Affective modulation of cognitive control: A systematic review of EEG studies

Affective modulation of cognitive control: A systematic review of EEG studies

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https://doi.org/10.1016/j.physbeh.2022.113743

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Abstract. In recent years, a growing corpus of research has been conducted utilizing a variety of behavioral and neurophysiological methodologies to investigate the relationship of emotion and cognition, yielding unique insights into fundamental concerns about the human mind and mental disease. Electroencephalography (EEG) has been utilized to investigate how emotional states alter neural markers of cognitive control. The current study is a systematic analysis of EEG research that looks at affective modulation (mood, emotion) of cognitive control and its many sub-processes (e.g., cognitive flexibility, inhibitory control, and working memory). The PRISMA standards were followed in this review, which looked at experimental designs and tasks, as well as methodological elements of EEG recording and analysis across research. A total of 35 articles were chosen for qualitative synthesis as a consequence of the search. The examination of event-related potentials (ERPs), which showed affective modulation of 19 different components, was the most common electrophysiological approach used across research. The majority of the investigations focused on N2 and P3, indicating that affective induction has a strong influence on attentional processes and response inhibition. Future research should look into different methodologies such as source location and connection metrics to better understand the brain's areas and dynamic response during affective induction activities. It is also suggested that the technical components of the report be more explicit in order to promote study comparability and replication.

Keywords: Affective modulation; Emotion; Cognitive control; Response inhibition; EEG, ERP

Highlights

• The search followed the PRISMA guidelines and resulted in 35 articles selected for qualitative synthesis.

• The main electrophysiological approach across studies was the analysis of event-related potentials (ERPs), with affective modulation of different components/waves during cognitive control task performance.

• Most of the studies focused on N2 and P3, showing a prevalent interest in the effects of affective induction on attentional processes and response inhibition.

• it is recommended a greater specificity in the report of the technical aspects of studies in this field to improve the comparability between studies and their replicability.

1. Introduction

1.1. Overview

Historical-philosophical perspectives have claimed that appropriate behavior is based on reason and rationality, whereas affective and emotional responses might be problematic. Similarly, in the literature on cognitive psychology and neuroscience, it is frequently considered that cognitive processes are distinct from affective processes. This assumption has had a significant impact on the information processing models of brain cognition and the experimental methodologies used in this field of research. In this context, a prevalent view, particularly in cognitive control research, has led to an understanding of it as a dry and cold ability impervious to mood and emotion. However, this notion has been called into question in recent decades, owing to the discovery of novel concepts that raise questions about the interactions between affective and cognitive processes, as well as the possibility that emotions may be a critical determinant of cognitive control.

Cognitive control is a term that refers to a collection of psychological processes that enable us to change our behavior in response to present goals [1], [2], [3]. Cognitive control encompasses both fundamental top-down cognitive processes such as inhibitory control (IC) of prepotent response tendencies, working memory (WM), and cognitive flexibility (CF) and higher-order executive functions that require the concurrent use of multiple fundamental executive functions (high cognitive control), such as reasoning, planning, and problem-solving [4, 5].

Notably, a considerable body of research in cognitive sciences demonstrates that cognitive control and emotion interact strongly at multiple levels and work hand in hand to promote socially appropriate and goal-directed behaviors [6]. Through bottom-up mechanisms, affective processes (i.e., emotion, mood) influence complex behavioral responses [[7], [8]], resulting in a modification of cognitive function in a wide variety of settings [9], [10], [11], [12], [13], [14], [15]. On the other hand, cognitive control is employed to exert regulatory control over emotions [15], [16], [17], [18], [19], [20]. There is increased interest in studies that examine the affective mechanisms underlying cognitive control and its numerous sub-processes

[6, [21], [22], [23], [24], [25], [26], [27], [28]]. While theoretical attempts have been made to elucidate the affect-cognitive control link [29], it is still unknown under what conditions emotion and mood facilitate or impede cognitive control tasks [26, 30]. What is certain is that stimuli that produce emotional and mood states have an affective effect on the fundamental and higher-order subprocesses of cognitive control [27, 31].

1.2. Behavioral tasks and evidence

Numerous studies have examined the interplay between affective processes and cognitive control using a variety of emotional stimuli, including faces [32, 33], images [18, [34], [35], [36]], videos [28, 37], and phrases [38, 39]. These stimuli are delivered via a variety of behavioral activities [26]. The emotional Stroop task [40, 41], the emotional stop-signal task [42], [43], [44], [45], the Eriksen flanker task test [37, 46], the emotional go / no go task [47], [48], [49], the attentional blink emotional task [50, 51], and the emotional n-back task [52, 53] are a few of the key procedures adapted for the presentation of emotional stimuli. Apart from the stimuli and tasks, there are distinctions in the temporal relationship between cognitive control and emotions. Indeed, cognitive control operates via two distinct control mechanisms: retroactive (or "late correction") and proactive (or "early correction") [54], and during a cognitive control task, emotional stimuli at various temporal points relative to a target are presented [55], [56], [57]. Additionally, research has examined the effects of varying the length of the emotional stimulus: a) tonic, i.e., global/persistent [58, 59] or b) phasic, i.e., brief/target-specific [60, 61].

Positive or negative affective stimuli appear to modulate cognitive control in comparison to neutral states [62]. Positive affect would improve CF, working memory, planning, and task switching, but it could also have negative consequences, such as decreased inhibitory control and increased distractibility [57]. Negative affect has contradictory results. Some studies indicate that it impairs general cognitive control performance, while others indicate that it enhances inhibitory control and attentional processes while impairing cognitive flexibility performance [63], [64], [65], [66]. While the antecedents support the affective modulation of cognitive control described, there are conflicting findings, most likely due to the variety of cognitive control processes involved and the variety of emotional stimuli and sensory modalities used [28, 67].

The following sections describe some of the most frequently used experimental tasks in the study of affective modulation of cognitive control.

1.2.1. Go/No-go

On this task, the participant receives an instruction to respond to certain conditions (Go-stimulus) and not respond to others (No-Go stimulus) [68]. Affective versions of the task include images surrounded by a colored frame that indicates whether the stimulus is Go or No-go [47], faces with emotional Go and neutral No-Go [48], or emotional faces followed by shapes (circle or square) that indicate whether or not to carry out

the response [49]. Among the 24 emotion-induction procedures of reviewed studies, the emotional Go / No-go tasks show the similarity of using explicit non-emotional targets (shapes, frames, letters, gender, drawings) and implicit emotional stimuli (faces or pictures) or verbal instructions.

1.2.2. Eriksen flanker test

This experimental paradigm [69] entails responding to a primary goal, such as letters or arrows, while being surrounded or "flanked" by irrelevant stimuli (e.g. →→←→→). Prior to the activity, the participant is exposed to a series of emotional images or videos of tonic duration in a mood Eriksen flanker [37]. In another kind of phasic presentation, the central target is a man or woman with a neutral expression flanked by emotive faces of the opposing sex, and the participant must guess the central target's sex [46].

1.2.3. To-be-remembered(TBR) – to-be-forgotten (TBF) tasks

It is a task of intentional forgetting where the participants are instructed to learn a series of stimuli, some TBR and others TBF, although later they must try to remember all the elements of the list [38]. The cue of remembered or forgotten can be presented in two ways: 1) list-method, at the beginning of the stimulus list affecting a segment of items or 2) item-method, affecting each of the items in the list separately [70]. A study of Zhang, Xie [71] used pairs of faces and images divided into 3 phases: training, TBR / TBF (Think and No-Think) and memory test. In the first phase, they were asked to remember pairs of faces / images and then make a description of the images paired with each face. In the second phase, they were shown some faces from the training phase again and they were asked to remember or forgotten the image associated with each face, indicated with a color frame as a cue. In the memory phase, they were asked again for a detailed description of the images associated with each face, regardless of whether it belonged to TBR or TBF.

1.2.4. N-Back

It is a standardized procedure to evaluate WM, where participants must indicate whether or not a stimulus coincides with a previously designated target in a variable interval, e.g. one previous trial (1-back), two trial (2- back) and so on [72]. Examples of emotional n-back include letters superimposed on emotional faces not relevant to the task [52] or emotional faces using the 2-back version where the participant must indicate if the expression is the same or different from the one presented two trials before [53].

1.2.5. Stop-signal

It is a classic inhibitory response task [73]. The participant must respond to a target each time it occurs, except when the stop-signal appears. In its emotional version, both the target and the stop-signal can have an affective component, for example emotional faces with a visual stop-signal [42, 74], affective images with an auditory stop-signal [43] or a non-emotional target with a stop-signal with emotionally aversive sound [44].

1.2.6. Stroop task

In the classic Stroop task [75], an incongruity occurs when words referring to colors (e.g., red or green) are presented with a color that does not correspond to their meaning (e.g., the word "red" of green color). People are required to identify the color of emotional and non-emotional words in emotional stroop [40]. In other variants, the emotional stroop effect is observed in a face-word paradigm, in which an emotion-related word (e.g., anger) appears on an expressive face [41].

1.2.7. AX-Continuous performance task(CPT)

The AX-CPT is a modified Continuous Performance Test [76] that was developed to examine proactive and reactive control by incorporating contextual cues that will be used to respond to subsequent items [77]. Participants must respond distinctively to a target probe (letter "X") when it occurs after the letter "A" (which serves as a contextual signal), and uniquely to all non-target probes (e.g., "A-Y", "B-X", "B-Y"). Typically, the proportion is 70% target "A-X" (dominant response) and 10% for each combination of non-target probes (non-dominant response). "B" denotes any letter other than "A," and "Y" denotes any letter other than "X" [78]. Rawls, Jabr [61] provides an example of affective AX-CPT by incorporating images with emotional valence to compare the A-X condition, conceptualized as planned action strategy, to the A-Y condition, conceptualized as change action strategy.

1.3. Research with electroencephalography (EEG)

Along with behavioral tasks, this area of research is frequently investigated physiologically via electroencephalogram (EEG) recordings, which are frequently analyzed for time-frequency and event-related potentials (ERP). This procedure aims to elucidate the topographic, functional, and temporal foundations of the affect-cognitive control relationship [66]. The EEG may aid in identifying neurophysiological processes and functional neuroanatomical networks involved in the modulation of cognitive control by affective stimuli. Additionally, electrophysiological techniques and ERPs enable the dissociation of distinct cognitive sub-processes based on their temporal occurrence, which is not possible with behavioral tasks. Additional electrophysiological techniques, such as source localization, enable the identification of brain regions associated with cognitive control dynamics.

In terms of time-frequency analysis, greater power has been observed in specific oscillations, such as the theta band associated with the presentation of words about anger/sadness [79] and the alpha band associated with affective masked priming tasks [80]. On the other hand, an increasing number of studies indicate that emotional stimuli, modulate various ERP components. N1 has been used in studies of perceptual processing, attention, congruence, fear, and positive or negative mood [65, 81]; N170 and VPP (vertex positive potential) in studies of emotional sensitivity to faces and decision making [45, 49, 82]; P2 in studies of incongruence, cognitive and emotional conflict, sadness, and anger [65, 79, 81]; P3 in studies of inhibitory response, fearful

and sad faces [32, 44, 83]; N2 has been used in studies of attention, irrelevant emotional stimuli, and emotional conflict [84, 85]; Mismatch negativity (MMN) has been used in studies of positive mood and selective attention [86]; and N400 has been used in studies of affective words [87].

1.4. Event related potential (ERP) components and frequency bands

Below, different ERP components and frequency bands that are included in the studies selected for this revision are described.

1.4.1.-CNV, ERN/Ne, Pe, and C1

The Contingent Negative Variation (CNV) is a slow negative deflection primarily in central and frontal sites, associated with attention allocation in anticipation of an expected stimulus [88]. Thus, it is a neural index of past experience of regularities (e.g. internal temporal estimates) [89] and preparatory brain activity [90]. The ERN, also known as error negativity (Ne) is an index of evaluative control [91] and reflects error monitoring [92]. It is a negative deflection with a frontocentral scalp distribution occurring approximately 50–100 ms after an erroneous response [93] and is related primarily to activity in the anterior cingulate cortex [94]. The most common tasks used to examine the ERN are the flanker and Go/No-Go tasks [95]. The error positivity (Pe) is a positive deflection that peaks between 100 and 200 ms after an erroneous response has been made. It is usually larger on trials with conscious awareness of an error, so it reflects the motivational significance of an error [96]. Thus Pe is linked to error awareness and cognitive control [97]. The C1 is the first early component (~50–100 ms time window) activated by visual stimuli, and may be identified as a negative-going component (with mastoid reference) or a positive-going component with peaks observed usually at 65–90 ms post-stimulus onset. Its topography (central occipito-parietal sites) reflects neural activities in V1 with fast peak latency, maybe earlier than feedback from later processing. Its polarity reversals with stimuli presented in upper versus lower visual fields, consistent with the cruciform organization of V1 around the calcarine fissure. Therefore, C1 changes would suggest learning-induced neural plasticity in one or more areas of the visual cortex [98].

1.4.2. P1, N1, N170, and P2

The P1 is the first positive ERP component (80–130 ms post-stimulus), and is followed by a negative wave, N1 (130–190 ms post-stimulus). They are modulated by the focus of attention and reflect sensory processing in the visual cortices. The distribution of these components is at occipital electrode sites of the contralateral hemisphere to the stimulus location. P1 and N1 are larger for stimuli presented at attended locations than stimuli presented at ignored locations. Other studies have shown that a Central N1 may index early inhibition of stimulus-activated actions [99]. Also, the auditory N1 measure early perceptual processing

and is a frontocentrally maximal component that peaks between 80 and 120 ms following stimulus onset. It can be elicited by auditory stimuli even in the absence of task demands.

The N170 is a negative posterior lateral deflection that peaks between 130 and 200 ms after stimulus onset. It has been identified as a face-sensitive neural marker [95]. Larger amplitudes have been observed for faces and emotional faces compared to objects or neutral faces, correspondingly. Its primarily neural sources are the middle and posterior fusiform gyri [100].

The P2 is a positive deflection at the frontal sites elicited approximately 200 ms following a visual stimulus and reflects selective attention following an initial perceptual processing [101]. Also, it has been shown that the P2 is enhanced by threat [102] and uncertainty [103]. The auditory P2 occurs together with N1(N1/P2 complex), and its maximum amplitude is noted in the central region with a broader range latency between 150 and 275 ms.

1.4.3. N2/P3, MMN, and N2pc

N2 is a negative deflection between 200 – 400 ms, which is considered a signature of inhibition with an anterior scalp distribution. The N2 can be divided into three subcomponents: N2a, N2b and N2c [104]. The subcomponents N2b and N2c require attention to the stimulus and always are combined with P3 components. The P3 has been one of the most studied ERP components. Its amplitude is related to stimulus task relevance and probability, and its latency reflects stimulus evaluation time. P3 can be divided into frontal P3a, associated with orienting of attention to significant or unexpected events, and parietal P3b, related to working memory updating [105]. In the field of cognitive control, P3 has been related to motor inhibition (Albert et al. 2010). N2 and P3, when studied as an inhibition index, i.e., as markers of response inhibition or response conflict, are usually elicited through the Go/Nogo paradigm with larger amplitudes on the Nogo trials. The Nogo-N2 (with frontal-midline maximum) has been related to a premotor inhibitory process that suppresses the incorrect response prior to reaction behavior. The Nogo-P3 (with a frontocentral maximum) is considered as a marker of evaluation and later monitoring of response inhibition [106].

Mismatch Negativity (MMN) is a negative component that has a frontocentral distribution, starting at the peak of a N1 and overlaps the P2. Usually, it lasts 100 to 250 ms post-stimulus and is elicited as an early auditory ERP even in the absence of attention. MMN is generated as an automatic brain response to any change in auditory stimulation exceeding a certain limit.

The N2pc is a negative going ERP component that typically appears at 150 −300 ms. It has been suggested as a more reliable measure of attention shifts [107, 108], which is maximal at posterior electrode sites contralateral to the location of an attended stimulus. It is associated with the ventral visual processing pathway [109].

1.4.4. N300, N400, and N450

The N300 is distributed frontally and occurs in response to pictures stimuli. It is thought to index rapid matching of visual input to stored semantic knowledge. The N300 is attenuated in congruent pairing relative to incongruent pairing [110]. The N400 is a component linked to meaning processing that can be observed as a negativity peaking at about 400 ms after the stimulus onset [111]. Its neural sources are related to the superior-middle temporal gyrus, the temporoparietal junction, the medial temporal lobe, and some frontal regions [112]. The experimental tasks that typically elicit the N400 are priming paradigms, manipulations of sentences or other tasks with high-level expectancy. The N450 is a negative deflection at the centro-parietal sites with a latency between 300 and 500 ms. It is detected in ERP studies of the Stroop effect and is a marker of stimulus and response conflict. The neural sources of the N450 are related to the activity of the Anterior Cingulate Cortex (ACC)

1.4.5. LPP, LPC, and LFW

The Late Positive Potential (LPP) is a late component (300–700 ms) related to facilitated attention to emotional stimuli. It has been observed that its amplitude is greater with emotionally arousing stimuli [113]. Its neural generators are located in ventral and dorsal visual areas [114]. The Late Positive Component (LPC) is similar to LPP but related to incongruent stimuli reanalysis. In recognition memory tasks it occurs around at 600 ms after stimulus onset, with a maximum peaking around 1000 ms in the left parietal lobe [115]. The Late Frontal Wave (LFW) usually is assumed as a frontal P3-like positive deflection related to encoding processes in cognitive control tasks that peak between 400 and 600 ms. It has been treated as a marker of the need of sustained recruitment of mental resources with greater amplitudes for low uncertainty and lower for high uncertainty [32].

1.4.6. Alpha and theta frequency band

The alpha rhythm is an oscillation at around 10 Hz (8–13 Hz) in the posterior cortex. Among its using in the evaluation of different tasks, the posterior-occipital alpha has been considered an index of cognitive control and an inverse measure of cortical excitability [116]. Also, it reflects attentional engagement [117], top-down adjustments of cognitive control [118]. Theta rhythm is a brain oscillation ranging from 4 to 8 Hz. Its power has been functionally related to increased Working Memory (WM) storage demands [119, 120]. Also, midfrontal theta oscillations are usually seen in tasks of cognitive control and are considered a neural marker of medial prefrontal cortex (mPFC) engagement to support goal directed control [121], [122], [123]

1.5. Purposes of this review

The present study aimed to review systematically studies carried out recently with EEG on the affective modulation (mood, emotion) of cognitive control and its different sub-processes (e.g., cognitive flexibility,

inhibitory control, working memory, etc.). This review has two primary purposes. First, the observed disparities in the results reported of the modulation of affective stimuli on cognitive control highlight an existing uncertainty about the exact nature of neurophysiological sub-processes associated with the cognitive control response. This work could potentially help to review the dynamics of the affective modulation of cognitive control and its different cognitive sub-processes. At the same time, it may address the gaps in the literature concerning these variables when studied through electrophysiological techniques. The second purpose is to review the methodological aspects of the recording and analysis of electrophysiological measures and the experimental designs and paradigms typically used in this topic. It could be a helpful foundation for future studies, enabling an evaluation of the current state of the research of affective modulation of cognitive control.

2. Method

This systematic review was conducted following the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) guidelines and its methodology [124], [125], [126]

2.1. Search strategy

The search was carried out using the online databases Web of Science (WoS) and Scopus, including articles published between January 2010 and February 2021. The search in WoS used the following terms: TS = (“cognitive control”) AND TS = ("Emotion") OR TS = ("mood") OR TS = ("affective") AND TS = ("electroencephalogram") OR TS = ("EEG") OR TS = ("event-related potential") OR TS = ("ERP") in title, abstract and keywords. The Scopus search used the same search terms for title, abstract, and keywords, TITLE-ABS-KEY ("cognitive control") AND TITLE-ABS-KEY ("emotion") OR TITLE-ABS-KEY ("mood") OR TITLE-ABS-KEY ("affective") AND TITLE-ABS-KEY ("electroencephalogram") OR TITLE-ABS-KEY ("EEG") OR TITLE-ABS-KEY ("event related potential") OR TITLE -ABS-KEY ("ERP"). Then, it was inspected to select those articles that met the selection criteria.

2.2. Inclusion criteria

The selected studies included the following criteria: 1) studies with experimental tasks involving emotional stimuli from sensory modalities (visual, auditory, or other; for example, images, words, and music) that modulate cognitive and behavioral responses of the participants, either presented lengthy (tonic, mood) or shortly (phasic, emotion), as well as before the response (proactive) or after the response (reactive). 2) Tasks or experimental paradigms that include non-emotional stimuli (before or after emotional stimuli) that inform participants of the required behavioral responses associated with cognitive control. 3) Use of EEG recording during the response to the experimental task.

2.3. Studies selection

The articles extracted from the databases (WoS and Scopus) were managed using the reference management software package Endnote. For the subsequent eligibility analysis, an Excel spreadsheet was used. Three different reviewers carried out this evaluation independently, checking the title, abstract, or the entire document if necessary. Regarding the cases in which there was not total agreement among the reviewers, the article's inclusion was resolved through a group discussion. The extraction of relevant information for the qualitative analysis of the articles included in the review was carried out with the review writing software "Review Manager" version 5.3 [127, 128]. This software provides guidelines for writing several types of systematic reviews (e.g., interventional, diagnostic, and methodological), allowing for the addition, ordering, and reference of studies, as well as the generation of flow diagrams (PRISMA) and tables, data classification, and analysis.

3. Results

3.1. Studies selected for the systematic review

The search in electronic databases yielded 3526 articles, of which 1433 were selected, after eliminating duplicates. The titles, abstracts, and full text were then read. 1342 articles were excluded based on non-compliance with at least one of the inclusion criteria. 91 articles were selected for complete analysis. Finally, 35 studies were identified and included in the systematic review and qualitative analysis. The flow diagram of this process is described in Fig. 1. Of the 35 studies reviewed, 17 different experimental tasks, 19 different ERP components, and 2 frequency band waves are included.

3.2. Participants

Concerning the participants' age range and characteristics, 71% of the studies include students or young adults, 17% older adults (two out of six studies comparing young adults with older adults), 9% children, and 3% not reported. 71% of the studies address a non-clinical population, 20% clinical (e.g., autism, attention deficit disorder, depression), and 9% other characteristics of interest (e.g., bilingual, meditation group, video game players).

3.3. Procedure, affective stimuli, and experimental tasks

Table 1 shows a description of the aims, experimental tasks, and affective induction of each study reviewed. In addition, Table 2 provides an overview of affective stimuli, experimental tasks, and cognitive control sub-

processes of the 35 studies included in the review. For a specific and detailed description of the sample, procedure, the number of block trials, software for stimuli presenting, etc., for each study, see Supplementary Material (Appendix A).

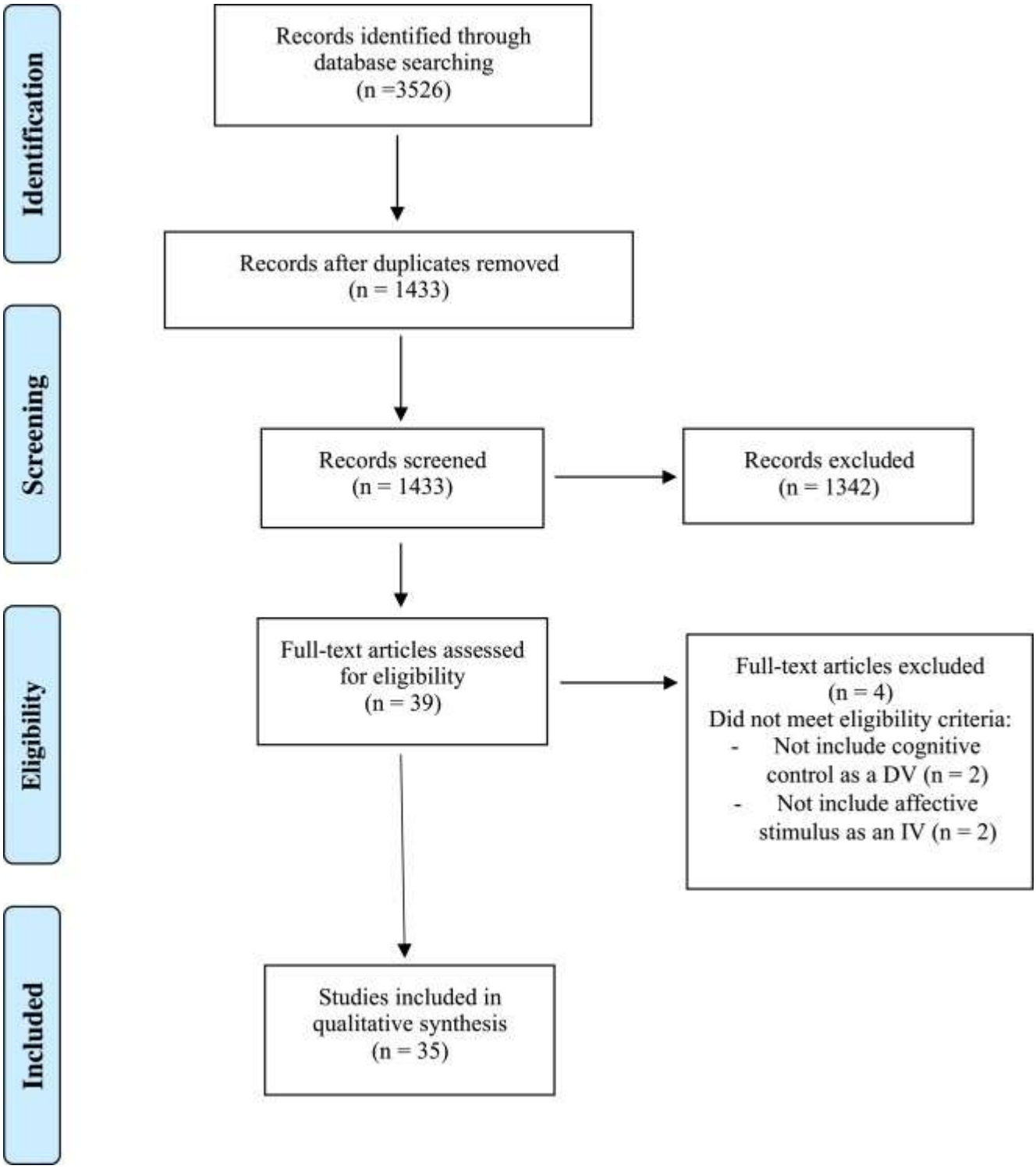

Fig. 1. PRISMA Flow diagram of the selection of the studies for this review.

Table 1. Aim and/or question, experimental task, cognitive process, and affective induction of each selected study.

Study	Aim/question	Experimental Task	CCprocess	Affective-induction
Moriya and Nittono (2011) [129]	To examine whether positive mood states would broaden the breadth of attentional focus in a flanker task as compared with neutral or negative mood states.	Eriksen Flanker Test with letters	IC1	IAPS
van Wouwe et al. (2011) [130]	Measuring probe-induced control processes that entail resolving possible interference between coactivated responses or correcting erroneous response tendencies by means of the ERP component that reflects response competition	AX-CPT	CF	Videoclip
Clayson et al. (2012) [131]	To replicate and extend previous findings that induced state negative affect alters electrophysiological reflections of performance monitoring.	Eriksen Flanker Test with letters	IC1	Affective feedback
Pinheiro et al. (2013) [132]	To examine affective modulation of semantic information processing under three different moods: neutral, positive and negative	Semantic Judgement task	Semantic judgement	IAPS
Vanlessen et al. (2013) [133]	To examine whether positive mood can causally lead to a change in the attention focus and promote early sensory stimulus processing using a standard visuospatial task	Attentional oddball detection	IC2	MIP
Vanderhasselt et al. (2014) [134]	To evaluate a condition-specific behavioral deficit, if present in MDD, mainly results from selective abnormalities during proactive control (i.e., cue-related ERP activities), or instead during reactive control (i.e., ERP time-locked to the faces), compared with a group of matched healthy control participants.	CECT	PRC	Emotional faces
Wang et al. (2014) [135]	To explore emotion regulation's influences on subsequent cognitive control during a Stroop task (emotion regulation strategies, reappraisal and suppression)	Navon global–local letter task	CF	IAPS and other images
López-Martin et al. (2015) [136]	How emotional contexts affect inhibitory control in children with ADHD.	Go / No-go task	IC1	EmoMadrid affective picture and IAPS
Owens et al. (2015) [46]	How cognitive control deficits are modulated by task demands and by the emotionality of the distractors (anxiety and attentional control theory)	Eriksen Flanker Task with faces	IC1	KDEF
Dudek et al. (2016) [137]	To examine the effects of two contrasting infant vocalizations (cries vs. laughs) on adult performance on a Stroop task using a cross-modal distraction paradigm in which infant distractors were vocal and targets were visual.	Stroop task	IC2	IADS
Farbiash and Berger (2016) [138]	To investigate the influence of a negative emotional experience – evoked by motivational manipulation – on kindergartners' IC.	Go / No-go task	IC1	Verbal instructions

Study	Aim/question	Experimental Task	CCprocess	Affective-induction
Pierguidi et al. (2016) [70]	characterizing the temporal dynamics underlining intentional memory control for neutral faces encoded with emotionally positive and negative contexts	TBR-TBF cue images	CC of memory	IAPS
Saunders et al. (2016) [139]	To investigate neural substrates of response inhibition to sad faces across explicit and implicit tasks in depressed female patients	Go / No-go task	IC1	Instructions and meditation
Zhang et al. (2016) [71]	To examine the neural correlates of the impaired memory facilitation/suppression in depressed individuals to help advance theories of depression and improve treatments for this disorder	TBR-TBF	CC of memory	IAPS
Carboni et al. (2017) [84]	To explore the interplay between exogenous attention to emotional distractors and the baseline affective state	Digit categorization task	IC2	Movie fragments
Cui et al. (2017) [140]	To investigate the time course of processing others pain under different conditions of working memory (WM) load.	Digit Span	WM	Painful pictures
Parkinson et al. (2017) [141]	How nonconscious, socially salient, and ecologically valid stimuli affect high-level volitional decisions to act or inhibit an action	Go / No-go task	IC1	Neutral, and angry faces
Putkinen et al. (2017) [86]	To investigate whether music-induced positive mood has comparable effects on selective attention in the auditory domain	Dichotic listening task	IC2	Instrumental music
Stockdale et al. (2017) [74]	Measure neural correlates of response inhibition in the context of implicit attention to emotion, and how these factors are related to empathic responding in frequent and infrequent players of video games with graphically violent content	Stop-Signal Task	IC1	Emotional faces
Yu et al. (2017) [33]	To investigate neural substrates of response inhibition to sad faces across explicit and implicit tasks in depressed female patients	Go / No-go task	IC1	The native Chinese Facial Affective Picture System
Denke et al. (2018) [50]	To examine the neural correlates underlying the attentional conflict between processing negative events and regulating behavior within a task that emulates how negative life experiences might contribute to unrestrained eating behavior	Attentional blink (AB) task	IC2	IAPS
Gallant et al. (2018) [38]	To examine age differences in the ERP correlates underlying control of memory for emotional stimuli via intentional forgetting.	TBR-TBF	CC of memory	ANEW
Hering et al. (2018) [142]	To investigate the influence of emotional material on prospective memory encoding, monitoring, maintaining, and retrieval in younger and older adults using behavioral and electrophysiological measures	n-back task and memory instructions	Verbal WM and proactive CC	IAPS

Study	Aim/question	Experimental Task	CCprocess	Affective-induction
Rawls et al. (2018) [61]	To decompose the chronology of neural mechanisms underlying the ability to effortfully-control behavior, and then explores whether deficits in these cognitive functions might then lead to aggressive behavior	AX-CPT	CF	IAPS
Senderecka (2018) [44]	1.- to test whether arousing, aversive sounds can influence inhibitory task performance and lead to increased error monitoring relative to a neutral task condition 2.- to examine whether the enhancement of error monitoring in an affective context (if present) could be predicted from stop-signal-related brain activity	Auditory Stop-signal task	IC1	Noises
Shushakova et al. (2018) [39]	To investigate attentional biases to positive and negative emotional words as possible contributing mechanisms, in adults with ADHD	Verbal dot-probe task	IC2	LANG
Wang et al. (2018) [59]	To test whether varying degrees of sadness had different effects on attention scope.	Navon global–local letter task	CF	IAPS and other images
Andreu et al. (2019) [47]	How long-term meditation practice may affect (emotional) response inhibition. Between Vipassana meditators and athletes	Go / No-go task	IC1	EmoMadrid affective picture
Barker and Bialystok (2019) [52]	Explore the relationship between working memory and non-verbal emotion regulation, both draw upon executive function mechanisms and can be affected by bilingualism	n-Back task	Verbal WM	NimStim Face Stimulus Set
Magnuson et al. (2019) [49]	To identify altered neurophysiological responses underlying inhibitory control and emotion processing difficulties in ASD	Go / No-go task	IC1	Emotional faces
Liu et al. (2020) [58]	To assess ERPs associated with food-specific inhibitory control among SRE, URE and NRE engaged in a food-related go/no-go task during negative versus neutral mood states	Go / No-go task	IC1	Videoclip
Murphy et al. (2020) [143]	To explore the mechanisms of cognitive control that allow to negotiate these competing demands between emotional stimuli and current goals.	Irrelevant-distractor task	Proactive Cognitive Control	IAPS
Nigbur and Ullsperger (2020) [37]	To investigate whether performance-independent, blocked mood inductions via mini-clips alter electrophysiological markers of performance monitoring.	Eriksen Arrow Flanker Task	IC1	videoclip
Peng et al. (2020) [32]	To investigate the modulation of behavior and brain responses to cognitive control by fearful emotional information under varying levels of uncertainty	Majority Function Task under different level of uncertainty	CC	Fearful and neutral faces

Study	Aim/question	Experimental Task	CCprocess	Affective-induction
Agudelo-Orjuela et al. (2021) [144]	Studying the bidirectional interactions between emotional language and inhibitory processes: aiming to verify whether a preestablished inhibition state (in NoGo trials) modulates the processing of emotional language	Emotional Go / No-go task	IC1	Affective sentences

Note: LFW=Late Frontal Wave; CC= Cognitive control; CF= Cognitive flexibility; tPCA= temporal principal component analysis; TFs= Temporal factors; TBR-TBF= to-be-remember or to-be-forgotten task; AX-CPT= Action change task (A-X or A-Y) continuous performance task; IC1=Inhibitory control response-inhibition; IC2= Inhibitory control Interference control; WM= Working memory; CF= Cognitive flexibility; IAPS= International Affective Pictures System; KDEF= The Karolinska Directed Emotional Faces, Affective Norms for English Words; LANG= Leipzig Affective Norms for German; IADS= International Affective Digital Sounds; CECT= the Cued Emotional Conflict Task; PRC=Proactive and Reactive Control; MIP= Mood induction Procedure.

Table 2. Summary of characteristics(affective stimuli, experimental task, and cognitive control subprocesses) of the studies included in this review.

Dimensions	Empty Cell	%
Affective stimuli[1]		
	Visual stimuli	**80**
	Images	**37**
	Faces	**22**
	Video clips	**14**
	Words or phrases	**7**
	Auditory stimuli tones, pieces of music, cry/laughing sounds, and verbal instructions (relaxation, imagery).	**20**
	Emotion-induction/Mood-induction	
	Affective pictures (IAPS, EMAPS)	**32**
	Emotional faces (NSFSS, KDEF, AR, NCFAPS)	**24**
	Sounds/music/instructions	**18**
	Excerpts from self-created video clips (IADS)	**12**
	Words or phrases (LANG, ANEW, BAWL-R)	**8**
	Unspecified	**6**
	Valence	
	PO + NE + Ne	**49**
	PO + NE	17
	PO + Ne	**17**
	NE	**9**
	NE + Ne	**8**

Dimensions	Empty Cell	**%**
Experimental Tasks[2]		
	Go/No-go task	**26**
	Eriksen Flanker Test	**11**
	TBR-TBF	**11**
	n-Back task	**5,7**
	Stop-signal task	**5,7**
	Stroop Task	**5,7**
	AX-CPT	**5,7**
	Other behavioral tasks (AB task, VDP, NG-L, D-S, D-C, C-E, ODD, ID, and M-F)	**28**
Cognitive Control sub-processes		
	Response inhibition	**42**
	Interference control focused/selective attention	**20**
	switching and change of perspective	**9**
	Verbal/visuospatial WM	**9**
	Cognitive control of memory	**9**
	Proactive cognitive control	**5**
	Semantic judgment	**3**
	Cognitive control	**3**

[1]IAPS= International Affective Pictures System; EMAPS= EmoMadrid Affective Pictures System; NSFSS= NinStim Face Stimulus Set; KDEF= The Karolinska Directed Emotional Faces, AR= Aleix Martinez and Robert Benavente face database, NCFAPS= Native Chinese Facial Affective Pictures System; IADS= International Affective Digital Sounds; LANG= Leipzig Affective Norms for German; ANEW= Affective Norms for English Words; BAWL-*R*= Spanish version of the Berlin Word List Reloaded; PO= positive; NE= negative; Ne= neutral.
[2]TBR-TBF= to-be-remember/to-be-forgotten; AX-CPT= AX-continuous performance task; VDP= Verbal Dot Probe Task; NG-*L*= Navon global-local letter task; D-*S*= digit-span; D-C= digit-categorization; C-*E*= cue-emotional conflict task; ODD= completing words and attentional oddball detection; I-*D*= The Irrelevant-Distractor task; M-*F*= Majority-Function Task.

3.3.1. Cognitive control sub-processes

The CCs sub-processes measured (Table 1) were mostly response inhibition (42%), and interference control focused/selective attention (20%). The other processes included switching and change of perspective (9%), verbal/visuospatial WM (9%), CC of memory (9%), proactive CC (5%), semantic judgment (3%), and cognitive control (3%). The cognitive tasks included did not crossload onto different CC sub-processes.

3.3.2. Number and sequence of presentation of blocks and trials

The number of blocks and trials of the experiment's formal execution are dissimilar among the reviewed studies. Experiments with one and up to 30 blocks were designed to carry out the entire experimental task.

The most typical number of blocks was three (26% of studies) or four (14%). 80% are between 1 and 8 blocks, and 20% used nine or more blocks. The total number of trials is diverse, in a range of 120 to 2100. However, 77% of the studies are between 201 and 800 trials, with 11.5% of studies with 801 trials or more and 11.5% with 200 trials or less. The procedure of the 11 mood-induction studies is mainly based on the use of excerpts from video clips/films (14.2%), images (8.5%), instructions/words (5.7%), or musical pieces (2.8%) with heterogeneous durations ranging from 2 s to 9 min. In line with the idea of induction, all stimuli are shown before starting the experimental block (Go/No-go, arrow flanker test, categorization digit, dichotic listening task, Stroop task, AX-CPT oddball detection, and completing words). Only one of the studies used visual stimuli of positive or negative valence simultaneously within the same experimental block (Eriksen arrow flanker test).

3.3.3. Behavioral measures

Behavioral measures of reaction time (RT) are the most used in the studies (85%), then accuracy (ACC) 51%, and error rate (ER) 23%. Response times were collected only for accurate trials in studies that included paradigms with correct and incorrect response options.

3.3.4. Software used

A 42% of the studies did not report the software used to design the experiment. The remaining studies reported using E-Prime Professional (34%), Inquisit Millisecond Task Programming (9%), Neurobehavioral System Inc. Presentation (6%), DMDX (6%), and Matlab MathWorks (3%).

3.3.5. Study design

A 77% of the studies do not explicitly report the type of research design, so they do not describe the factors and levels of emotional inducers and experimental tasks, cognitive control processes (e.g., CF, IC, WM), behavioral measures, and/or classification within/between-subject. The 23% who did report it mainly indicate within-subject design with repeated measures.

3.4. EEG measures

For a specific and detailed description of the acquisition and pre-processing of the EEG signal for each study, see Supplementary Material (Appendix A).

3.4.1. Type of EEG measurement and / or analysis

A 97% of the reviewed studies analyzed ERP components (See Table 3). Only one study performed exclusively alpha wave analysis. In addition to ERP analysis, some of the papers added source localization

analysis (20%), time-frequency analysis of theta and alpha wave (11%), and analysis of electrodermal activity (5%).

Table 3. Number of studies reviewed for each ERP/wave.

ERP/Wave	N of studies	Author and year of each study
N2	24	Agudelo-Orjuela, 2021; Andreu, 2019; Carboni, 2017; Clayson, 2012; Cui, 2017; Denke, 2018; Farbiash, 2016; Hering, 2018; López-Martin, 2015; Liu, 2020; Magnuson, 2019; Moriya, 2011; Nigbur, 2020; Owens, 2015; Parkinson, 2017; Peng, 2020; Pierguidi, 2016; Rawls, 2018; Stockdale, 2017; van Wouwe, 2011; Wang, 2018; Yu, 2017; Zhang, 2016 [32, 33, 37, 46, 47, 49, 50, 58, 59, 61, 70, 71, 74, 84, [129], [130], [131], 136, 138, [140], [141], [142], 144]
P3	17	Agudelo-Orjuela, 2020; Andreu, 2019, Barker, 2019; Liu, 2020; López-Martin, 2015; Magnuson, 2019; Moriya, 2011; Peng, 2020; Pierguidi, 2016; Putkinen, 2017; Rawls, 2018; Senderecka, 2018; Stockdale, 2017; Vanlessen, 2013; van Wouwe, 2011; Wang, 2018; Yu, 2017 [32, 33, 44, 47, 49, 52, 58, 59, 61, 70, 74, 86, 129, 130, 133, 136, 144]
N1	7	Carboni, 2017; Cui, 2017; Hering, 2018; Moriya, 2011; Pierguidi, 2016; Putkinen, 2017; Senderecka, 2018 [44, 70, 84, 86, 129, 140, 142]
ERN	6	Clayson, 2012; Nigbur, 2020; Saunders, 2016; Senderecka, 2018; van Wouwe, 2011; Wang, 2014 [37, 44, 130, 131, 135, 139]
LPP	5	Carboni, 2017; Cui, 2017; Gallant, 2018; Hering, 2018; Pierguidi, 2016 [38, 70, 84, 140, 142]
P1	5	Moriya, 2011; Shushakova, 2018; Stockdale, 2017; Vanlessen, 2013; Wang, 2018 [39, 59, 74, 129, 133]
Pe	5	Clayson, 2012; Nigbur, 2020; Saunders, 2016; Senderecka, 2018; Wang, 2014 [37, 44, 131, 135, 139]
N170	3	Barker, 2019; Magnuson, 2019; Stockdale, 2017 [49, 52, 74]
Theta wave	3	Andreu, 2019, Farbiash, 2016; Parkinson, 2017 [47, 138, 141]
P2	2	Dudek, 2016; Rawls, 2018 [61, 137]
N450	2	Dudek, 2016; Wang, 2014 [135, 137]
C1	1	Vanlessen, 2013 [133]
N300	1	Hering, 2018 [142]
N400	1	Pinheiro, 2013 [132]
MMN	1	Putkinen, 2017 [86]
N2pc	1	Shushakova, 2018 [39]
CNV	1	van Wouwe, 2011 [130]
LPC	1	Zhang, 2016 [71]
LFW	1	Peng, 2020 [32]
Alpha wave	1	Murphy, 2020 [143]

3.4.2. EEG equipment or system

The equipment and amplifiers used for recording brain electrical activity were mainly BioSemi (31%), Brain Products (20%), Geodesic Sensor Net (17%), and Neuroscan SynAmps (14%). The remaining 18% includes ElectroCap International, g.Nautilus EEG systems, ANT Neuro, ASA acquisition hardware, and EEG1100 Nihon-Kohden.

3.4.3. Coordinate system and number of electrodes

A 49% of the studies do not specify the coordinate system used. 51% of the remaining studies used the 10/20 coordinate system. The number of electrodes most used in the studies was 64, 128, or 32 (34%, 22%, and 14%, respectively), the remaining 30% show a different number than the standard (8, 11, 24, 26, 28, 30 or 63). The auxiliary electrodes used were preferably electrooculogram (EOG) in 82% of the studies. The most used combination of auxiliary electrodes (57%) was two horizontal EOG (HEOG) and two vertical EOG (VEOG). Some studies did not report this specific information (18%), and the remaining 25% show different combinations with at least one VEOG alone or combined with one HEOG and up to four VEOG.

3.4.4. Reference, sample rate and baseline

The most widely used on-line reference and off-line re-reference electrodes were the mastoids, with 37% and 51%, respectively. Regarding other on-line references, various channels are included, such as Cz, TP10, C3 or C4 (24%), Common Mode Sense (21%), ear lobes (6%), nose tip (6%). A 6% did not report the on-line reference. Other off-line re-references used were common average (25%), ear lobes (3%), and nose tip (3%). 18% did not report the re-reference. The sampling rate in 80% of the studies was between 210 Hz to 512 Hz. The most used sample rates were 512 Hz (25%), 500 Hz (22%), and 250 Hz (20%). A sampling rate from 1000 to 2048 Hz was found in 20% of the studies. The most widely used baseline was pre-stimulus onset in 80% of the studies, with 51% standing out with 200 ms pre-target. The remaining 20% use a baseline pre-cue onset (6%) and pre-response onset (6%). 8% of the studies did not report the characteristics of the baseline used.

3.4.5. Filters

In terms of online filters, 37% of papers did not mention their use. It's worth noting that some amplifiers include inbuilt filters, which means that researchers utilizing these amplifiers may not report an additional filter but may actually have one installed at the hardware level. 45 percent of studies report using a high-pass filter (HPF) between 0 and 0.05 Hz, while 11% report using one between 0.1 and 0.3 Hz. The most frequently used on-line low-pass filter (LPF) frequencies were 100 Hz (23%), 40 Hz (8%), and 70 Hz (8 percent). Finally, 40% used a 0.1 - 0.5 Hz filter for off-line pre-processing using HPF. 24 percent in the 0.01 - 0.05 Hz range, and 4% at 2 Hz. 32% did not report using HPF. The most often utilized off-line LPF

frequency was 30 Hz (46 percent). 60% used a filter between 12 and 30 Hz, whereas 21% used a filter between 40 and 61 Hz. 19% did not report using LPF.

3.4.6. Artifacts and method of correction or rejection

The main artifacts detected in the pre-processing of the signal are the movement of the eyes or blinking (74% of the studies), changes in the amplitude of the signal (peak-to-peak deflections) above/below a threshold set to μV (63%), other channels, line, or clipping noises (31%) and muscle activity (14%). In addition to ocular inspection, the main method used for the rejection or correction of artifacts (e.g., ocular, muscular, noise) was the Independent Component Analysis (ICA) in 34% of the studies. The application of other methods, such as the one used by Gratton et al. (1983), was observed in 17% of the studies, and Principal Component Analysis (PCA), in 3% of them.

3.4.7. Epochs

Most of the studies segmented the data into epochs around the stimulus or target (69%). The most common epoch was between −200 ms pre-stimulus (51%) and 1000 ms (20%) or 800 ms (20%) after stimulus onset. The remaining 31% were segmented associated with a cue, response, or specific ERP components (e.g., ERN, N2, and N450), or were not reported.

3.4.8. ERP components and frequency bands

Table 3 provides an overview of 18 ERP components and 2 frequency bands with alpha or theta waves of the 35 studies included in the review.

3.4.9. Time-windows and topography

Table 4 describes the Time Windows and specific topography for each of the studies analyzed. Also, complementary information is included regarding the artifact rejection, epochs, statistical analysis, among others.

Table 4. ERP/oscillation, analysis, software and main results of each study in this review.

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
Moriya, 2011 [129]	P1, N1, N2 and P3	Ocular artifacts were corrected by the method ofGratton, Coles, and Donchin (1983) implemented in	NR	P1 – N1 as mean amplitudes of 80–130 ms and 130–190 ms.	P1-N1: left and right occipitotemporal electrode sites (PO7/8), respectively. N2-P3:	NR	Greenhouse–Geisser epsilon.	RM ANOVAs,	NR	Brain Vision Analyzer 1.05	NR	P1 amplitude is larger in the positive mood than neutral and negative. N1smaller in positive mood than negative.

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
		Brain Vision Analyzer 1.05 (Brain Products, Germany).		N2 – P3: as mean amplitudes of 250–350 ms and 350–600ms	frontocentral electrode site (FCz) and at the parietal electrode site (Pz), respectively,							N2 and P3 are larger in incompatible trials than incompatible trials (but not significantly different according to mood),
van Wouwe, 2011 [130]	P3b, CNV, N2, ERN	EEG was corrected for ocular artifacts (Gratton, Coles, & Donchin, 1983)	NR	P3b 240 to 610 ms after for A cues 350 to 640 ms for B cues CNV: −200 msec to 0 ms before the probe. N2: 230 to 300 ms after the probe ERN: 0 to 100 ms after the response	P3b: electrode site Pz CNV: site Cz; Probe-locked N2 mean amplitudes over FCz, Fz, FC3, and FC4 ERN: over FCz, Fz, FC3, and FC4	NR	NR	RM ANOVAs,	NR	NR	NR	The cue-related P3b was unaffected by positive affect, whereas the ERN and N2 amplitude decreased in AY trials and the N2 remained equal for both affect conditions in BX trials. CNV is not significantly different in both groups, although shows more proactive preparation in the positive affects group.
Clayson, 2012 [131]	ERN, Pe and N2	Eye movement and blink artifacts were corrected using the Gratton et al., (1983) algorithm.	ERN and Pe:-400 ms before to 600 ms after response onset N2:-250 ms before to 500 ms after stimulus onset	200 ms time window from 400 to 200 ms before the response for baseline correction	ERN and N2 amplitudes were averaged across four fronto-central electrode sites [numbers 6 (FCz), 7, 106 and Ref (Cz) Error-trial and correct-trial Pe amplitudes were extracted as the mean amplitude from 200 to 400 ms post-response across seven centro-parietal electrode sites [Cz, 31, 54, 55 (PCz), 62 (Pz), 79 and 80].	NR	Huynh–Feldt epsilon adjustment	2x(Group) x 4(time) x 2(accuracy) Mixed-Model ANOVA. T-Test, Pearson's Correlations	NR	NR	NR	Increases in vigilance were associated with more negative N2 amplitudes. No other changes in affective states were associated with changes in ERP measures. Changes in negative affective state did not alter early error-detection, error-awareness or conflict-monitoring processes as indexed by the ERN, Pe and N2 components of the ERP.
Pinheiro, 2013 [132]	N400	Eye blink and movement Gratton et al. (1983, BrainVision Analyzer package). Trials containing excessive eye movements, blinks, muscle activity or amplifier blocking	Individual ERP epochs for each target type were constructed with 150 ms pre-stimulus baseline and 1000 ms	300–500 ms post-stimulus latency window	N440 mean voltage at frontal (Fz, F1/2, F3/4), central (Cz, C1/2, C3/4) and parietal (Pz, P1/2, P3/4) regions.	NR	NR	3x(Mood), 3x (Sentence Condition), 3x(Regions), 5x(electrodes) MANOVA.	NR	Brain Vision Analyzer	NR	Neutral mood: least negative N400 was associated with EW, most negativeness for unexpected word from different category. Positive mood: decreased N400 amplitude for WCV resulting in a lack of a difference between EW and WCV. Negative mood: N400 to WCV and BCV had similar amplitude

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
		voltage exceeding 80 μV	epoch after the stimulus onset.									
Vanlessen, 2013 [133]	C1, P1 and P3	Eye-blink (Gratton, Coles, & Donchin, 1983). Epochs of the EEG containing residual artifacts exceeding ±75μV were semiautomatically rejected.	Stimulus-locked epochs from 100 ms pre- to 800 ms post-stimulus-onset.	C1: 95–115 ms post-stimulus-onset. P1: 165–185 ms poststimulus-onset. P3: 400–600 ms post-stimulus-onset	Topographies corresponding to C1, P1 and P300	NR	Greenhouse–Geisser correction	2 (SimulusType) x 3 (maps config) x 2 (Mood) Mixed ANOVA	NR	Brain Vision Analyzer 2.0	NR	C1 amplitude is greater in positive than neutral mood in all the 3 locations (close, medium, far). P1 larger with positive mood, but sensitive to the content more than to the position of the targets. P300 does not differ in the two moods but it's influenced by task's demand.
Vanderhasselt, 2014 [134]	P1 N170 P2 N2 P3 CNV	vertical ocular correction for blinks (Gratton, Coles, & Donchin, 1983) using the difference amplitude of two electrodes attached above and below the left eye, (4) artifact rejection [*M*= 84.47 trials, SEM = 1.98 amplitude scale (|xV) across participants: no difference between ND (*M*= 86.32 trials, SEM = 2.56) and MDD patients (*M*= 82.63 trials, SEM = 3.04) was evidenced; / = 0.93, *p* = .36],	CUE - 250 ms before to 800 ms after cue onset TARGET: - 500 ms before to 2000 ms after target onset	A spatio-temporal cluster analysis was performed on a large time-window (2000 ms) encompassing P1, N170, P2, N2, P3	Topography mapping analysis of the ERP data through a K-means cluster method. sLORETA for source localization analysis.	NR	NR	2(Group) x 2(Emotion) x 2(Cue) mixed ANOVA (behavioral data) Mixed ANOVA (ERP)	NR	CARTOOL software (Version 3.34; developed by D. Brunet, Functional Brain Mapping Laboratory, Geneva, Switzerian)	NR	Longer duration of a dominant topography (bilateral dorsal medial frontal areas, with a spread towards ventral medial frontal sides, including the ACC) for an incongruent (sad) condition with respect to the other conditions in MDD patients, who also show decreased CNV amplitudes in all conditions with respect to Control Group.
Wang, 2014 [135]	ERN/Pe N450	artifact rejection excluded all epochs containing a voltage step of more than 50 mV between sample points, a voltage difference of 300 mV within a segment, and a maximum voltage difference of less than 0.50 mV within 100 ms intervals.	ERN/Pe: - 400 ms before to 800 ms after stimulus onset N450:- 200 ms before to 1000 ms after stimulus onset	ERN: mean amplitude from 20 ms before response and 50 ms after response Pe: mean amplitude from 220 to 400 ms N450: mean amplitudes between 420 and 550 ms after stimulus	ERN: FCz Pe: Pz N450: FCz, Cz, and CPz	NR	NR	ANOVA (behavioral data and ERP)	NR	‘‘Vision Analyzer’’ software (Brain Products, Munich, Germany).	NR	Suppressing of emotions during sad movies showed reduced ERN after error commission, and is related to more errors in incongruent Stroop trials. There were no significant main effects or interactions of group for reaction time, Pe and N450.

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
López-Martin, 2015 [136]	N2 P3	Epochs containing eye movements or blinks over 100 μV in amplitude were deleted.	-200 ms before to 1000 ms after stimulus onset	Factor peak latency determined by tPCA N2: 310 ms P3: 465 ms	Frontocentral N2 and frontocentral P3	NR	Greenhouse–Geisser (GG) epsilon correction Bonferroni correction	ANOVA (behavioral data and ERP)	SPSS software package (version 20; SPSS Inc., USA).	NR	NR	Altered emotional modulation of response inhibition in children with ADHD, indexed by a hyper-activation of inhibition-related mechanisms (no-go P3)
Owens, 2015 [46]	N2	Independent component analysis (ICA) to identify stereotypical ocular, muscle, and noise components (Jung et al., 2001). Then Artifact detection and rejection on epoched uncorrected data files.	NR	N2: averaged component between 215 ms to 275 ms	N2: 12 frontal sites: Fp1, Fp2, F3, F4, Fz, FC1, FC2, FCz, F1, F2, FC3, and FC4.	NR	Greenhouse-Geisser correction	ANOVA (behavioral data and ERP)	NR	MATLAB	EEG Lab ERP Lab	N2 amplitudes were larger under high-load conditions. Under high but not low load, trait worry was associated with greater N2 amplitudes.
Dudek, 2016 [137]	P2 N450	Segment in which the signal exceeded 150 μV were identified as bad channels, 140 μV as eye blinks, and 40 μV as eye movements.	-100 ms before to 1000 ms after stimulus onset	P200: 128–260 ms N450: 350–550 ms	Frontal central electrodes	Shapiro-Wilk	ERP data was winsorized to restore a normal distribution Bonferroni correction for multiple comparisons.	Multiple regression analysis Pearson correlations eta-squared function fir effect sizes ANOVA Paired t-tests MANOVA: exp.1 vs exp.2	NR	Net Station (4.0)	Net Station artifact detection tool.	Cries more than laughs reduced attention to the task (smaller P200) and increased conflict processing (larger N450), albeit differently for incongruent and congruent trials. Amplitudes of P200 and N450 were inversely related, suggesting a reciprocal relationship between attention and conflict processing.
Farbiash, 2016 [138]	N2 Theta SL	Automatic artifact detection for bad channels and/or eyeblinks	-200 ms before to 680 ms after stimulus onset	N2 and Theta Power (4–8 Hz): 250 −400 ms	Frontal N2 and Theta Power: 9 electrodes around FCz and Fz	NR	Greenhouse-Geisser's correction	GLM one-way repeated measures ANOVA (behavioral data and ERP)	STATISTICA-Windows version 9.2 (Statsoft, Tulsa, OK)	NR	NR	Inhibition of No-go trials was associated with larger N2 amplitudes and theta power. Negative emotional experience resulted in better IC performance and larger theta power. Band power more sensitive to IC Source: Posterior frontal regions
Pierguidi, 2016 [70]	Face and emotional scene (encodi	All epochs contaminated with ocular artifacts greater than 40	-200 ms before to 1000 ms	Early LPP: 400–550 ms LPP: 550–800 ms	LPP: Fronto-parietal electrodes. N1: fronto-	Shapiro-Wilk Test (onl	Greenhouse–Geisser correction,	ANOVA (behavioral data and ERP)	NR	NR	NR	LPP greater amplitude for negative images compared to neutral (encoding) N1 enhanced in processing

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
	ng): LPP Recognition: N1 (automatic attentional processes) N2 (intentional memory suppression) P3 (attentional deployment toward memory enhancement)	μV were automatically rejected. Then, visual rejection of muscle noise and alpha wave intrusions.	after stimulus onset	N1: 100–180 ms N2: 270–330 ms P3: 330 −450 ms	central sites N2: sites NR P3: sites NR	y for behavioral data)	Bonferroni correction (for post-hoc tests)					TBF cues following faces in negative scenes compared to those following faces in positive scenes
Saunders, 2016 [139]	ERN/Pe	Eye blinks correction: Regression based procedures; Automatic procedures: a voltage more than 25μV between sample points, a voltage difference of 150μV within 200-ms intervals, voltages above 85μV and below −85μV, and a maximum voltage difference of less than 0.05μV within 100-ms intervals.	-200 ms before to 800 ms after stimulus onset	ERN: Amplitude distance between the maximum negative peak following (0 to 120 ms) and the positive peak preceding (−80 to −20 ms). Pe: the mean amplitude 200–400 ms after mistakes at an electrode.	ERN: FCz Pe: Pz	NR	NR	RM-ANOVA (behavioral data and ERP) Partial eta-squared for ANOVA effect sizes (behavioral data and ERP) ANCOVA for RT and error differences controlling (behavioral data)	NR	NR	NR	Mindfulness meditation boosts early neural performance monitoring (ERN amplitude), specifically influencing on affective processing.
Zhang, 2016 [71]	N2 LPC	Ocular artifacts were removed from EEGs using a regression procedure implemented in software. Trials contaminated with large artifacts (peak-to-peak deflection exceeded± 100μV) were excluded	-200 ms before to 1700 ms after stimulus onset	N2: 190 −230 ms after the cues onset. LPC: 500 to 800 ms post stimulus.	Frontal N2 (Fz, FCz, F1 and F2) Parietal LPC (Pz, CPz, P1 and P2)	NR	Greenhouse–Geisser correction, Bonferroni correction (for post-hoc tests)	RM-ANOVA (behavioral data and ERP)	NR	NeuroScan software (Scan 4.3).	NR	Frontal N2 (reflecting voluntary memory inhibition) and parietal late positive component (LPC) (reflecting conscious recollection) showed deflection for negative items in depressed compared with nondepressed participants.

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
		from the averaging.										
Carboni, 2017 [84]	N1 N2 LPP	Outlier trials (responses before 250 ms or after 2000 ms), erroneous trials, and trials with no response were excluded ICA: Ocular artifact removed	-200 ms before to 800 ms after stimulus onset	Temporal factors (TFs) were extracted from the ERPs, explaining 85% of the total variance: N1 (TF4): 90 ms N2 (TF5): 294 ms LPP (TF1): 563 ms	P1, N2, LPP: Cz, Pz	NR	Bonferroni (post hoc test)	Two-way RM-ANOVA (behavioral data) Two-way RM ANOVA (ERP)	SPSS 19.0 software package	NR	Fieldtrip.	N1. Amplitudes were significantly greater when the participants' state was emotional (negative and positive) than when it was neutral N2. Positive distractors, rather than neutral ones, elicited more negative amplitudes at fronto-central sites. Negative and positive distractors, compared to neutral ones, at parieto-occipital sites. LPP. Negative mood state: amplitudes in response to positive distractors were greater than to neutral ones. Neutral state: negative distractors elicited greater amplitudes than neutral ones. Positive mood state: both negative and positive distractors elicited higher amplitudes than neutral ones. The difference of negative versus neutral distractors varied significantly from the negative to the positive mood
Cui,2017 [140]	N1 N2 LPP	ICA Components representing artifacts were identified using the ADJUST (an automatic algorithm for artifact identification in EEG data). Epochs with amplitude values exceeding + 50μV at any electrode were excluded from the average.	-200 ms before and 1000 ms after the onset of the picture	N1: 90–140 ms N2: 220–280 ms LPP: 550–750 ms	N1/N2: FC3, FCz, FC4, C3, Cz and C4 LPP: C3, Cz, C4, CP3, CPz and CP4	NR	Greenhouse–Geisser (ANOVA) Bonferroni-corrected (post-hoc)	RM-ANOVA (behavioral measure) RM-ANOVA (ERP)	IBM SPSS Statistics 22 (IBM Corp.)	Matlab R2011b	EEGLAB toolbox	N1. The interaction of WM-load × Picture, WM-load × Site and Picture × Site were not significant. N2. High WM-load, the painful pictures elicited significantly larger amplitudes than the non-painful pictures. Low WM-load, there was no significant difference between the painful and non-painful pictures. LPP. High WM-load, the painful pictures elicited significantly larger amplitudes than the non-painful pictures. Low WM there was no significant difference between the

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
												painful and non-painful pictures.
Parkinson, 2017 [141]	N2 Theta power	Eye movement or blink artefacts, signals from vertical EOG electrodes were filtered using a two-pass finite impulse response (FIR) band-pass filter between 1 and 15 Hz, and then examined for signals that exceeded a± 100 μV threshold. EOG signals exceeding this threshold were marked as potential ocular artefacts, and any trials during which such artefacts occurred between −100 and 600 ms relative to target onset were excluded from further analysis	time locked to the onset of the target stimulus	N2: 50 and 300 ms relative to target onset Theta: from target onset until 500 ms after target onset	N2: Fz, FCz, Cz, CPz, and Pz	NR	NR	RM-ANOVA (behavioral data) RM-ANOVA (ERP)	MATLAB and Statistics Toolbox Release 2014b	MATLAB	Field Trip software toolbox	N2 magnitudes were not modulated by subliminal emotional primes (angry vs. neutral faces).
Putkinen, 2017 [86]	N1/MMN P3a P3b	Epochs with large, idiosyncratic artifacts were identified by eye and removed before an ICA. Components due to eye blinks and horizontal eye movements were removed and epochs with amplitudes exceeding ±100 μV were discarded.	−100 to 400 ms relative to stimulus onset	N1/MMN (early sound encoding): 100–150 ms P3a (bottom-up attention capture): 225–275 P3b (top-down-controlled processing of task-relevant stimuli): 350–400	MMN and P3a: frontal C18, C19, C20 and C21/Fz and central A1/Cz, A2, A3 and A4. P3b. A19/Pz, A20, A21 and A22	NR	False discovery rate procedure (Benjamin and Hochberg, 1995)	Mixed RM-ANOVA (within emotion / between group) Univariate ANOVA (ERP)	NR	NR	EEG Lab (Delorme and Makeig, 2004)	For the distractor sounds N1/MMN was significantly larger for the subjects in the Happy condition than for those in the sad or neutral conditions. P3b of the subjects in the Happy condition was smaller at a trend level than the P3b of the subjects in the Sad and Neutral Conditions
Stockdale, 2017 [74]	P1 N170 N2 P3	A spatial PCA filter was applied to correct for ocular artifacts. EEG contaminated with muscle or movement artifacts were identified by visual inspection and removed from the raw EEG signal and a	For the go-trials the ERP epoch was time locked to face-onset (Face ERP), while for stop-trials the	P1: 70 to 140 ms N170: 140–200 ms N2/P3: 140–400 ms	P1: N170: T5 and T6 N2/P3: Cz	NR	NR	Mixed-model ANOVA (behavioral data) Two-mixed-model ANOVA (ERP)	NR	NR	NR	Go-trials: Mean amplitude and 50-percent area latency scores (P1-N170) - P1: Amplitude was decreased for frequent players of graphically violent video games compared to infrequent players. Frequent players of graphically violent video games had reduced P100

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
		100 mV trial-by-trial rejection criterion was applied during averaging.	ERP epoch was time locked to the stop-signal onset (Stop ERP).									amplitudes evoked by happy facial expressions than infrequent players. Latency: afraid facial expressions evoking later latencies than happy facial expressions. Participants were slower to disengage their attention from afraid facial expressions or afraid facial expressions capture attention later than happy facial expressions. N170: amplitude evoked in response to afraid facial expressions was larger compared to happy facial expressions. Infrequent players of graphically violent video games had faster latencies for afraid facial expressions compared to happy facial expressions Stop trial: amplitude and latency (N2/P3) Frequent players of graphically violent video games had a reduced mean amplitude compared to infrequent players of graphically violent video games The group - valence interaction was not significant.
Yu, 2017 [33]	N2 P3	Ocular artifacts were removed from the EEG signals using a regression procedure implemented in Neuroscan software. Trials with remaining EOG artifacts, amplifier clipping artifacts, or peak-to-peak deflections exceeding ± 100 μV were excluded from averaging.	-200 ms before to 1000 ms after stimulus onset	N2: 250–350 ms P3: 500–600 ms	N2 and P3: F3, Fz, F4, C3, Cz, C4, P3, Pz, and P4	NR	Greenhouse–Geisser (ANOVA) Bonferroni (multiple comparisons)	three-way mixed design ANOVA (behavioral data) A five-way mixed design ANOVA (ERP data)	NR	NR	NR	N2: No-go stimuli elicited larger N2 amplitudes than go stimuli, which were smaller in the sad than in the neutral condition. Largest at FCz electrode sites, were mainly distributed in central prefrontal areas P3: amplitudes were larger in the sad than in the neutral condition. The depression group showed smaller P3 amplitudes than controls. Amplitudes induced by sad stimuli were significantly larger than that induced by neutral stimuli in no-go condition. Amplitudes induced by sad stimuli were significantly larger than that induced by neutral stimuli in no-go condition in control group. Sad faces elicited larger P3 amplitudes than neutral

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
												faces, and the depression group showed smaller P3 amplitudes than the control group
Denke, 2018 [50]	N2	Eye blink artifacts, the threshold was set to 140 µV threshold (peak-to-peak) and all trials in which this threshold was violated were excluded from analyses.Signal activation change (peak-to-peak) exceeding 100 µV across the entire segment were marked as bad and interpolated.	Time-locked to the T2	N2: 340–470 ms after T2 stimulus	N2: Medio-frontal FCz	NR	NR	regression analyses (anxiety and emotion) t-tests RM-ANOVA (behavioral data) Linear regression analyses (ERP)	NR	EGI software (Net Station; Electrical Geodesics, Inc., Eugene, OR, United States)	NR	N2 activation moderates the association between anxiety and emotional-eating behavior. Interaction anxiety combined with more negative N2 activation can contribute to emotional-eating behavior.
Gallant, 2018 [38]	LPP	ICA Included components indicative of horizontal (e.g., saccades) or vertical eye movements (e.g., blinks).	-200 ms before target/cue onset and 800 ms after target/cue	LPP word-based: 600–900 ms LPP Cue-based parietal: 350–550 ms LPP cue-based frontal: 150–250 ms, 350–550 ms, 600–800	LPP word-based: P1, Pz, and P2 LPP cue -based: P1, Pz, P2, AF4, Afz, and AF3	NR	Bonferroni	RM-ANOVA (behavioral data) RM-ANOVA (ERP)	IBM SPSS version 24 (IBM Corp., 2014).	MATLAB R2015b	EEG LAB (version 13.5.4b) and ERP LAB toolboxes (version 5.1.1.0).	LPP was greater for negative than positive words in younger adults, older adults showed a reduced LPP for negative versus positive items. Younger and older adults are able to forget information intentionally that varies in emotional valence but that the neural mechanisms underlying these processes may change with age.
Hering, 2018 [142]	LPP N1, N2, N3	ICA (algorithm from the EEGLab toolbox). Activity above of ±75 µV were excluded.	-200 ms before stimulus onset and 2400 ms after stimulus onset. *Re*-segmented from –200 ms before stimulus onset until 1400 ms after stimulus onset for stimuli with correct	LPP: 600 and 1200 ms after stimulus onset	Fp1, Fpz, Fp2, F7, F3, FZ, F4, F8, FC3, FCZ, FC4, T7, C3, CZ, C4, T8, CP3, CPZ, CP4, P7, P3, PZ, P4, P8, PO3, POZ, PO4, O1, OZ, O2	NR	Greenhouse-Geisser (behavioral data, ANOVA) Bonferroni (behavioral data, t-test)	Mixed-ANOVA (between group, within behavioral data) Partial least square (PLS) for ERP	NR	Matlab (Version R2016, MathWorks, Natick, MA, United States). PLSGUI for Matlab	EEG Lab 14.1.1 toolbox	LPP. Encoding Phase (RPs elicited by unpleasant, neutral, and pleasant pictures): LV1: recruit more attentional resources for pleasant and unpleasant cues compared to neutral cues expressed in the increased LPP component for emotional material. LV2: The unpleasant prospective memory cues differed substantially compared to both neutral and pleasant cues. Enhanced amplitudes in the negative components that occurred in the time windows between 100 and 180 ms (i.e., N1), 250–350 ms (i.e., N2), and 420–600 ms (i.e., N3)

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
			responses									
Rawls, 2018 [61]	P2 N2 P3	Eye blink artifacts, the threshold was set to 140 µV (peak-to-peak) and all trials in which this threshold was violated were excluded. Trials with more than 10 bad channels were excluded from analyses. Signal activation change (peak-to-peak) exceeding 150 µV across the entire segment and fast transits exceeding a difference (peak-to-peak) of 140 µV were marked as bad and interpolated.	-150 ms before to 600 ms after probe onset	P2: 200–240 ms N2: 300–330 ms P3: 350–420 ms	P2 and N2: four midline electrodes (VREF [Cz], 6 [FCz], 11 [Fz], and 16) as well as ten flanking electrodes (10, 18, 19, 4, 5, 12, 106, 7, 112, and 13) P3: four midline electrodes (VREF [Cz], 55 [CPz], 62 [Pz], 72) as well as eight flanking electrodes (80, 79, 78, 77, 31, 54, 61, and 67).	NR	Greenhouse-Geisser (repeated measure) Bonferroni (ANOVA)	Regression analyses (emotion) RM-ANOVA (behavioral data) RM-ANOVA (ERP)	NR	NR	NR	P2. There was no main effect of emotion N2. Main effect of emotion on N2 amplitudes, with neutral trials resulting in more negative N2 amplitudes than negative trials P3. Amplitudes were larger for AY (action change) stimuli than AXE (no action change) stimuli in neutral emotional conditions and positive emotional conditions N2 activation, but not P2 or P3 activation, moderated the relationship between effortful control and aggression.
Senderecka, 2018 [44]	N1 P3 ERN Pe	Ocular and other stationary artifacts with ICA algorithm using the Brain Vision Analyzer 2 (Brain Products, Munich, Germany). Trials exceeding maximum/minimum amplitudes of ± 65 µV	-100 ms prior to stimulus onset to 700 ms after stimulus onset -150 ms prior to response to 600 ms after response	N1: 120–190 ms P3: 270–400 ms ERN: 0–80 ms Pe: 120–270 ms	N1: central sites (FC1, FC2, C3, C4, Cz, CP1, and CP2) P3 and Pe: centro-parietal sites (Cz, CP1, CP2, P3, P4, and Pz) ERN fronto-central sites (F3, F4, Fz, FC1, FC2, C3, C4, and Cz).:	Kolmogorov–Smirnov test (Continuous variables)	Bonferroni (post-hoc t tests corrected for multiple comparisons)	T tests (behavioral data) two-way RM-ANOVA (ERP)	NR	NR	NR	N1. Emotional stop signals elicited larger amplitudes than neutral stop signals sounds, in both the successful and the unsuccessful trials. P3. Amplitude was more pronounced in the aversive trials than in the neutral trials; in both the successful and the unsuccessful trials. ERN. The amplitudes were statistically comparable in the aversive and neutral response error trials. Pe. Amplitudes time-locked to the motor reaction were greater in the EMO than in the NEU response error trials.
Shushakova, 2018 [39]	N2pc P1	Trials with missing or erroneous responses were rejected. Large muscle artifacts and extreme offsets following visual inspection. Eye blinks and horizontal eye	−200 to 500 ms respect to the cue and target onset	N2pc: 50-ms centered at the peak of the averaged difference waves of the whole group (223–273 ms for the negative-neutral trials	N2pc: P7 and P8 P1: O1 and O2	NR	NR	mixed-model ANOVA (between Group ADHD, HC and the within Emotion / behavioral data)	NR	BrainVision Analyzer 2.1 software (Brain Products, Munich, Germany).	NR	Cue-locked N2pc Significant N2pc in both conditions in the ADHD group; in HC group only positive condition Target-locked P1Overall lower P1 amplitudes in the ADHD group compared with the HC. Higher P1

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
		movements were corrected using ICA. Epochs with voltage steps exceeding 50 mV between the sample points and voltage differences exceeding 200 mV within a 200 ms interval were automatically rejected		and 283–333 ms for the positive-neutral trials). P1: 50–210 ms				one-sample t-tests (ERP) mixed-model RM ANOVAs (ERP)				amplitudes in negative-neutral vs. positive-neutral trials, in both groups.
Wang, 2018 [59]	P1 N2 P3	Incorrect response trials and artifacts exceeding ± 75 µV were excluded from ERP analysis	-200 ms before stimulus onset and 1500 ms after stimulus onset	P1: 100–150 ms N2: 230–450 ms P3: 300–600	P1: P1, P2, Pz, PO3, PO4, and POz N2: Fz, FCz, and Cz P3: Pz, POz, and Oz	NR	NR	RM-ANOVA (behavioral data) RM-ANOVA (emotion) RM-ANOVA (ERP)	NR	NR	NR	P1. After participants viewed neutral and high-sadness images, local stimuli evoked larger positive amplitudes than did global stimuli. Positive amplitudes evoked by global stimuli were significantly larger after participants viewed low-sadness images compared with neutral and high-sadness images N2. Local stimuli evoked larger positive amplitudes than did global stimuli at high, low and neutral degrees of sadness (no interaction effect) P3. Positive amplitudes evoked by local stimuli were smaller after participants viewed high-sadness images compared with neutral images
Andreu, 2019 [47]	N2 P3	After ocular correction, trials in which the EEG signal exceeded ±100 mV were automatically excluded from the analyses	-200 ms before and 800 ms after stimulus onset	N2: 250–350 ms (after stimulus onset) P3: 400–500 ms	N2: frontocentral (Fz, FC1, FC2 and Cz) P3: central (Fz, Cz, C3 and C4)	NR	Greenhouse–Geisser (repeated measures ANOVA)	RM-ANOVAs (between group, behavioral data, emotion, ERP)	NR	Matlab	Field Trip toolbox	N2. Amplitude: no difference between group, larger for positive pictures in both group, meditation experience did not modulate the go/no-go N2 effect. P3. Amplitude: no difference between group, larger for negative pictures, in no-go vs. go trials, compared with positive and neutral. Maximal at electrode Cz. Meditation experience did not modulate the go/no-go P3 effect

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Barker, 2019 [52]	P3 N170	ICA (ocular, muscular, line noise, and channel noise components were selected for removal)	-200 ms prior to stimulus onset to 1000 ms after presentation	P3: 300 – 450 ms from stimulus presentation N170 = 150–200 ms	P3: Centroparietal (Cp1, Cpz, Cp2, P1, Pz, and P2) N170 = P7 and P8	NR	NR	One-way ANOVAs (between group: monolingual / bilingual) 3way ANOVA for group (behavioral data) 3-way ANOVAs for group (ERP)	NR	Matlab:	EEGLAB and ERPLAB toolboxes	P3 emotion trials. Amplitude: 1-back produced higher P300 potentials than the 2-back; target trials elicited a larger P300 than non-target trials; angry trials produced larger P300 amplitudes than neutral condition Latency: longer latencies for target trials than non-target trials on emotional trials N170. Amplitude: happy and angry trials produced larger amplitudes than neutral trials
Magnuson, 2019 [49]	N2 P3 N170	Trials with significant eye movements and eye blinks were rejected based on a z-value cutoff of 6 obtained from average EOG. Trials containing components with peak amplitudes greater than 150 μV or less than −150 μV in the EEG channels Fz, Cz, Pz, P3, and P4 were also rejected.	-200 ms before the onset of the stimulus to 800 ms after the onset of the stimulus N2/P3: locked to the onset of the go/no-go stimuli. N170: locked to the onset of the face stimuli	N2: 300–400 ms P3: 450–600 ms N170: 220–320 ms	P3/N2: Cz, Pz N170: P3, P4	NR	Bonferroni correction	Mixed-model RM-ANOVA (behavioral variables) Independent samples *t*-test (behavioral data) RM-ANOVA (ERP) post hoc *t*-test (ERP)	SPSS	Matlab	Fieldtrip toolbox	N2 (go/no-go). Amplitude: larger on no-go trials compared to go trials in both the ASD and TD groups. Latency: peaks (go and no-go) were significantly more negative in the TD group compared to the ASD P3 (go/no-go). Amplitude: greater no-go Cz, compared to go Pz in both the ASD and TD groups. Latency: longer no-go Cz, compared to go Pz in both the ASD and TD groups. N170(emotional face). No significant overall N170 amplitude or latency differences were identified between groups. Location × Face × Group effect was identified: ASD group showed a larger difference between happy and angry trials than the TD group in site P4 compared to the P3
Liu, 2020 [58]	N2a N2b P3	Trials with electrooculographic (EOG) artifacts, artifacts because of amplifier clippings, bursts of electromyography activity, or peak-to-peak deflections	-200 ms prior to stimulus onset to 800 ms after presentation	N2a:180–250 ms N2b: 260–330 ms P3: 350–550 ms	Frontal (F1, Fz, F2) Frontal-central (FC1, FCz, FC2) Central (C1, Cz, C2) Central-parietal (CP1, CPz, CP2) parietal (P1, Pz, P2)	NR	Greenhouse-Geisser method (all analysis) Bonferroni (post-hoc t-tests)	Analysis of variance (between group) Repeated measure (RM) ANOVA (behavioral data) RM-	SPSS 21.0	Matlab R2014a	EEGLAB toolbox 14.1.1b	N2a: Amplitudes in SREs were significantly greater than those in UREs in no-go trials No-go amplitudes were significantly greater than go amplitudes in all brain regions. Amplitudes in no-go trials were greater after inducing

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		exceeding ±80μV. ICA						ANOVA (ERP) post-hoc *t*-test				a negative mood state than a neutral state Amplitudes were greatest in frontal region. N2b. no-go amplitudes were significantly greater than go amplitudes were greatest in frontal region no significant differences in group and mood state P3. no-go amplitudes were significantly greater than go no-go amplitudes were significantly greater than go amplitudes in frontal
Murphy, 2020 [143]	Alpha Power	Change in voltage exceeding ±100 μV over posterior electrodes (01, 02, 0z, Pz, P3, P4, P7, and P8) were excluded. Mean total trial rejection= 4.9% (*SD* = 4.7).	Two partitions (pre- and post-stimulus) Pre-stimulus measures: 2700 ms segments: −600 before and 2100 after fixation onset Post-stimulus measures: 2100 ms epochs: −600 ms before and 1500 ms after stimulus onset.	A mass univariate approach was used to identify the TW within the pre-stimulus period. Additional analysis comparing alpha power at the beginning and end of the fixation period, two-time windows: 200 ms Pre-fixation onset 700–900 ms. After fixation onset.	Posterior Alpha: O1, O2, Oz Lateralized Alpha Power: P7 and P8.	Shapiro-Wilk Test	Greenhouse–Geisser when Mauchly's test of sphericity was violated.	Mixed ANOVA (pre-stimulus Alpha) Bonferroni corrected one sample *t*-test and Mixed ANOVA (Alpha lateralization) Mass univariate ANOVA (Post-stimulus Alpha power)	R software	Brain-vision Analyzer 2.0 (Brain Products, Gilching, Germany).	NA	Alpha was tonically suppressed in the high compared to low distractor frequency condition, indicating greater baseline attentional engagement when distractors were expected to appear often, consistent with the use of sustained (i.e., block-wide) proactive control. Expected emotional (compared to neutral) distractors did not increase either tonic or phasic alpha suppression. This means that the same level of alpha suppression was sufficient to guard against both emotional and neutral distractors in the high-frequency condition.No systematic alpha lateralization in any condition, and therefore no evidence that anticipatory spatial inhibition served as a mechanism of proactive control. In both distractor frequency conditions; post-stimulus alpha suppression was greater following distractors (relative to when targets were presented alone) and was more pronounced when the distractors were emotional. This pattern of findings is in line with previous reports that alpha suppression is greater following high compared to low conflict stimuli

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
Nigbur, 2020 [37]	N2 ERN Pe	ICA rejecting noisy segments (max. allowed voltage step = 50 μV/ms; max. allowed difference values in intervals = 200 μV/200 ms; min/max allowed amplitude = ±200 μV; lowest allowed activity = 0.5 μV/100 ms).	N2:-400 to 1000 ms ERN =-400 to 600 ms	N2 = 180–300 ms after stimulus onset ERN = −100 to 0 prior to response Pe: 220–320 ms	N2 = FCz ERN: FCz Pe = P3, Pz, P4	NR	NR	Three-factorial ANOVA (behavioral data) two-factorial ANOVA (ERP) Paired-samples t-tests (skin conductance response, mood)	NR	Brain Vision Analyzer (2.04) software environment	NR	ERN. increased amplitudes after funny videos N2. interaction effect mood-congruency not significance
Peng, 2020 [32]	N2 P3 Late frontal wave (LFW)	Epochs with a signal range exceeding ±100 μV at any electrode and electrooculograms were removed from the analyses.	100 ms. before to 800 ms. after stimulus onset	N2: 210–240 ms. P3: 350–550 ms. LFW: 400–600 ms.	N2: F3, Fz and F4 P3: P3, Pz and P4 LFW: F3, Fz and F4	NR	NR	3 (uncertainty: low, mid, high) × 2 (facial emotion: fearful, neutral) RM-ANOVA on RTs (correct responses) and ACC.	NR	NR	residue iteration decomposition (RIDE) toolbox	RT: participants require a longer reaction time when searching for most orientations as the uncertainty increases ACC: there was a significant main effect of uncertainty, with higher accuracy for low and mid uncertainty compared to high uncertainty There was neither a significant effect of facial emotion, nor a significant interaction between uncertainty and facial emotion N2: there was a significant main effect of uncertainty, with the amplitude being more negative for the high uncertainty condition and mid uncertainty condition than low uncertainty condition. Amplitude was more negative for neutral faces. Significant differences between neutral and fearful faces under low and mid uncertainty, but the effect for facial emotion was not significant in high uncertainty. LFW: amplitude becomes more positive as uncertainty decreases. More positive amplitude for fearful faces compared to neutral faces. Significant differences among uncertainty for fearful faces, but this uncertainty effect was not significant in neutral face trials. P3: main effect for uncertainty and facial emotion.

Author, Year	ERP/wave	Artifact rejection	Epochs	Time window	ERP measured (position o topography)	Normality test	Sphericity Test	Inferential statistics	Software statistical analysis	Software of data processing (EEG/ERP analysis)	Tool box	Main affective/ERP results
Agudelo-Orjuela, 2021 [144]	N2 P3	ICA (remove the effects of blinks and eye movements) Drifting or large movement artifacts with voltages exceeding 70 μV measured from peak to peak at any channel Experiment 1: rejection of 16% of the trials Experiment 2: rejection of 19% of the trials	-200 ms. Before affective adjective and 1100 ms after	N2 and P3: 300 ms. After adjective onset N2: 220–290 ms after cue onset (Source localization)	Fronto-central	NR	Bonferroni	Error rate: two-way RM-ANOVA with cue and valence as within-subject factors Reaction time: one-way RM ANOVA with valence as within-subject factor Accuracy: two-way RM ANOVA ERP: Effect size Source localization: Local Auto-Regressive Average (LAURA) Post-hoc test	NR	Matlab	Fieldtrip Tool box	N2. No-Go trials in the context of negatively valenced adjectives elicited smaller N2 amplitudes than the No-Go trials in the context of positive and neutral adjectives. - Go trials was not affected by valence - The interaction in this cluster reflects reduced N2 amplitudes for inhibitory activity initiated in the context of negatively valenced adjectives. - Affective valence of the adjectives had a restricted influence on inhibition-related processes, modulating specifically those associated with the N2 component.

Note: NR=Not Reported; ICA=Independent component analysis; SL=Source location; LPP=Late positive potential; LPC=Late positive complex; ERN=Error related negativity; MMN=Mismatch Negativity.

3.5. Statistical analysis used

The tests used to correct the multiple comparisons associated with the post-hoc *t*-test and the analysis of variance (ANOVA) were mainly the Bonferroni correction (43%) and the Greenhouse-Geisser method (40%) for the violation of sphericity. 37% did not report this information and 9% included other correction tests (Huynh-Feldt, false Discovery Rate Procedure or Winsorized ERP data). As inferential statistical analysis, all the articles reviewed performed an analysis of variance in its various modalities (e.g., repeated measurement, mixed-models) to obtain the results of behavioral and electrophysiological data, together with post-hoc *t*-test. Other types of analysis included in 25% of the studies are regressions, Partial eta-squared for ANOVA effect size, MANOVA, ANCOVA, and Partial Least Square.

3.6. Software and/or toolbox for electrophysiological data processing

40% of the studies did not indicate the software utilized for the processing of electrophysiological data. In the studies that described it, MatLab (29%) and Brain Vision Analyzer Software (20%) were the most used. The remaining 11% includes EGI software Net Station, Neuroscan, and CARTOOL. 60% of the works did

not indicate a toolbox for signal processing. Those that include it indicate EEGLab / ERPLab (20%), Fieldtrip (14%), Net Station Artifact Detection (3%) and the residue iteration decomposition (RIDE) toolbox (3%).

3.7. Synthesis of results by ERP component/frequency band

A summary of the studies for each ERP/oscillation is showed below.

The results are summarized below according to each ERP/oscillation used to study affective modulation (emotion/mood) of CC processes in various experimental tasks. The ERPs results will be presented based on the neural processes associated with the different stages of information processing according to their correlation with sensory, perceptible, and cognitive functions. First, a group of early ERPs components that reflect basic sensory processing, i.e., lower-level processing, since they usually do not involve an active cognitive response or processing. Then the results of the later ERP components that reflect the active perceptual and cognitive processing of stimuli will be presented. Finally, we describe the results related to two frequency band power (Theta and alpha).

3.7.1. Early ERP components (low-level processing)

3.7.1.1. ERN, Pe and CNV

The study of Clayson, Clawson [131] measured ERN and Pe, and showed that the affective state did not affect these ERP components related to automatic performance monitoring. The study of Nigbur and Ullsperger [37]measured the amplitude of the ERN and other cognitive control related components such as the N2 or Pe to determine whether positive affect alters error processing. They found that ERN and Pe, but not N2, were influenced by mood induction, leading to enhanced amplitudes after blocks that includeed funny videos, which suggested that a specific affective evaluative component is inherent to error processing. Thus, they conclude that the ERN amplitude can be modulated by an affective context that is unrelated to the task involved, with positive affect leading to increased and not reduced ERN amplitudes. The latter is in line with theories that assume an elimination of the aversive error affect by positive mood.
The study of Saunders, Rodrigo [139] measured ERN and Pe to examine whether mindfulness (as a nonjudgmental experience of emotion) facilitates rapid neural responses to errors. They showed that ERN was enhanced when participants underwent and emotion-focused induction procedure compared to thought-focused induction. This result was interpreted as a higher neural sensitivity to errors for emotion-focused participants, with a boosting effect on early neural performance monitoring.
Senderecka [44] measured the Pe to study whether arousing, aversive sounds lead to increase conscious error monitoring. The results showed that the Pe amplitudes time- locked to the motor reaction were greater in the emotional than in the neutral response error trials. It suggests that short-duration affective states, induced by aversive, arousing sounds, exert a positive influence on error monitoring. The Pe emotional effect reflects an

increase in the error significance or an enhancement of the error evidence strength after the presentation of an aversive stop signal.

The study of van Wouwe, Band [130], also measured the component ERN and CNV. They observed that induced positive affect influenced the evaluative components of control, indexed by the ERN elicited after incorrect responses. Cue-induced proactive maintenance processes remained largely unaffected, as reflected in the CNV. Thus, positive affect did not change proactive updating or maintenance.

Wang, Yang [135] in their study examined two major emotion regulation strategies, reappraisal and suppression. They used three ERP measures to explore emotion regulation's influences on subsequent cognitive control during a Stroop task. Two of these measures were related to error (ERN and Pe). The results showed that emotion suppression during a sad movie clip led to attenuated error detection (indexed by ERN) during a subsequent Stroop task. However, reappraisal did not weaken subsequent error detection, with ERN amplitude similar to those from a solely watching control group. There were no group differences related to Pe. They concluded that reappraisal is an effective and cost-free emotion regulation strategy, and suppression is an ineffective and costly emotion regulation strategy.

The study of Vanderhasselt, De Raedt [134] examined proactive and reactive control mechanisms with different measures, including ERP, in Major Depressive Disorder (MDD) patients and healthy controls (ND) during the cued emotional conflict task. Even though they used a large time window (2000 ms) to perform a spatiotemporal cluster analysis encompassing early (P1, N170), midlatency (P2), and late (N2, P3) ERP components generated in response to sad or happy faces, the more striking result was a significant difference among groups in CNV amplitudes after the presentation of the cue. Compared with ND participants, the results showed proactive control abnormalities in MDD patients. In the ND group, the CNV component was found largest (i.e., more negative) when anticipated a detection task. Also, CNV amplitudes in MDD patients were robustly decreased in general (i.e., more positive amplitudes for all the cue types). Such decreased CNV amplitudes have been interpreted as related to problematic attentional resource allocation caused by mind wandering, daydreaming or active distraction by some other tasks.

3.7.1.2. C1, P1, N1, MMN and N170

The study of Vanlessen, Rossi [133] examined possible downside effects of positive mood on early sensory stimulus processing, presumably resulting from a change in top-down attention control mechanisms. They measured ERP measures during a demanding task at fixation that includes also peripheral irrelevant visual textures, whose position was systematically varied in the upper visual field. Among the ERPs they included early components (C1, P1). They measured C1 assuming that it would be possible based on the using of eccentric/peripheral visual stimuli, expecting that it could reflects early retinotopic encoding of the stimulus in V1, i.e., the striate cortex, being sensitive to top-down attention control effects. Also, they measured P1 expecting that it could reflects the extrastriate activity related to content and not position of the stimulus in the visual field. P1 also usually varies according to the affective state of the participant, and its amplitude is

larger for attended stimuli. The results of the study showed that positive mood could alter the earliest cortical stage of stimulus processing, presumably taking place in V1. This implied a broadening of spatial attention with positive emotion, with a strong dominant topography of the C1, regardless of the position of the texture in the visual field. The C1s of participants in the neutral mood condition showed a clear and sharp topographical change according to the same manipulation. Analyses of the extrastriate P1 component failed to reveal any change as a function of stimulus position in the visual field. Thus, mood had no effect on the topographical properties of the P1 component.

In the study of Moriya and Nittono [129] examined whether positive mood states would broaden the breadth of attentional focus in a flanker task as compared with neutral or negative mood states. They measured P1 (a marker of early sensory processing in the visual modality) and N1 during the flanker task that was presented simultaneously with a task-irrelevant probe stimulus (i.e., a white light spot) to examine whether the effect of mood states on the attentional focus occurs at early visual processing stages. They showed that probe-evoked P1 amplitude was larger in the positive mood state than in the neutral and negative mood states, which indicates that positive mood states may broaden the focus of attention during visual input stage. In the case of N1, it was observed a contralateral preponderance effect on the probe-evoked early negativity amplitude. This effect was smaller in the positive mood session than in the negative mood session.

In turn, the study of Carboni, Kessel [84] found that N1 had amplitudes significantly greater with both positive and negative emotional trials compared to neutral ones.

Putkinen, Makkonen [86] measured the N1/MMN index to examine whether music-induced positive mood has effects on selective attention in the auditory domain, broadening the scope of auditory attention with heightened distractibility. The N1/MMN response to the distractor sounds was enlarged for subjects that listened happy mood music. Thus, happy mood leads to more diffuse allocation of attentional resources across the attended and the to-be-ignored channels.

Senderecka [44] measured the N1 to examine the perceptual processing of unpleasant sounds and their influence on the performance in an inhibitory task. Results showed an improvement in perceptual processing with enhanced N1 amplitudes after listening aversive sounds compared to neutral ones. This effect was interpreted in the sense that discrimination between emotionally significant and insignificant stimuli occurred during early sensory stages of processing.

The study of Shushakova, Wiesner [39] investigated with P1 and N2pc the attentional bias to emotional stimuli (positive and negative words) as a potential mechanism of heightened emotional reactivity in adult ADHD patients. The attentional biases have been related to emotional dysregulation in healthy patients and in the maintenance on mood and anxiety pathologies. They use the target-locked P1 (an exogenous visual component associated with neural generators in the extrastriate visual cortex) which has been found to be higher for probes with emotional vs. neutral cues. ADHD patients showed less efficient processing of the probes than healthy controls, reflected in smaller P1 amplitudes, especially when the probes were presented

in the right visual field. This was interpreted as a less efficient allocation of cognitive resources in ADHD patients.

Wang, Chen [59] studied (as mentioned above) the influence of sadness on attention scope and included the measuring of P1 to explore the early perceptual processing sensitive to physical properties of the stimuli. The results showed that low-sadness participants put more attention resources toward processing large letters (global stimuli) with increased amplitude of the P1 component compared with high-sadness participants and participants at control condition. Therefore, they interpreted that different levels of sadness had different effects on attention scope, mainly in the early stages of visual processing, so low levels of sadness extended the scope but as sadness increased, this extension disappeared.

Stockdale, Morrison [74] measured neural correlates of response inhibition in the context of implicit attention to emotion, and its relationship with empathic responding in frequent and infrequent players of video games with graphically violent content. They used P1 as an index of early attention to affective information, threat sensitivity (e.g., greater amplitudes with angry faces). Also, this study measured the N170 to examine the structural encoding of an observed face, because this component has proven to have more sensitivity to fearful and angry facial expressions with larger N170 amplitudes compared to neutral facial expressions. The results showed that frequent players of graphically violent video games had smaller P100 amplitudes in response to happy facial expressions compared to infrequent players, and this relationship was moderated by empathy. At low levels of empathy, frequent players had reduced P100 amplitudes compared to infrequent players. These findings suggest that frequent players of graphically violent video games attend less to facial expressions with valence compared to infrequent players of graphically violent video games, particularly for those with less empathetic concern for others. With regard to N170, infrequent players of graphically violent video games had faster latencies for afraid expressions as compared to happy expressions. Frequent players of graphically violent video games displayed the opposite pattern, with faster latencies evoked in response to happy expressions than afraid expressions. This group difference in N170 latency response to facial expressions suggests that chronic exposure to media violence modulates processing of facial expressions during structural encoding, which previous researchers have shown is influenced by perceptual information. The study of Barker and Bialystok [52] measured N170 and found that there were no differences according to the direction of the valence of stimuli, with both positive and negative emotional trials eliciting larger amplitudes than the neutral ones.

3.7.1.3. P200

Even though we included the presentation of this component among the group of early ERPs it is important noting that it has been studied along with other later components. In a study [137] that measured the performance of adults in the stroop task with the presence of emotional distractors (cries or laughs of babies), it was observed that components P2 and N450 in frontocentral topography show an inverse relationship. Negative valence (cries) reduces the amplitude of P2 and increases that of N450 compared to positive/neutral

valence in tasks associated with IC-attention (Stroop task) and CF processes. The smaller P2 is interpreted as reduced attention to the task and the N450 as increased conflict processing, and its inverse relation suggests a reciprocal relationship between attention and conflict processing.

3.7.2. Late ERP components (high-level processing)

3.7.2.1. N200 and P300

For component N2 (Frontocentral), in no-go trials the negative valence elicited reduced amplitudes compared to the positive or neutral ones [144]. Other study [47] observed larger amplitudes in N2 for positive images and maximal in the Cz site. P3 was observed with greater amplitude related to the presentation of pictures with negative valence. The same was observed in another study [52] with larger amplitudes in angry trials and longer latencies in target trials compared to non-target emotional trials.
In another study [84] that included emotional distractors, those with positive valence elicited greater N2 amplitudes than the negative and neutral ones in frontal sites. In turn, at parieto-occipital sites both the negative and positive valence elicited greater N2 amplitudes compared with the neutral ones. In a study that includes different WM-load conditions [140], more painful pictures (i.e., negative valence) elicited more negative amplitudes than the neutral ones at fronto-central sites (FCz, Cz) with significantly larger amplitudes of N2 in the high WM-load condition. In the low WM-load condition, there were no differences for painful and non-painful pictures in N2 amplitudes. The study of Denke, Rawls [50]showed that the activation of the N2 component (more negativity) combined with anxiety states was related to emotional eating behavior (cope with negative emotions through the eating of large amounts of sweet and/or high fat food). Lopez-Martin [136] conducted a study to examine how emotional contexts affect inhibitory control in children with ADHD measuring inhibition-related neural mechanisms (N2-P3). Frontocentral P3 amplitudes resulted greater for the ADHD group than for the control group on Nogo trials. The authors declared that these results suggest an altered emotional modulation of response inhibition in children with ADHD, indexed by a hyper-activation of inhibition-related mechanisms (no-go P3) during highly emotional contexts in patients relative to control subjects. Such contexts might increase the need for top-down control and put children with ADHD at greater risk for impulsive behaviors and emotional dysregulation. The study of Magnuson, Peatfield [49] included a clinical population as well but of children with ASD. Their aim was to identify altered neurophysiological responses underlying inhibitory control and emotion processing (emotional go/nogo task) difficulties in ASD using N2/P3. They found that N2 amplitudes were reduced in children with ASD compared to a typically developing group, with no differences in P3, which would indicate that the individuals with ASD might only present conflict-monitoring abnormalities. In another study, Moriya and Nittono [129] examined whether positive mood states would broaden the breadth of attentional focus in a flanker task as compared with neutral or negative mood states. They use different ERPs to observe if the mood effect occurs either at the sensory stage or at the response stage or both. They use N2/P3 to examine the effect at the response stage, finding that mood states did not influence their

amplitudes. Thus, they concluded that positive mood states would not influence attentional focus in response selection and post-perceptual processing stages.

In Another study, Owens, Derakshan [46] examined if the trait susceptibility to worry modulated the inhibition of the distractors in low and high working memory load conditions. They used N2 to measure the neural activation in response to distractors, assuming that it reflect functional activation of the anterior cingulate cortex (ACC) related to conflict monitoring processes and cognitive control of working memory. They found that trait susceptibility to worry modulated the distracting effect on the N2 amplitude. Greater levels of trait worry were associated with enhanced N2 amplitudes under high but nor low cognitive load. As they observed an absence of a modulation of worry on behavioral performance, the authors interpreted that increased N2 amplitudes under high cognitive load suggest that worry could lead to a compensatory mechanism with greater use of cognitive resources to accomplish the task goal.

The study of Peng, Xuan [32] measured the N2/P3 index to examine the effects of uncertainty during different stages of cognitive control and the influence of emotional information on cognitive control under varied levels of uncertainty. Under low uncertainty, frontal N2 showed greater amplitudes to neutral faces compared to fearful faces. Parietal P3 amplitudes were smaller under high uncertainty. Fearful faces elicited enhanced P3 amplitudes compared to neutral faces under all levels of uncertainty. The authors interpreted these results as an interaction of emotion and uncertainty in the frontal cortex both during the early and late stages, while no interaction existed in the parietal cortex during the late stage. These results would support the fronto-parietal network hypothesis of cognitive control related to uncertainty.

The study of Rawls, Jabr [61] examined which ERPs (P2, N2, P3) moderate the effortful control - aggression association. They found that only the N2 activation (smaller amplitudes) moderated the relationship under study. These results were interpreted as a neural mechanism that influences resolution of response conflict over aggressive tendencies.

Only one study [39] measured N2pc. Its aim was to examine the attentional bias towards positive and negative emotional words in adult ADHD patients. Specifically, they used the cue-locked N2pc as a more reliable measure of attention shifts compared to reaction times, and its amplitudes indicated a significant attentional bias towards emotional words in patients with ADHD and healthy controls. In healthy controls, the bias was only significant in positive trials. In patients, the bias was associated with ADHD severity and self-reported poor emotion regulation skills.

Stockdale, Morrison [74] included the N2 and P3 as one broad N2/P3 complex to evaluate in frequent and infrequent players of graphically violent video games the role of response inhibition in the presence of affective distractors. They aimed to increase generalizability to violent video gaming contexts, which require players to ignore affective stimuli in order to shoot successfully a targeted enemy. The results showed that frequent players had significantly reduced N200/P300 amplitudes when inhibiting behavior compared to infrequent players of graphically violent video games. They interpreted that the reduction in N200/P300

amplitude for frequent players of violent video games involves less neural resources recruited to inhibit behavior and may simply reflect a practice effect.

Wang, Chen [59] in their study about the influence of sadness on attention scope included the measuring of N2 as an index of interference inhibition or cognitive control and P3 as an index of attention monitoring and working memory. The results showed that there were no significant differences for N2 and P3 components amplitudes between low-sadness and high-sadness conditions.

The study of Zhang, Xie [71] examined the neural correlates (ERPs) of the impaired memory facilitation/suppression of negative and neutral materials in depressed individuals. They measured N2 as an index of an inhibitory process that attempts to avoid memory retrieval. The results showed N2 deflection for negative (but not neutral) items in depressed participants, suggesting that depressed participants can hardly suppress the memory retrieval of negative materials.

The study of van Wouwe, Band [130] aimed to identify the modulating influence of positive affect (induced by a movie clip) on cognitive control by means of ERPs (N2, P3b). They observed that induced positive affect influenced the reactive components of control (indexed by the N2 elicited by the target). Cue-induced proactive preparation process remained largely unaffected as reflected in the P3b.

The study of Putkinen [86] measured the P3a as an index of bottom-up attention allocation to an unattended channel and the P3b as a response related to top-down controlling processing of task-relevant stimuli. They found that participants that previously listened happy mood music, the P3b elicited by the target sounds was diminished compared to Sad and neutral conditions. Senderecka [44] included the P3 component to examine the inhibitory process in an emotional stop-signal task that required response inhibition to aversive and neutral auditory stimuli. Aversive sounds evoked larger P3 indicating improvement in inhibition. This large emotional enhancement of the P3 amplitude was associated with an increase of error significance in failed, aversive stop trials. Also, inhibitory performance monitoring was the only factor that accounted for the difference in error detection between the emotional and neutral context. This was interpreted assuming that the cognitive system found more inhibition-monitoring evidence to effectively detect errors on aversive, unsuccessfully inhibited trials than on neutral ones. The authors declared that this observation seems to point to the crucial role of the midcingulate cortex (MCC) in the execution of internal processes leading to the emotional enhancement of error detection.

The study of Vanlessen, Rossi [133] measured the decision-related P3 component to explore the possible effects of mood on the processing of central, task-relevant stimuli, and the efficiency of central target stimulus processing assuming that P3 amplitude varies strongly with the amount of resources allocated to task demands. They also tested whether or not attention allocation toward central (task- relevant) stimuli could be altered after the induction of positive mood, because P3 component has been shown to vary with the (negative) affective state of the participant. The results showed that mood did not change the processing of the centrally presented/task-relevant stimuli. As expected, the amplitude of the P300 component was strongly influenced by task demands, being larger for perceived deviant than for standard targets. However, this effect

was not different between the two mood groups. These findings suggest that the effects of positive mood did not influence task- relevant, central stimuli.

Yu, Zhou [33] aimed to investigate neural substrates of response inhibition to sad faces across explicit and implicit emotional Go/Nogo tasks in depressed female patients. They measured the Nogo-N2 as an index of conflict monitoring and Nogo-P3 as an index of conflict resolution and behavioral inhibition. Their findings suggest that N2 amplitudes elicited by no-go trials were decreased in the depression as compared to the control group, indicating that the processing of conflict monitoring was disrupted in depression irrespective of valence and task. Depression patients showed decreased go/no-go difference P3 amplitude when inhibiting responses to sad faces across implicit and explicit tasks. This P3 difference wave was positively correlated with discrimination accuracy in the depression group.

3.7.2.2. N400 and N450

Pinheiro, del Re [132] measured the N400 amplitudes to examine affective modulation of semantic information processing under neutral, positive and negative moods. Under neutral mood, N400 amplitudes were greater for unexpected endings and for between-category violations (compared to within). Also, N400 showed differences as a function of mood. Under the negative mood, the N400 to Expected words (EW) was significantly less negative than the N400 amplitudes to positive or neutral mood. In the case of category violations, the N400 amplitudes to both the negative and positive mood were similar. The reduction of N400 amplitudes to EW was interpreted as revealing of the generation of a narrowed set of predictions seems to dominate linguistic processes such that the language comprehension system is sensitive only to contextual information and congruency effect, but not to relationship between concepts in the long-term memory.

The study of Wang, Yang [135] measured N450 as a conflict monitoring index to explore (as described above in the ERN section) emotion regulation's influences on subsequent cognitive control during a Stroop task between groups according to the emotion regulation strategies used. They did not found significant group differences in the N450 amplitudes.

3.7.2.3. LPP, LPC and LFW

LPP has been used to reflect the intensity of subjective emotional experience, with amplitudes predicting the arousal of self-reported emotion. In the study of Carboni, Kessel [84] there was a modulation of this component according to the affective state. In negative mood, positive valence distractors evoked greater amplitudes; in positive mood, both positive and negative evoked greater amplitudes of LPP; and when the affective state was neutral, the negative pictures evoked higher amplitudes compared to the neutral ones. The study of Cui, Zhu [140] showed that painful pictures elicited larger LPP amplitudes than non-painful pictures, with an interaction of WM-load and painful pictures with high WM-load eliciting greater amplitudes when painful pictures were presented. Gallant, Pun [38] used LPP amplitudes to study the neural correlates of the ability to selectively remember information and forget irrelevant details in younger and

older adults. The results showed that the neural mechanisms underlying the intentional forgetting of information with emotional valence might change with age. In young adults, the LPP was greater for negative valence, meanwhile in older adults it was reduced for negative valence. Also, in response to memory cues, TBR cues evoked more positivity than TBF cues over parietal sites in both groups. However, age differences were found in frontal sites with young adults showing more positivity for TBF relative to TBR cues, which was not observed in older adults. Another study of Hering, Kliegel [142] also studied the influence of emotional factors on age-related differences in memory with LPP. Their purpose was to use ERPs to assess the neural correlates of intentional encoding, maintenance and self-initiated retrieval and its differences between younger and older adults. They found in both age groups elevated LPP amplitudes for the emotional cues, which was interpreted as an attentional processing of emotional cues during encoding. Younger adults showed increased ERPs (N1, N2, and N3) activity for unpleasant cues, and older adults an increased activity of ERPs related to cue detection and retrieval mainly for pleasant cues, which indicated the relevance of these cues. Their results demonstrated a different bias in younger adults (negativity) compared to older adults (positivity bias).

Pierguidi, Righi [70] measured the LPP as an index of motivated emotional attention in a study to examine whether is it possible to forget a face that has been encoded within a particular emotional context. The results showed that the LPP amplitudes were enhanced under faces-in-negative-scenes compared to faces-in-neutral-scenes.

Along with the N2 / P3 complex, one study [32] also measured the LFW component correlated with the encoding process. The results indicated a greater amplitude associated with negative emotions in situations of low uncertainty. On the other hand, when the uncertainty is medium or high, the maintenance and update of CC processes are more required than the emotional processes.

Another study [71], besides measuring N2 to examine the neural correlates (ERPs) of the impaired memory facilitation/suppression of negative and neutral materials in depressed individuals, also included LPC component measuring. They used the LPC to reflect an episodic memory (EM) effect and as an index of conscious recollection, assuming that enhanced LPC predicts retrieval success, and that can be downregulated during attempts to stop recollection The results showed parietal LPC deflection for negative (but not neutral) items in depressed participants. LPC result indicated that negative memories are more likely to be revisited by depressed participants (compared with nondepressed ones) due to their mood-congruent and intrusive nature, which is consistent with one of the most robust findings in the depression literature about a higher recall rate for negative materials in depressed, compared with nondepressed individuals.

3.7.3. Theta band power

Two of the studies included, in addition to the N2 / P3 complex, time-frequency theta power analysis. The study of Farbiash and Berger [138] included a kindergarten children sample to examine their inhibitory control and its related brain activity through N2 and Theta power during a negative emotional situation.

Their results showed that, as expected, children has larger N2 amplitudes and Theta power in Nogo trials. The negative valence of the emotional stimuli was related with better IC performance and larger theta power. Also, Theta power resulted a more sensitive index for IC of children than N2 amplitudes. The study of Parkinson, Garfinkel [141] addressed the question of whether volitional self-control can be manipulated by ecologically valid and socially relevant stimuli (i.e., emotional human faces) for which salience of volition cannot be accounted for in terms of low-level properties of congruence or incongruence. They use subliminal emotional faces (anger compared to neutral) during a Go/Nogo task, measuring theta band power (frontal-midline theta) as a signature of cognitive control and N2, as an index of reactive stopping but also linked to volitional decisions to execute or inhibit action. They found that N2 amplitudes were not modulated by subliminal emotional primes. Subliminal angry faces reduced FM-theta power, which was interpreted as the behavioral effect of predisposing and individual to withhold the action. Thus, if the subliminal prime was to withhold the action with an angry face, then the volitional choice involves reduced demands on cognitive control processes related to that spontaneous decision.

3.7.4. Alpha band power

One study [143] exclusively measured the alpha power as a neural index of proactive control while participants performed a target detection task with emotional or neutral irrelevant peripheral distractors. The alpha power was measured during the pre-stimulus period (proactive control) and during the post-stimulus period (consequences of control for subsequent processing). The results showed that the pre-stimulus alpha power was tonically suppressed in the high distractor frequency condition, regardless of expected distractor valence, which indicates a sustained use of proactive control. Therefore, this strategy accounts for the reduction in both emotional and non-emotional distraction when distractors are expected to appear frequently.
For a detailed description of each reviewed article regarding processing, analysis, software, and main results, see Table 3.

4. Discussion

This systematic review examined the evidence obtained in EEG studies investigating affective modulation of performance in cognitive control tasks. We identified the main experimental tasks, sample, EEG recording and analysis procedures.

Most participants in the reviewed studies were university students or young adults. Affective or emotional stimuli were primarily visual, with the most used tasks being the Go/No-go or the flanker task, and the most studied cognitive control process was response inhibition. EEG signals were mainly recorded using 64 channels and the 10/20 coordinate system. The measure analyzed in the vast majority of studies was ERP,

including 19 components (N2/P3, N2a, N2b, N2pc, P3a, P3b, ERN, Pe, CNV, N1, N170, LPP, LPC, P1, P2, N400, N450 and LFW) and oscillations, including two frequency bands (theta, alpha).

In general terms, the results of the studies included in the qualitative synthesis confirm the consistency of affective modulation of cognitive processes and the possibility of obtaining evidence through electrophysiological recording and ERP components analysis [145]. Positive and/or negative valence affective stimuli, compared to neutral, modulate cognitive control processes, and this is reflected in changes in the amplitude and latency of various ERP components. These findings have previous evidence in the literature for the N2 / P3 complex [146], [147], [148], [149], [150], N1 [151], [152], [153], N170 [154], N400 [155], N450 [156], ERN/Pe [135], P1 [157], P2 [158] or LPP [159, 160]. There are also some results indicating that affective stimuli do not cause modulation of the electrophysiological response associated with cognitive control [37, 133, 135, 141, [161], [162], [163]], mainly regarding the N2 component.

Most of the studies that investigated the interaction between emotion and cognition focused their analysis on late ERP components such as the early posterior negativity (200–300 ms), P300 (300–450 ms), or LPP [101, [164], [165], [166]]. Some studies investigated components related to the earlier stages of emotional processing, such as P1, N1, and N170 [167, 168]. These early ERP components were useful in studies that aimed to investigate inhibitory control, top-down processes, and attentional resources directed at visual, emotional stimuli, mainly images, and faces. For example, markers of visual attention focus P1 / N1 [129], conflict monitoring and complex attentional resources N2 / P3 [58], attention control and detection with N2a and N2b [105, 169], conflict processing and meaning in N400 / N450 [137, 170], attention to LPP emotional material [171] or awareness of error [172].

As mentioned above, affective modulation of several ERP components is quite consistent across studies, although there are also incongruencies. Several factors could explain such divergence including the diversity of affective stimuli, sensory modalities, and paradigms used to investigate different components of cognitive control and even the induction procedure to generate phasic or tonic affective emotional states [37, 140]. These different results are more evident for the N2 / P3 complex. Possibly these components are observed for a variety of experimental paradigms. Indeed, they were elicited using different sensory modalities (visual and auditory), types of stimuli (faces, images, video clip, sounds), stimulus durations (tonic and phasic), experimental tasks (Go / No-go, n-back, stop-signal task, Eriksen flanker test, AX-CPT, Navon global-local letter task) to probe different cognitive control processes (IC, WM, CF, proactive or reactive).

Another source of variability related to the time window used to investigate ERP components across studies. Indeed, the review studies show a good agreement for some of these components (N1, N170, N2, N2a, N2b, N2pc, N400, N450, ERN, LPC, P1, P2), whereas for later components, namely P3, P3a, P3b, Pe, and LPP we observed less agreement between different authors. Some of the studies use previous works as a reference to calculate in each component the mean of the amplitude in a specific time interval, eventually also representing a source of variation. Some studies do not indicate this information in detail, making it difficult to understand the rationale behind. Therefore, several factors need to be considered when comparing the

studies, the affective induction and experimental task used, the objectives and participants, such as the electrophysiological signal processing and analysis.

Regarding the technical aspects of EEG records and studies with ERP in general terms, some procedures have had a striking evolution, comparing the oldest in this review with the most recent. When conducting the review, it was observed in the studies, especially of the last five years, a much more detailed description of the conditions in which the records were made, including specifications regarding the type of amplifier, filters, preprocessing stages, removal of artifacts, re-referencing, etc. Part of the explanation could perhaps be attributed to recent guidelines that have been published in this study area [e.g., 173], which have sought to set rather more delimited international standards for reporting studies with EEG measures. In addition, another significant concern in recent years has been the crisis of replicability of scientific studies, which has been promoted from psychological science, a notable milestone being the publication of the Open Science Collaboration [174]. These discussions have recently also expanded to the field of cognitive neurosciences [175], projecting the analysis of the replicability of different key experiments through different international laboratories' collaborative efforts. Assuming the current concerns for findings reproducibility, it is necessary to highlight the need for adherence to procedures and analyses developed through well-defined protocols. In this review, we found that many studies did not specify key elements to reproduce the procedures, such as the type of platform or software used to present the stimuli and the laboratory's characteristics and the devices either of response or of visualization of the experiment. The same occurs concerning the type of procedure for the treatment and analysis of the data obtained regarding the recording of the brain wave, being described either in a very general way (e.g., Matlab) without specifying the more detailed toolbox or instrumental procedure, or in some cases simply not even mentioning the platform or software used in a general way. Therefore, according to the evidence, there is little uniformity regarding the more specific technical procedures in the reports in EEG studies reviewed in affective modulation studies of cognitive control. It should be noted that this could reflect a more general problem in EEG reports, which can influence replicability. Therefore, in line with current discussions in the scientific field, it is suggested to increase the rigor in the uniformity of standards that allow, on the one hand, comparing different results obtained by different studies and, on the other, the reproducibility of the studies by researchers working in different laboratories. It would also provide an advantage allowing performing meta-analyses in the future, which would be attractive considering the small sample size usually included in EEG studies, thereby increasing the statistical power to obtain robust evidence and quantitative assessment of methodological sources of variability.

Finally, it is worth noting that most of the studies focus almost exclusively on ERP, with just a few studies addressing oscillatory patterns. However, other approaches would also allow addressing hypotheses regarding both location (it is recommended for greater precision of this measurement to have a greater number of electrodes) and functional dynamics in terms of phase coupling or network functioning of different areas of the cortex. Thus, it is worth to continue exploring EEG signals using both classical and

novel approaches, clarifying evidence about source location and connectivity in research on affective modulation of cognitive control. It should also be added that currently there are open-access tools to carry out this type of analysis in a facilitated way with quite advanced software and toolboxes, e.g., Brainstorm [176] or Fieldtrip [177].

Also, two oscillations (alpha and theta) were used in studies of this subject as EEG measurements on tasks that depend on the participation of memory, both working and long-term, as usual within the most general field of research of cognitive control [123, 178]. In this sense, increases in Theta power are associated with increases in working memory storage demand. It has also been documented that the increase in Theta coherence is associated with top-down activation, reflecting central executive functions [120], thus being an interesting marker to include in the design of studies that inquire about cognitive control. In turn, the alpha oscillation could also be considered in cognitive control studies in line with the findings of this review. It has been observed that it is related in a complementary way with theta oscillations in the development of tasks that involve cognitive control, facilitating specifically the maintenance of the representations, as a kind of task set in preparation for the conditions expected for a task [178]. Both oscillations could then be indicators of individual differences in cognitive control tasks, thus being recommended for use in future studies in the area.

5. Conclusion

This review has shown that there has been a continuous development of the research on the association of cognitive control's affective modulation through EEG during the last decade. EEG data are of central importance for psychophysiological research and can help identify neural markers of cognitive control. Therefore, they are useful for knowing how these cognitive control processes are modulated temporally and spatially. The reviewed studies allow concluding that there is consistent evidence of affective modulation in brain responses underlying cognitive control. The specific focus in most of the EEG studies has used visual stimuli in their experiments. Thus, early markers of visual attention such as N1 and P1 have been included in the ERP analysis of affective modulation. The N2 component and P3 are associated with cognitive monitoring and attentional resources allocation. As would be expected in studies with emotional stimuli, the LPP component was elicited and analyzed in several reports as well. Compared to the use of ERP, the analysis of oscillations is scarce. Among the few studies that used it, the waves specifically included were theta and alpha, which is consistent with the literature that characterizes them as reflecting cognitive processes related to cognitive control.

Finally, we can conclude that the relationship between affectivity and cognitive control through EEG measures has been evidenced, but it is an area still under development. Some methodological commonalities enable the conclusion that, overall, there is consistency in the affective modulation of cognitive processes. However, it is suggested that future studies will clarify whether this is because such modulation

exists at a higher-order level or simply reflects the popularity of particular methodologies. Also in the future, hypotheses that go beyond the ERP as a measure could be addressed, expanding towards research that includes, for example, the source location and connectivity measures. It is also recommended a greater specificity in the report of the technical aspects involved both in the EEG recording and analysis to improve the comparability between studies and their replicability.

Declaration of Competing Interest The authors disclose no conflicts of interest.

Acknowledgements This work was funded by the National Agency for Research and Development (ANID), Scholarship Program Doctorado Becas Chile 2020 – 21201037; Internal Scholarship Program of Vicerrectoría de Investigación y Postgrado, Universidad Católica del Maule (UCM), 2018; BL is funded by grant FONDECYT 11190562. AA is funded by grants from Bial foundation (347/18); Fondazione del Monte di Bologna e Ravenna (grant 339bis/2017); Cogito foundation (R-117/13 and 14–139-R); Ministero Istruzione Università e Ricerca (2017N7WCLP)

Appendix. Supplementary materials

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