are particularly instrumental in illuminating the neural basis of emotion processes. The late positive potential (LPP) is an ERP component that manifests as sustained positivity starting from approximately 300 ms after stimulus onset and peaks broadly around centro-parietal regions after 850-1,600 ms, persisting for up to several seconds. Since its amplitude is larger for emotionally arousing, compared to non-arousing, stimuli, the LPP is considered a neural marker of emotional reactivity and ER (Hajcak & Foti, 2020; Hajcak et al., 2010; Moser et al., 2006, 2014). The LPP is theorized to reflect the unfolding of multiple, overlapping processes involved in emotional processing, with early time windows (300–1,000 ms) marking attention allocation and later time windows (>1,000 ms) marking memory and meaning construction processes (Moser et al., 2014).

The LPP responds to changes in the motivational significance of seen and imagined visual content, affective context, and attentional targets, as well as personally relevant, emotionally evocative, and task-relevant stimuli, and has been suggested to index a system that underlies temporal tracking of stimulus significance (Hajcak & Foti, 2020; Hajcak et al., 2010; Speed et al., 2017). In regards to contextual factors, perceived emotional intent and temporal immediacy seem to modulate the motivational relevance of a stimulus, as demonstrated in an experiment that showed significantly enhanced amplitudes in the very early (250-400 ms) time window during the perception of angry faces with immediate, but not delayed, intent, and significantly enhanced amplitudes in both early and later time windows during the perception of threatening faces (Rischer et al., 2020). Moreover, the LPP is thought to reflect appetitive arousal and increased salience to stimuli, which is supported by studies that have linked variation in the LPP to individual differences in stimulus preferences, e.g., in studies on cocaine addiction and arachnophobia (Hajcak & Foti, 2020; Hajcak et al., 2010; Moser et al., 2014).

Ample evidence shows that the LPP is modulated by ER. For example, it has been shown that reappraisal, distraction, and suppression modulate LPP amplitude and latency in comparison to passive viewing (PV) during emotionally arousing stimulus presentation (Foti & Hajcak, 2008; Hajcak et al., 2010; Hajcak & Nieuwenhuis, 2006; Moser et al., 2006). However, the strategies modulate the LPP at different time periods and to various degrees.

Compared to reappraisal, distraction seems to attenuate the LPP at an early stage (Langeslag & Sanchez, 2018; Schönfelder et al., 2014), while expressive suppression has been found to modulate both the early and late LPP (Kraus & Kitayama, 2019; Li et al., 2020; Moser et al., 2006; Paul et al., 2013). In sum, although all involve the LPP, the variation across the strategies may reflect slight differences in underlying mechanisms. Examining the consistency of these strategies may therefore be productive.

Among the strategies, distraction stands out for several reasons. First, compared to instructions for reappraisal tasks, instructions for distraction tend to be more homogenous across studies, thereby allowing more focussed comparisons. Second, compared to suppression, distraction is generally considered to be a more adaptive ER strategy and as such, it may be a more valuable target for investigation. Third, compared to distancing, there is currently a greater number of studies on distraction which renders it more ripe for comparisons.

Aim of the Present Thesis

The aim of this thesis is to conduct a systematic review on the consistency of the LPP as a marker of explicit distraction. Narrowing down the exact manifestation of the LPP during explicit distraction may contribute to a greater understanding of the variety of ER strategies. As noted, this may provide novel insights into the neurocognitive processes that underlie adaptive and maladaptive ER, and, consequently, mental well-being and ill-being. Laying the groundwork for improved testing and development of effective interventions for addressing maladaptive ER, these advances may benefit clinical, and given the ubiquity of emotion in human life, also nonclinical, populations.

Methods

Literature Search

A literature search in the databases PubMed, Scopus, and Web of Science was conducted. The timespan was set to the earliest publication (2002, 2006, and 1989, respectively) to present (2021, February 24). Each database was searched for using the following keyword combination: ("late positive potential" OR LPP) AND ("affect regulation" OR ("emotion regulation" OR reappraisal OR suppression OR distraction OR distancing)) AND ((electroencephalogram* OR EEG) OR ("event-related potential" OR ERP)), without any filters applied. Reference lists of recent articles and reviews were inspected to locate potentially missed articles of interest.

All results were imported into the online software Rayyan (Ouzzani et al., 2016), in which duplicates were removed via Rayyan’s duplicate removal function. First, the titles and abstracts were screened by two reviewers (one the author of the thesis, the other the supervisor), working independently using the “blind” mode in Rayyan. Articles were selected for further scrutiny if they fulfilled the criteria detailed below. Articles whose inclusion was not agreed upon were included. At this stage, due to the large number of resulting papers on the various strategies, the author decided to narrow the initial scope of the review to only one ER strategy (see below).

The remaining full-text articles were then assessed for eligibility, in accordance with the added limitation, by the author of the review. Articles that failed to meet inclusion criteria were further excluded. All articles were screened for the required information and the results were tabulated. Studies lacking the necessary information, detailed below, were excluded.

Inclusion and Exclusion Criteria

Articles were included if they examined the LPP as a dependent measure of explicit distraction. Specifically, according to preset criteria, each included study had to: 1) be an empirical study, published in a peer-reviewed journal; 2) contrast explicit distraction tasks against PV conditions; 3) employ EEG/ERP methods to assess LPP amplitude and latency during distraction vs. PV throughout the same stimulus exposure; 4) study nonclinical adult populations; 5) be written in the English language. Studies that only investigated other ER strategies, implicit or passive forms of distraction, or trait ER rather than state/task-associated ER, were excluded.

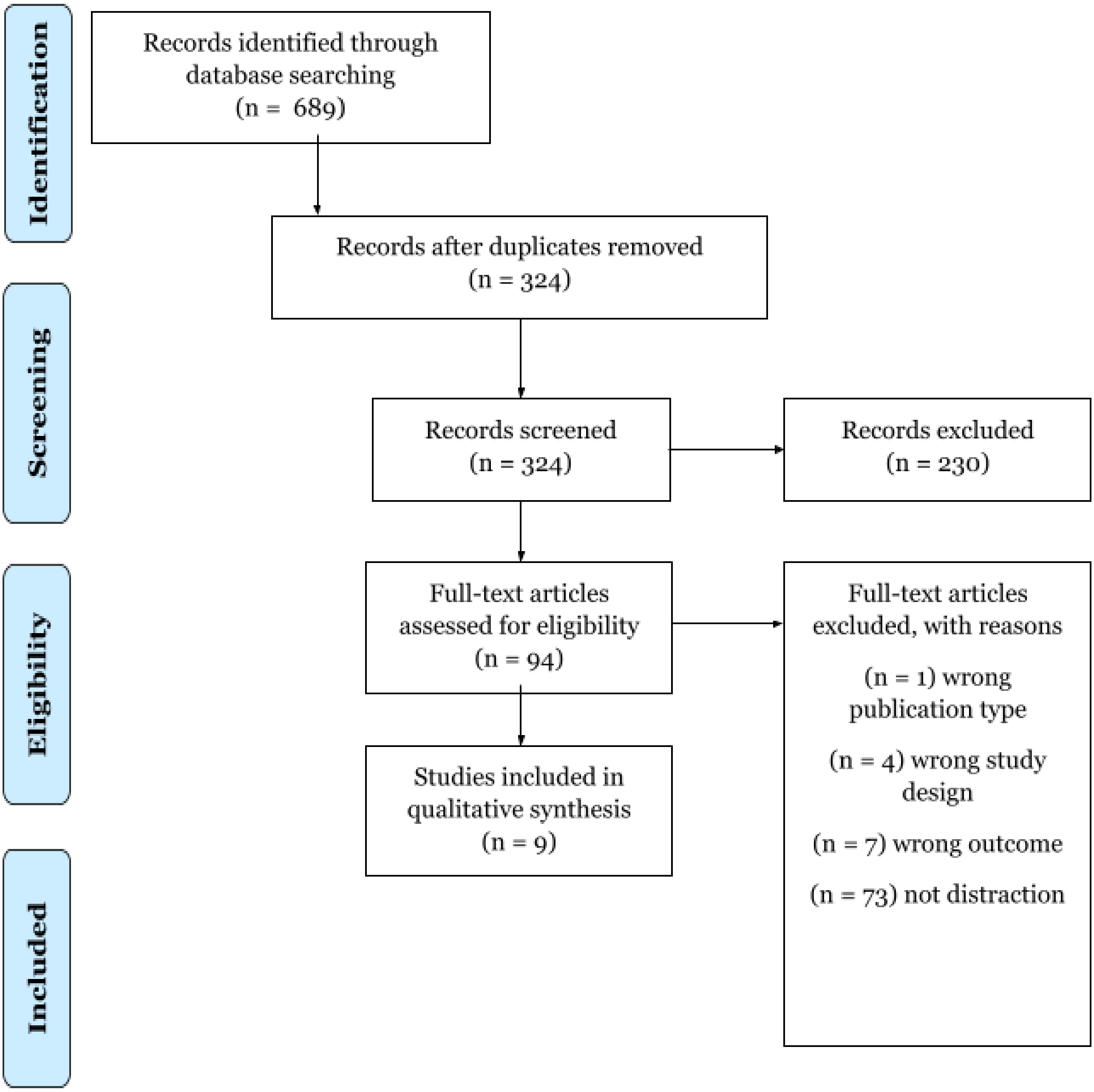
Note that at the initial stages of the literature search, additional ER strategies had been included (reappraisal, suppression, and distancing), as the original intention had been to compare the LPP across all explicit ER strategies. Although including these in the review would have yielded broader results, the decision to limit the scope further to include only distraction was made for the sake of focus and greater comparability of different studies. The reasons for selecting distraction rather than another strategy were explained in the introduction.

Data Extraction

The primary outcome measures were mean differences in the LPP amplitude (μV) and latency (ms), with mean LPP amplitudes during distraction contrasted against those in PV during various time windows. The following data were extracted from the selected articles: first author, publication year, geographical region, sample size, sex, age (range, mean, and standard deviation), stimuli (source, normative ratings for valence and arousal), instructions for distraction and PV, study design, electrodes of the LPP component, LPP time windows (ms), mean LPP amplitudes (μV) recorded during distraction and PV, and metrics denoting mean differences in the LPP between distract and PV conditions.

Figure 2

PRISMA 2009 Flow Diagram: Literature Search Process



Note. The literature search process, illustrated in a PRISMA 2009 Flow Diagram. Adapted from “Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement,” by D. Moher, A. Liberati, J. Tetzlaff, D. G. Altman, The PRISMA Group, 2009, *PLoS Med, 6*(7), p. 8 (doi:10.1136/bmj.b2535). CC BY-NC.

Results

Study Selection

PubMed provided 217 results, Scopus 230, and Web of Science 242, adding up to a total of 689 articles (see Figure 2). No additional records of interest were identified via other sources. Duplicates were then removed, resulting in 324 articles. After the two independent reviewers had sifted through the remaining titles and abstracts, 230 articles were excluded by both reviewers, 82 were included by both reviewers, and 12 were not agreed upon. This yielded a total of 94 articles for inclusion after the first assessment phase. In the second phase, after the decision to narrow the scope had been reached, 73 of the assessed full-texts were excluded due to not involving distraction, seven due to not providing the necessary outcome data, four due to wrong study design, and one due to wrong publication type. Thus, 84 articles were excluded and nine remained for final inclusion.

Study Characteristics

Table 1 displays the available demographic and methodological details of the included studies. Three of the studies were conducted in Germany, three in China, two in Israel, and one in the United States; all were published in the last decade. Sample sizes ranged from 18 to 48, adding up to a total of 270 participants across the nine studies, of which 142 (52.6%) were women. Similarly balanced sex ratios were reported in all individual studies except for one study (Paul et al., 2016a), in which 66% were female. The samples generally reflected a young adult population, with mean ages ranging from 19.3 to 31.2. Two studies did not report mean age but were included because it was clear that the participants were adults.

Table 1

Demographics and Methodology of Included Articles

Study and region	Participants	Mean age (*SD*)	Stimuli	Instructions for distraction	Instructions for PV	Design
Jiang et al., 2020 (CN)	*n* = 48 (24 women)	Unreported (range 19-22)	Images from IAPS	Feel neutral to the aversive image by thinking of something irrelevant to the image presented on the screen.	Attend to the unpleasant images and do not regulate.	Within-subject, between-subject*
Li et al., 2020 (CN)	*n* = 19 (10 women)	19.7 (1.8)	Images from IAPS A = 5.9, V = 7.5 (high intensity) A = 4.4, V = 6.2 (low intensity)	Ignore the background picture by solving the presented mathematical equation and judging whether the displayed solution is correct or not.	Watch the picture seriously and respond naturally without changing your emotional response.	Within-subject
Paul et al., 2013 (DE)	*n* = 20 (10 women)	24.0 (2.4)	Images from IAPS A = 6.6 V = 2.5	Generate thoughts or mental images unrelated to the presented picture and of neutral content.	Attend to and respond naturally to the picture without trying to alter the feelings elicited.	Within-subject
Paul et al., 2016a (DE)	*n* = 35 (23 women)	24.1 (5.1)	Images from IAPS A = 6.5 V = 2.8	Distract from the pictures and emotions by thinking of something else such as the way to the supermarket.	Attend to the pictures and let emotions arise naturally without changing them.	Within-subject
Paul et al., 2016b (DE)	*n* = 24 (13 women)	31.2 (8.2)	Images from IAPS A = 6.6 V = 2.5	After picture onset, generate neutral thoughts or mental images unrelated to the picture.	Attend to and respond naturally to the picture without altering accompanying emotions.	Within-subject, between-subject*
Shafir et al., 2015 (IL)	*n* = 27 (15 women)	Unreported (adults)	Images from EmoPicS, GAPED, IAPS, researchers' own pictures A = 6.5 V = 2.0	Disengage attention from emotional pictures by producing unrelated neutral thoughts.	Allow natural thoughts and feelings to arise while looking at the pictures.	Within-subject
Shafir & Sheppes, 2018 (IL)	*n* = 28 (14 women)	24.5	Images from EmoPicS, GAPED, IAPS, NAPS A = 6.0 V = 2.7	Disengage attention by forming neutral thoughts that are unrelated to emotional stimuli.	Engage with emotional stimuli and allow natural thoughts and feelings to emerge.	Within-subject

Thiruchselvam et al., 2011 (US)	*n* = 18 (8 women)	19.3	Images from IAPS A = 6.0 V = 3.4	Feel neutral in response to the aversive image by generating thoughts that are unrelated to the image presented on the screen.	Attend to the presented image, allowing yourself to experience whatever thoughts and feelings happen to arise.	Within-subject
Zhang et al., 2019 (CN)	*n* = 26 (13 women) (sleep control)	20.0 (1.7)	Images from IAPS A = 5.7 V = 2.8	Think of unrelated thoughts or neutral scenes to feel emotionally neutral while looking at a picture.	Maintain your attention to a picture and react in a natural way.	Within-subject, between-subject*
	n = 25 (12 women) (sleep deprived)	20.2 (1.7)				

Note. CN = China. DE = Germany. IL = Israel. US = United States. GAPED = Geneva Affective Picture Database. EmoPicS = Emotional Picture Set. IAPS = International Affective Picture System. NAPS = Nencki Affective Picture System. A = mean arousal, V = mean valence (normative ratings). *Between-subject design was not used for acquiring the data collected for this thesis.

Stimuli

All studies used stimuli from the International Affective Picture System (IAPS; Lang et al., 2008), a database of standardized pictures developed for the study of emotion and attention. Two studies (Shafir et al., 2015; Shafir & Sheppes, 2018) used additional validated pictorial datasets (Geneva Affective Picture Database [GAPED]: Dan-Glauser & Scherer, 2011; Emotional Picture Set [EmoPicS]: Wessa et al., 2010; Nencki Affective Picture System [NAPS]: Marchewka et al., 2014; researchers’ own pictures, validated in their own lab).

All stimuli consisted of color photographs designed to induce emotional responses. IAPS-derived ratings for normative valence and arousal differed across studies. Positive stimuli, used only in one study (Li et al., 2020), had mean arousal ratings ranging from 4.4 to 5.9 and valence from 6.2 to 7.5, while negative stimuli had mean arousal ratings ranging from 5.7 to 6.6, and mean valence ratings from 2.0 to 3.4. Unpleasant (i.e., negative) images were aimed to induce emotions such as sadness, fear, and disgust, and contained scenes of, e.g., car accidents, a dirty toilet, and mutilations. To ensure that the intended emotions were reliably evoked, participants additionally rated the valence and arousal of the stimuli.

Procedure

All except for two (Shafir et al., 2015; Thiruchselvam et al., 2011) studies reported ethical approval from relevant ethics committees or review boards, and all but two studies (Shafir et al., 2015; Shafir & Sheppes, 2018) reported obtaining written informed consent from participants, prior to their participation.

During stimulus presentation, participants were asked to either passively view (PV; also referred to as 'attend', 'maintain', and 'watch' across studies), or actively distract themselves from, the stimulus content. PV was the control condition against which the effects of distraction were evaluated. Instructions for distraction were highly similar across studies, prompting participants to generate neutral thoughts or mental images that were unrelated to the presented picture, e.g., by imagining complex geometric shapes or a familiar location. Breaking this trend, Li et al. (2020) instead displayed mathematical problems against a background of emotional images, instructing participants to solve the problem and judge whether the presented solution was correct or not. In three studies, participants were explicitly asked to implement the given instructions only after the image appeared on the screen, and to perform the task throughout the full duration of the stimulus presentation (Paul et al., 2013, 2016b; Thiruchselvam et al., 2011).

Instructions for PV were also similar across studies, prompting participants to allow natural thoughts and feelings to emerge without regulating their reactions while attending to the presented pictures. In all studies, participants were given the opportunity to practice the distraction and PV tasks several times before performing the formal experiment.

Most studies followed similar procedures, as follows. Participants were seated in front of a computer screen. A fixation cross was presented for 500-2,000 (the timing differed across studies) ms to establish participants' focus on the screen, followed by a visual word cue lasting 2,000 ms that prompted participants to either distract or view upcoming stimuli. Then, a picture was presented for 4,000-8,000 ms, during which the participants were expected to engage in the instructed task. In one study (Zhang et al., 2019), instructions were presented in auditory form 1,000 ms after stimulus onset. In this way, the researchers intended to prevent participants from implementing cued instructions prior to stimulus onset. Pictures were presented in a randomized or pseudorandomized sequence.

Study Design

All studies employed within-subject designs for acquiring the data relevant for the present review; however, three studies (Jiang et al., 2020; Paul et al., 2016b; Zhang et al., 2019) also employed between-subject designs for other aspects of the experiment, from which data was not used in this thesis due to its limitations. One of these studies (Zhang et al., 2019), however, explored distraction in two separate groups (sleep deprived participants and non-sleep deprived controls), thus providing two eligible samples for the purposes of this review.

Moreover, all studies used some form of block-design, consisting of two to six blocks, with 14 to 60 trials per condition. Paul et al. (2016a) divided their experiment into two phases: a habituation phase, during which participants were initially exposed to the stimuli, and a re-exposure phase, during which participants were presented with the same stimuli ten minutes later but did not distract; thus, only data from the first phase is included in this review (Paul et al., 2016a). One study conducted six blocks with 30 trials per condition, with high-intensity distraction and PV contrasted against low-intensity distraction and PV, thus providing four conditions of relevance for this thesis (Shafir et al., 2015).

EEG Recordings

Table 2 provides an overview of mean LPP amplitudes (µV) for distraction and PV, according to time windows and electrode sites.

LPP Time Windows. The mean LPP (µV) was measured at different time windows in each study, ranging from 300 ms to 5,000 ms after stimulus onset. The terms ‘early’ and ‘late’ LPP were used inconsistently across the studies. The early LPP was defined as the 300-1,000 (Shafir & Sheppes, 2018), 300-1,700 (Paul et al., 2013; Shafir et al., 2015; Thiruchselvam et al., 2011), 350-1,750 (Jiang et al., 2020), and 500-700 (Li et al., 2020) ms time windows, thus ranging from 300 to 1,750 ms and spanning 200-1,400 ms across studies. Conversely, the late LPP was defined as the 700-1,500 (Li et al., 2020), 1,000-2,400 (Shafir & Sheppes, 2018), 1,700-3,100 (Shafir et al., 2015), and 1,750-5,000 (Jiang et al., 2020) ms time windows, thus ranging from 700 to 5,000 ms and spanning 800-3,250 ms.

Electrode Sites. The LPP waveforms were pooled from predominantly centro-parietal sites, although measurements were also gathered via parieto-occipital and frontal electrode sites. More specifically, for centro-parietal regions, the most used electrode sites from which the average amplitudes were pooled to evaluate the LPP were as follows: CPz, used in all studies; Pz, used in six studies; CP1, used in four; CP2, used in three; Cz and Fz, used in two; and the remaining electrode sites CP3, CP4, P1, P2, PO1, and PO2 were only used by one study. The frontal LPP, reported in one study, was measured at Fz in the 800-1,000 time window (Shafir et al., 2015).

Reference Montage. During recording, the Cz electrode, which is located at the very top of the head, was most commonly used as online reference (Paul et al., 2013, 2016a, 2016b), followed by FCz (Li et al., 2020) and Pz (Thiruchselvam et al., 2011). In two studies (Jiang et al., 2020; Zhang et al., 2019), no online reference was reported, and in two other studies (Shafir et al., 2015; Shafir & Sheppes, 2018), electrode voltages were separately referenced online according to Common Mode Sense/Driven Right Leg electrodes.

More importantly, all but one study explicitly reported offline re-referencing the data from all electrodes to the average activity of the left and right mastoids, T9 and T10. One study (Zhang et al., 2019) reported that the data had been “re-referenced to the average of two mastoid channels” (p. 287), without specifying which these were. Given the homogenous use of offline references across the studies, meaningful comparisons of the results are possible.

Differences in Mean LPP Amplitudes Between Distraction and PV

Table 2 provides an overview of the findings, to the extent that the data was extractable, about the differences in mean LPP amplitudes between distraction and PV. In all studies included in this systematic review, PV constituted the control condition against which distraction effects were measured. The findings are briefly summarized next.

Table 2

Mean LPP Amplitudes (μV) by Time Window and Task

Study	Electrodes	Time (ms)	Distract *M (SD)*[a]	PV *M (SD)*[a]	*F*	*t*
Li et al., 2020	Pz, CPz	500-700	4.4 (0.8) (high intensity)	8.8 (1.4) (high intensity)		
			5.8 (1.1) (low intensity)	7.4 (1.1) (low intensity)		
		700-1,500	2.9 (0.8) (high intensity)	6.4 (1.1) (high intensity)		
			5.3 (1.1) (low intensity)	5.5 (0.9) (low intensity)		
Jiang et al., 2020	CPz, CP3, CP4	350-550	6.4 (6.0)	6.5 (4.6)	0.02*	
		550-750	8.2 (6.9)	9.2 (5.9)	4.06**	
		750-950	7.7 (7.8)	9.5 (7.6)	6.67**	
		950-1,150	6.4 (8.5)	8.5 (8.7)	8.09***	
		1,150-1,350	5.4 (7.7)	7.9 (9.5)	11.43***	
		1,350-1,550	4.4 (6.6)	7.2 (8.7)	12.97***	
		1,550-1,750	4.1 (6.8)	6.4 (8.7)	7.90***	
		1,750-5,000	2.3 (5.7)	4.3 (7.0)	9.67***	
Paul et al., 2013	CPz, P1, P2, Pz, PO1, PO2	300-5,000	1.9 (2.9)	4.5 (4.5)		2.53**
Paul et al., 2016a	Cz, CPz, CP1, Pz	300-1,000	3.8 (6.5) 5.6 (4.7) 5.8 (5.9)	6.4 (6.8) 7.6 (4.8) 7.9 (5.1)		3.63***
		1,000-2,000	3.9 (4.7) 4.2 (3.6) 4.3 (5.1)	6.7 (6.0) 6.2 (5.0) 6.2 (4.7)		
		2,000-3,000	3.3 (5.6) 3.3 (3.7) 2.6 (5.0)	6.5 (5.9) 4.6 (5.5) 4.4 (5.0)		
		3,000-4,000	2.6 (5.6) 3.0 (4.3) 2.3 (4.7)	5.8 (5.7) 3.0 (5.8) 2.4 (4.6)		
Paul et al., 2016b	CPz, CP1, CP2	300-5,000	-0.7 (4.1)	3.6 (5.4)		6.08****

Shafir et al., 2015	Pz, CPz	300-1,700	6.4 (1.0)†	7.6 (0.9)†	4.29*	
		1,700-3,100	5.1 (1.0)†	7.9 (1.0)†	9.34**	
	Fz	800-1,100	4.6 (1.4)†	5.6 (1.2)†	1.74, n.s.	
Shafir & Sheppes, 2018	Pz, CPz	300-1,000	4.1 (0.9)†	7.1 (0.8)†	17.4****	
		1,000-2,400	3.0 (0.9)†	7.1 (0.9)†	19.31****	
Thiruchselvam et al., 2011	CPz, CP1, CP2	300-500	0.2 (4.7)	2.4 (5.3)		2.97**
		500-700	4.2 (5.0)	6.6 (6.1)		2.63*
		700-900	5.8 (4.8)	8.9 (5.6)		3.37***
		900-1,100	5.7 (5.3)	8.7 (4.7)		2.98**
		1,100-1,300	5.4 (5.6)	8.5 (4.8)		3.09**
		1,300-1,500	5.1 (5.0)	8.2 (4.6)		3.07**
		1,500-1,700	4.3 (5.4)	8.2 (4.3)		3.69***
Zhang et al., 2019	CPz	1,900-5,000	0.6 (1.0)† (sleep control)	4.2 (0.8)† (sleep control)		4.03****
			1.11 (0.99)† (sleep deprived)	1.10 (0.74)† (sleep deprived)		0.00, n.s.

Note. Mean LPP amplitudes (μV) by instruction and time window, recorded during negative and positive conditions. *F* and *t* values are only reported for studies in which that data was available. PV = passive viewing.

[a] *SE* is reported for articles in which *SD* is unavailable. †*SE* (not *SD*).

**p* <.05. ***p* <.01. ****p* = < .005. *****p* <.001.

Only one study (Li et al., 2020) investigated the LPP during distraction and PV of positive stimuli. Two separate time windows were assessed via two centro-parietal electrodes in both high- and low-intensity conditions as participants distracted from, or viewed, positive pictures. In that study, it was found that, compared to PV, distraction modulated the LPP in both the 500-700 ms and 700-1,500 ms time windows during the presentation of high-intensity (but not low-intensity) positive stimuli. During low-intensity, however, distraction only modulated the LPP at the 500-700 ms time window, compared to PV. In all other studies, presented below, only negative stimuli were used.

In the earliest article included in this review, Thiruchselvam et al. (2011) examined the LPP at three centro-parietal sites during seven distinct time windows, from 300 ms to 1,700 ms. They found that distraction, relative to PV, significantly modulated the LPP at 300 ms, and that the effect persisted during the subsequent epochs, i.e., until 1,700 ms after stimulus onset. Replicating and extending that study, Paul et al. (2013) explored the LPP in the 300-5,000 ms time window, deriving the waveform from six centro-parietal and parieto-occipital electrode sites. They found that the LPP amplitudes were significantly reduced from 300 ms after stimulus onset when participants engaged in distraction while viewing negative pictures. The amplitudes were found to stay significantly attenuated during the subsequent time epochs. Specifically, contrasting distraction against PV, the LPP mean differences changed from 1.35 μV ($p < .020$) at 300-500 ms to 2.33 μV ($p = .001$) at 1,500-1,700 ms, with the largest mean difference of 2.46 μV ($p = .003$) found at the 900-1,100 ms time window. As a consequence of the division of the LPP into the seven time windows, along with the comparatively simple and straightforward study design, this study provided clear results on the dynamics of the LPP during distraction contra PV.

Likewise resembling the earlier study by Thiruchselvam et al. (2011), a recent study (Jiang et al., 2020) investigated the LPP in the 350-1,750 ms time window, divided into seven equal epochs, and additionally examined the LPP at the 1,750-5,000 ms time window. Pooling waveforms from three centro-parietal electrodes, they found that distraction modulated the LPP, both in the early and the later time windows.

In one study (Paul et al., 2016b), the effects of distraction on the LPP were compared between patients with obsessive-compulsive disorder (OCD) and healthy controls. As this systematic review was limited to healthy participants, only the data from the healthy control group was considered. In the study, the LPP was measured in the 300-5,000 ms time window at three centro-parietal electrode sites. The findings indicated a significant reduction of LPP amplitudes during distraction relative to PV during the measured epoch. Paul et al. (2016a) examined the effects of distraction during repeated exposures to stimuli, probing distraction in relation to habituation. The researchers measured the LPP via four centro-parietal electrodes, between 300 and 4,000 ms, divided into four windows. It was found that compared to PV, distraction significantly attenuated the LPP during stimulus presentation, with a mean difference of 1.91 μV ($p = .003$) between distraction and PV across the measured epochs.

Another study (Shafir et al., 2015) explored distraction during high-and low-intensity negative conditions. Due to unclear data, only high-intensity data was extracted from the article for this systematic review. In that study, the LPP was assessed during three different time windows, 300-1,700 and 1,700-3,100 ms at two centro-parietal electrode sites, and 800-1,100 ms at one frontal site. It was found that, relative to PV, distraction significantly modulated the centro-parietal LPP at both the early ($F(1,26) = 4.29$, $p < .05$) and the late ($F(1,26) = 9.34$, $p = .01$) time windows during high-intensity negative conditions. However, relative to PV, distraction did not significantly modulate the frontal LPP ($F(1,26) = 1.74$, n.s.). In another study, Shafir and Sheppes (2018) investigated the effect of anticipatory information on neural processes underlying ER. While most of their findings were out of the scope of this review (as was the case for several other studies), data about the general modulations of the LPP by distraction was collected. In this study, the LPP was measured at two centro-parietal electrode sites in two time windows, 300-1,000 and 1,000-2,400 ms. Here, distraction was found to significantly attenuate the LPP both at the early stage ($F(1,27) = 17.4$, $p < .001$) and at the later stage ($F(1,27) = 19.3$, $p < .001$), compared to PV.

Zhang et al. (2019) examined the effect of sleep deprivation on the performance of ER strategies, contrasting sleep deprived and non-sleep deprived participants during distraction and PV. In this study, the LPP waveform was gathered from one centro-parietal electrode within a single, comparatively late, time window between 1,900 and 5,000 ms. They found that compared to PV, distraction significantly attenuated the LPP in the control, i.e., non-sleep deprived group. However, in the sleep deprived group, the effect was not present; the mean difference between the distract and PV conditions were negligible. Thus, distraction appeared to be successful in attenuating the LPP only in persons who had slept adequately, thus indicating that sleep deprivation significantly reduces the regulatory effects of distraction.

Discussion

Summary of Evidence

First of all, it seems clear from the examined evidence that distraction is an effective ER strategy. The findings seem to confirm that, during distraction, the modulation of mean LPP amplitudes is most pronounced at the earliest stages. The findings imply that the LPP is attenuated by distraction mainly in the 300-1,500 ms time window, with the modulation especially pronounced during the 900-1,100 ms time window. Moreover, compared to PV, distraction seems to have a stronger and more long-lasting effect on the LPP in high-intensity than in low-intensity conditions, regardless of emotional valence (Li et al., 2020; Shafir et al., 2015).

As mentioned earlier, the LPP is theorized to reflect the unfolding of multiple, overlapping processes involved in emotional processing, with early time windows reflecting attention allocation and later time windows reflecting memory and meaning construction processes (Moser et al., 2014). The findings by Shafir et al. (2015), that distraction was nonsignificant in frontal regions, whereas it was significant in centro-parietal regions, lend some support to the idea that distraction is not closely associated with cognitive effort and instead reflects attentional processes. Given that frontal regions, such as the prefrontal cortex, are associated with cognitive effort and executive function (Gazzaniga et al., 2014), the findings of Shafir et al. (2015) indicate that the mentioned cognitive functions may not be prominently involved in the mechanisms that constitute distraction. This was also suggested by the authors of that study.

The findings that distraction attenuates the LPP at the earliest stages and at centro-parietal, but not frontal, sites, support the predictions of the process model and distraction being an antecedent-focused ER strategy that is associated with early attentional phases of information processing. However, since only one of the ER strategies of the model was examined, it is difficult to make broader claims.

Limitations, Strengths, and Future Directions

One limitation of this review is the narrowing of focus and subsequent change of inclusion criteria after the first phase of the literature search. This compromised the consistency of the search strategy. Comparing the consistency of the LPP over several ER strategies, as initially intended, may be a productive objective for a future systematic review. Additionally, the review is limited by incomplete retrieval of the identified research. As studies reported differing outcome measures, ranging from F and t statistics to mean differences in μV, results were not easily comparable. Thus, metrics for mean comparison were inconsistently extracted, which weakened the comparisons.

The review is further limited by the generally low mean age in the samples of the included studies. As the majority of participants were young adults, the results may not be generalizable to older individuals and thus the population at large. To ameliorate this imbalance, future studies may seek to include participants of a greater variety in age. Furthermore, the review is limited by the sheer number of studies and relatively small sample sizes. In order to increase generalizability, it may be beneficial to collect and synthesize data from larger samples. Moreover, this systematic review exclusively focussed on data from healthy populations. Several studies have examined clinical populations. Using these studies to compare healthy populations to clinical ones may be a fruitful objective for future systematic reviews. Since almost all studies relied exclusively on pictures from the IAPS for emotion induction, another limitation is the lack of diversity in stimuli. Exploring distraction by means of other forms of stimuli, and modalities other than vision, might uncover other patterns in the LPP and render the findings more generalizable.

Another limitation is that, despite largely uniform instructions, it is not known what mental images or cognitions participants distracted themselves with. This may be an important aspect to consider as, for example, neural activity may vary depending on whether one is thinking of a person or an object. It has been shown that motivational significance may be greater for stimuli involving people than for stimuli merely containing objects; this may affect the LPP (Ferri et al., 2012). Therefore, differences in contents of the cognitions evoked by distraction may account for some inconsistencies in the LPP across studies. Whereas the studies included in this systematic review exclusively involved active forms of distraction, previous studies have also examined passive forms of distraction. Passive distraction typically involves distracting participants with external stimuli, rather than having them generate an inner, mental distraction; thus, the contents of consciousness during passive distraction may be more homogenous than in active forms.

A strength of this review is its inclusion of relatively diverse populations in terms of geocultural distribution. There is a pervasive trend in psychology and cognitive neuroscience to make broad claims about human cognition based disproportionally on Western, educated, industrialized, rich, and democratic (WEIRD) populations while underrepresenting other groups (Henrich et al., 2010). While Germany and the United States would be categorized as prototypically WEIRD, Israel and China are typically categorized as non-Western. However, compared to vastly less Westernized regions, such as most of Africa and South America, China and Israel may still resemble the West sufficiently to justify more active inclusion of other, non-WEIRD, participants in future research. Further increasing diversity, extending studies to include more non-WEIRD populations, may improve the generalizability of experimental results and contribute to a more robust understanding of human cognition and behavior.

Ethical and Societal Aspects

Ethically, the review was limited by that two studies did not report gaining approval from any ethical review board, and further, that two studies failed to report obtaining written informed consent from their participants. The ethical aspect, although typically not prominently emphasized, is a crucial component of the scientific process in modern times. Thus, failure to report ethical treatment of participants is a major drawback of any study, and subsequently, of any systematic review including these studies. Therefore, the ethical quality of this thesis is partially compromised. However, as already noted, a greater understanding of distraction—among other forms of ER—may contribute to increased understanding and treatment of psychopathology, which may have beneficial ripple effects on society at large. The results of this systematic review may constitute a modest contribution to this process.

Conclusion

The aim of this thesis was to conduct a systematic review on the consistency of the LPP as a marker of explicit distraction. Although results were not sufficiently detailed to warrant strong conclusions, the evidence seems to support the conceptualization of distraction as an antecedent-focused strategy, in the context of the process model, as the examined evidence seemed consistent in showing early activation in centro-parietal areas and negligible activation in frontal areas. However, additional research is needed to further the scientific understanding of ER and its mechanisms.

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