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REJECTING EMOTIONAL DISTRACTORS:

EXPERIENCE-MEDIATED ATTENTIONAL LEARNING AND MOTIVATIONAL RELEVANCE

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Abstract

Survival depends on the ability to rapidly detect emotionally significant stimuli, and adapt one's behavior accordingly. When an emotional stimulus occurs, attention is involuntarily diverted to it, causing a disruption in performance in a concurrent task. Emotional distractors not only capture attention but also engage cortico-limbic motivational systems, as reflected by several electrophysiological changes. In terms of cortical responses, it is well established that emotional pictures elicit a larger late positive potential (LPP) than neutral ones. The behavioral interference and emotional modulation of the LPP have been interpreted as evidence that emotional stimuli are prioritized in terms of perception, and that the engagement of motivational systems occurs automatically. However, few studies have examined whether we can learn to ignore constantly irrelevant emotional stimuli through direct experience. The current thesis examines the extent to which experience with task-irrelevant images modulates attentional capture by emotional (pleasant and unpleasant) pictures, and which stage of emotional processing is affected by distractor experience. In Experiment 1 (Experiments 1a and 1b), the role of distractor experience was examined in terms of distractor frequency, showing that frequent exposure to distracting images reduced the interference of novel (never repeated) emotional stimuli, even when they were rare, and consequently, highly significant. In line with this finding, Experiment 2 (Experiments 2a and 2b) provided evidence that practice with variable distracting images reduced the emotional interference effect. Conversely, the affective modulation of the LPP persisted despite the frequent occurrence of distractors and the prolonged exposure to distractors. Altogether these findings suggest that evaluative processes are mandatory, and continue to engage motivational systems, as suggested by the affective modulation of the LPP. However, observers can adaptively ignore irrelevant emotional stimuli after the evaluation process has occurred, indicating that the ability to

overcome emotional attentional capture results directly from experience with distracting events, and depends, therefore, on the possibility to learn that such stimuli are inconsequential.

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Al mio piccolo Lorenzo.

Ringraziamenti

“Non si insegna quello che si sa o quello che si crede di sapere: si insegna e si può insegnare solo quello che si è” **Jean Lèon Jaurés**

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Chapter 1

1. Introduction

Imagine you have just received this thesis to review and decide to read it in a coffee house in the city center. The café, however, is crowded and remaining concentrated on it despite the noise becomes challenging; people come in and out, making the doorbell ring continuously, the barman calls people loudly when their coffee is ready, and a baby starts to cry. You're getting a general idea about the content of the thesis; however, you'll need to ignore all those distractors in order to understand what you are reading efficiently.

This everyday example highlights one of our major critical tasks: responding selectively to the subset of stimuli that is the most relevant in a given moment, and ignoring the vast sea of irrelevant information in which we are literally immersed. This selective prioritization and suppression of information has been attributed to a set of many different processes that is collectively termed *attention*. Acting as a screening process, attention is the determinant of which aspects of sensory input are selected for cognitive processing, memory storage, and awareness.

Regarding this thesis, the crucial issue is the extent to which attention is involuntarily drawn or "captured" by emotional events, and whether such capture is modulated by the observer's experience with the stimuli. This work provides evidence that different types of experience – namely: frequency of distractor occurrence (Experiment 1a, Experiment 1b) and extensive practice (Experiment 2a, Experiment 2b) - are effective in attenuating susceptibility to emotional distraction, as indexed by the behavioral interference effect. However, evaluation processes and motivational systems continue to be engaged regardless of the degree to which observers are exposed to distracting stimuli, as indexed by the affective modulation of the LPP. Therefore, although the evaluation of emotional stimuli is mandatory, there are top-down rejection mechanisms that attenuate or prevent further allocation of attention toward clearly inconsequential emotional stimuli, and hence prevent counterproductive and reiterated emotional distraction.

In this introduction, I will start by selectively reviewing some of the studies that are relevant in demonstrating an effect of experience and learning on the attentional capture by perceptually salient neutral stimuli, before discussing the main findings that demonstrate that attention is also diverted to motivationally significant stimuli; however, such capture seems to be resistant to the top-down control and contextual factors.

1.1. Characterization of visual attention

Humans are fairly unique in their reliance on sight as the dominant sense, which is reflected in the finding that the largest part of our brain is devoted to the processing of visual information. With its hundred billion neurons and several hundred trillion synaptic connections, our brain is a massively parallel computational system able to process large amounts of visual information in a matter of seconds. Yet, counter-intuitively to this complexity, it is incapable of processing all the incoming information with which it is bombarded, and attention is therefore necessary to select which stimuli get access to this capacity-limited process. However, in turn, attention has been considered a capacity-limited resource allocator (e.g., Broadbent, 1957; Kahneman, 1973; Luck & Vecera, 2002). If we can barely attend to one piece of information at a time and we can scarcely focus on two tasks simultaneously, an obvious question arises: what is attended to? How is it decided which information to prioritize and which to ignore?

In a multi-item scene, in which different stimuli compete for attention, some control process is required to resolve this competition in order to allow some stimuli to be selected over others.

Prominent models have converged to distinguish two main categories of process underlying the control of attention allocation (e.g., Posner, 1980; Desimone & Duncan, 1995; Yantis, 2000; Corbetta & Shulmann, 2002; Theeuwes, 2010). The most intuitive way in which attentional control has been categorized is in terms of one's current goal, knowledge, and expectation. To return to my opening example, if we have to correct this thesis or we would like to eat a dark chocolate muffin, we will obviously attend to the stimuli that help us to reach these goals (the printed copy of the thesis, or the red packet we know that the chocolate muffin is wrapped in), and we won't attend to those that are not inherent. In this case, when attention allocation is initiated in line with the "internal state" of the observer one refers to this as top-down attentional control (sometimes referred to as endogenous or goal-directed control).

It may happen, however, that while reading this thesis or searching for the muffin, the loud crash of a coffee mug on the floor or a dog near the glass window that suddenly barks and growls makes our head turn rapidly, distracting us from the task at hand. Irrespective of whether we attend to these stimuli overtly (i.e., shifting attention by moving the head and eyes) or covertly (i.e., without eye movements), when a stimulus diverts or "captures" attention due to its intrinsic properties, attention is said to be under bottom-up control (also referred to as exogenous or stimulus-driven control), and stimuli capable of producing this involuntary attentional bias are events with perceptually salient or motivationally significant properties, or novel events. Compared to the volitional top-down control, in which the information needs to be directed from the higher cortical areas to the earlier ones in order to guide selection, bottom-up control is usually faster (e.g., Muller & Rabbitt, 1989).

1.2. The attentional capture debate

The discovery of the *attentional capture* phenomenon was a significant one, in that it suggested that attention is not strictly under our will and intention. As a result, considering the implications that this phenomenon entails for everyday behaviors, a huge research effort has been conducted to investigate under which conditions attention is involuntarily diverted by certain stimuli and whether such attentional capture is mandatory, and immune to modulation by top-down control.

From this research at least three different theoretical perspectives have traditionally emerged.

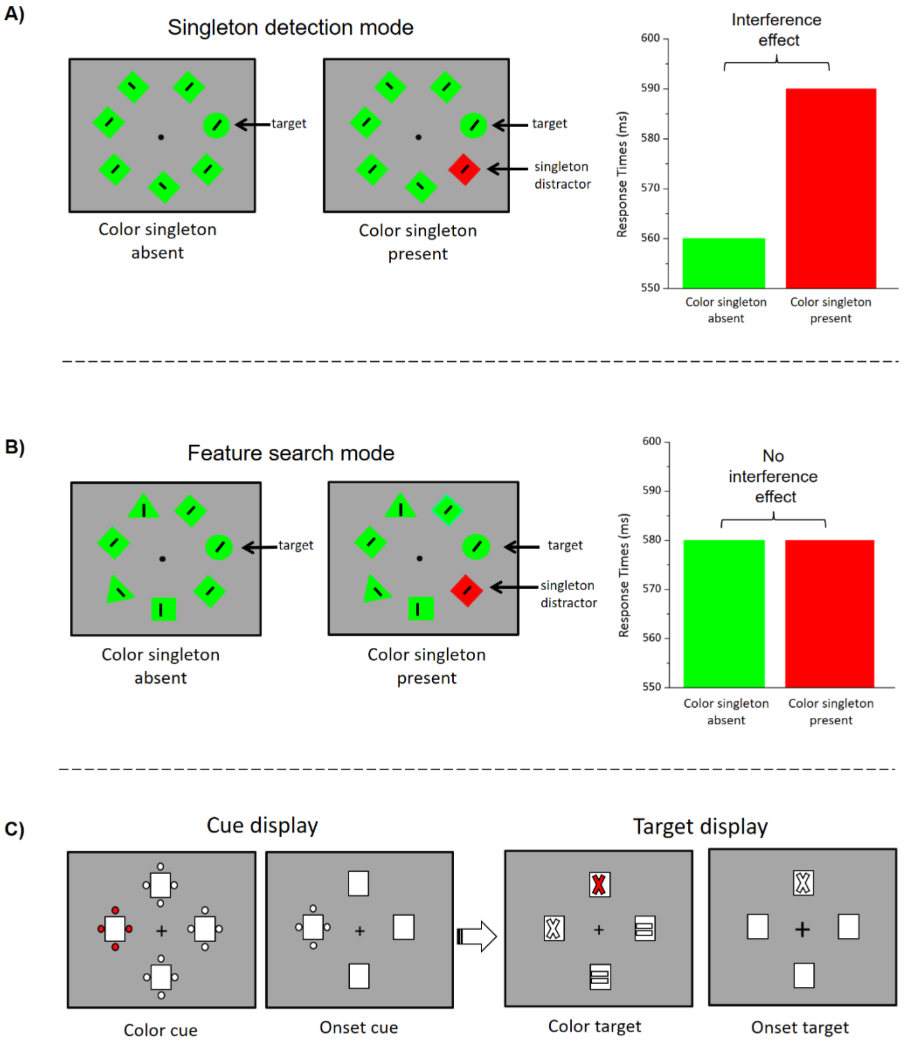

Figure 1.1. Typical paradigms used for studying attentional capture, which have empirically demonstrated the bottom-up salience perspective (A) and the contingent attentional capture perspective (B and C). Modified from Gaspelin & Luck (2016) (A and B), and Folk et al. (1992) (C).

I. Bottom-up salience perspective

On one hand, the bottom-up salience perspective argues that initially, after the moment light hits the retina, attention is exclusively guided by the relative salience of objects and, only later, goals and intentions bias the visual selection in a top-down manner (see Theeuwes, 2010, for a review). According to this account, any class of features can automatically capture attention as long as it stands out from the environment, and, hence, when it significantly differs from the surrounding features. The strongest evidence of this comes from the *additional singleton paradigm.* As shown in Figure 1.1a, in the typical version, participants are instructed to look for a unique shape (target) among homogeneous shapes (e.g., a circle among diamonds) and to respond to the orientation of the inner line of this "singleton". In some trials, one of the non-target shapes appears as a singleton in a different dimension (e.g., color: a red item among green items); in this case, although the target is never the color singleton and participants know they can ignore it, its presence slows down search times. Critically, when the singleton distractor is less salient than the target (e.g., a light blue item among bright green items), it no longer disrupts performance (e.g., Theeuwes, 1992; 1994). Thus, the cost in response times - named **distractor interference effect** - is taken as a demonstration that the most salient object in the visual display always captures attention, irrespective of one's current goals.

II. Contingent attentional capture perspective

On the other hand, other research indicates that stimuli do not have the intrinsic capacity to capture attention. According to the contingent attentional capture perspective, objects capture attention when they contain attributes or features associated with the task goal, and hence if they match what the observer is actively looking for (i.e., the **attentional set** of the observer) (Folk, Remington & Johnston, 1992). Going back to the example in which we look for a muffin in a coffee shop, knowing that its wrapper is red biases the selection processes in such a way that our attention can be involuntary attracted by other red objects, but we ignore salient items that fall outside our attentional set.

The first evidence for this perspective is primarily provided by a *spatial cueing paradigm* in which the feature properties that define distractors and targets can be independently manipulated. Folk et al. (1992) (Fig 1.1c), for example, presented participants with a cue display consisting of clusters of four dots appearing around each of four boxes. One set of dots (the cue) was a color singleton since it differed in color (red) compared to the rest (white). The target display appeared after the cue display and consisted of the abrupt onset of a single "X" or "=" appearing inside one of the four boxes, and participants responded to the identity of this target character. Importantly, across trials the target was no more likely to appear in the cued location than in any of the uncued locations, providing no incentive to voluntarily allocate attention to the color cue. Thus, any obtained cueing effects would be attributed to involuntary shifts of spatial attention. Critically, no cueing effects were obtained for color singleton cues. However, when the cue was replaced by the abrupt onset of a single set of dots around one of the four boxes, participants were faster in detecting the target when it appeared in the same, rather than a different, cue location. Vice versa, when the target was a color singleton (red "X" among three white non-targets "="), the exact same abrupt onset cue that produced capture when paired with an onset target now had no effect on performance, whereas the same color singleton cue that produce no evidence of capture when paired with an onset target now produced a significant cueing effect. These findings have been replicated in numerous studies, indicating that attentional capture depends strictly on the top-down attentional set adopted by the observer (e.g., Folk et al., 1992; Folk, Remington & Wright, 1994; Folk & Remington, 1998; 2008).

Within this perspective, given that in the additional singleton paradigm the target is a shape singleton, participants may search for it by adopting the strategy to look for singletons more in general (*singleton detection mode),* attending sometimes to the singleton shaped target (correctly) and sometimes to the singleton colour distractor (incorrectly). Supporting this view, the distractor interference effect is eliminated by adding different shapes to the display so that participants are forced to search for the exact shape that defines the target (i.e., *feature search mode)* instead of its uniqueness (Fig 1.1b) (Bacon & Egeth, 1994; Leber & Egeth, 2006a). Thus, these findings support the top-down theories which indicate that attention is initiated in line with the goal of the observers and stimuli can involuntary capture attention when they match these goals, not in virtue of their perceptual salience.

Consistent with the account of an attentional set, other studies suggest that observation of capture reflects the absence of an active set for the target property, rather than the inability of top-down control to override capture. For example, it is shown that when attention is unfocused, onset stimuli are able to distract; but if attention is completely focused on the upcoming target location prior to the onset, distraction is eliminated, indicating that attentional capture is not immune to modulation of top-down control.

III. Special classes perspective

A different explanation in the attentional capture debate comes from the special classes perspective, according to which certain classes of stimuli have a “special” status in the attention allocation system. Support for this perspective comes from an *irrelevant singleton paradigm* developed by Yantis and Jonides (1984; 1990) in which they required subjects to indicate whether a target letter (“A” in this example) was presented among heterogeneous non-target letters. In these experiments, each trial began with a set of figure-eight placeholders from which, a second later, a search letter array was revealed by removing some elements from the placeholders (offset items) and by simultaneously presenting a letter at a previously blank location (abrupt onset item). Although the target was no more likely to be the onset letter than any of the offset letters, and hence participants were disincentivized to attend to this feature, detection of the target was faster when it was the onset item compared to when it was one of the offset items. Moreover, reaction times for onset targets were unaffected by the display size, which suggests that participants did not bother searching the offset letters when the onset letter was the target. Critically, no effect was found when the target showed a difference in color or luminance (e.g., Jonides & Yantis, 1988; Yantis & Egeth, 1999). These results are interesting in that they dissociate from the previous perspective; differently from the bottom-up salience perspective, these results suggest that an abrupt onset singleton, and not the most salient stimulus in general, is a "special" event that is able to automatically capture attention, due only to its intrinsic properties. In contrast with the contingent attentional capture perspective, from this paradigm it emerges that onset attracts attention even when participants adopt a feature search mode, and therefore indicates that an active attentional set cannot override onset capture.

Subsequent studies provided evidence that other classes of events enjoy this "special status", such as the appearance of new objects (Yantis & Hillstrom, 1994), and looming and sudden motion (Franconeri & Simons, 2003). Specifically, in an experiment similar to that by Jonides and Yantis (1988), Franconeri and Simons (2003) showed that behavioral responses were slower when one of the irrelevant letters had an abrupt onset, or was a looming or translating stimulus compared to when the distinctive item was the target, suggesting that observers attended to these features even when to do so was counterproductive. From these findings, authors revisited the special class perspective in their "**behaviorally urgent hypothesis**" by suggesting that all types of stimuli considered to be “behaviorally urgent” capture attention obligatorily, independently of the current top-down goal. In that sense, objects that appear or move suddenly and looming objects may indicate the potential need for a prompt reaction, and the attentional allocation system could therefore be evolved to detect them as rapidly as possible. For example, noticing an object that looms progressively closer to us is crucial in order to move and avoid the collision. In support of this hypothesis, the authors found that an object that does not require an immediate response, such as a receding stimulus, does not capture attention even though it is as dynamic as a looming object, thus excluding the possibility that moving objects represent a special class per se. Even when the receding object is the only dynamic stimulus among static stimuli, the same attention is not allocated as would be given to a looming object, regardless of its salience and uniqueness. In more recent years, in a similar evolutive perspective, other classes of “behaviorally significant” stimuli such as biological motion (Pratt, Radulescu, Guo & Abrams, 2010), rare and unexpected stimuli (e.g., Turatto & Pascucci, 2016; Neo & Chua, 2006; Horstmann, 2002), and **emotional stimuli** (e.g., Failing and Theeuwes, 2017; Lang and Bradley, 2010) have been considered capable of capturing mandatory attention, independently of the top-down control.

In summary, the interpretation of evidence supporting an automatic, bottom-up attentional capture has given rise to a debate that still continues after 20 years. Problematically, over time, each different perspective has found support in empirical results from specific paradigms; some paradigms have consistently been used to support top-down, contingent explanations of capture (e.g., contingent cueing paradigm: Folk et al., 1992; contingent blink paradigm: Folk, Leber & Egeth, 2002) and some support stimulus-driven, bottom-up salience explanations of capture (e.g., irrelevant singleton paradigm: Yantis & Jonides, 1984; additional singleton paradigm: Theeuwes, 1992). Critically, results across paradigms are often conflicting, making it difficult to falsify one of them (e.g., Roque, Wright & Boot, 2016). Overall, despite evidence showing that top-down control affects attentional capture, there are certain events that are capable of grabbing our attention no matter what we are doing or what we are looking for (just think of the flashing blue lights of an ambulance) (see Folk, 2015). Is attentional capture by salient events mandatory and impenetrable by top-down capture? In attentional control literature, great efforts have been made to converge toward a coherent resolution to this long-running debate.

1.3. Experience-mediated attentional learning

As far as common real-world situations are concerned, it is rare for us to interact in complex contexts without any expectations; indeed, we usually acquire expectations and redundancies about the environment as we gain experience. In this regard, experience and learning represent important determinants of how we select relevant information and ignore constantly irrelevant input.

In accordance with this view, a growing number of studies has converged to indicate that an observer’s experience with a given feature or context biases the way in which attention is driven. One demonstration is the well-documented “priming of pop-out”, which describes the effect by which a stimulus (feature) that has been repeatedly attended to in the recent past is more rapidly selected on the current trial (e.g., Maljkovich & Nakayama, 1994; 1996; Folk & Remington, 2008; Lamy & Kristjansson, 2013). For example, during search tasks participants were faster at identifying a target when the target-distractor color remained the same as that of the previous trial compared to when the color changed, and this facilitation occurred for up to eight consecutive trials, regardless of the participants’ awareness of repetitions (Maljkovich & Nakayama, 2000). Although short-lasting, intertrial priming provided the first evidence of an attentional bias to items that had been previously attended to.

In addition, well-known substantiation of a long-lasting experience effect is provided by a series of works by Leber and co-workers (Leber & Egeth, 2006a; 2006b; Leber, Kawahara & Gabari, 2009; but see also Cosman & Vecera, 2014), who show how the current search mode or top-down goals are influenced by past experiences with contexts requiring a specific type of search rather than another. In one of their studies (2006b), two separate groups of observers were trained to use different strategies to detect a color target in a search array. One group of observers was trained on a "singleton search" task in which they reported the identity of a varying shape target (circle, triangle or square) that appeared among homogeneously shaped non-targets (e.g., all square) (fig. 1a), while the other group was trained on a "feature search" task in which they were instructed to search for a target of consistent shape (e.g., always a circle) among heterogeneously shaped non-targets (fig. 1b). Crucially, after the training, the two groups were transferred to a test phase in which they had to detect a specific shaped target (always a circle) among homogeneously shaped non-targets (squares). Testing trials were "optional" in that they could be performed in either a singleton search mode (search for the uniquely colored target) or a feature search mode (search specifically for the circle target). During the training, as discussed earlier (paragraph 1.2), only the singleton search group's attention was captured by an irrelevant color singleton distractor, and this interference effect was strongly attenuated for the feature search group. Interestingly, during the option trials, the singleton search group continued to show a greater interference effect compared to the feature search group, clearly indicating that participants used their past experience in the training phase to search for the target in the following test phase. Moreover, participants continued to employ the search mode adopted in the preview even when tested after a week (Leber et al., 2009).

Taken together, these findings give the first indications that attentional capture by salient events is attenuated or even prevented when observers have experience with the task and its stimuli. Overall, the intertrial priming phenomenon may indicate that observers learn "what to attend to" over time, and hence learn to prioritize the task-relevant stimuli. In line with this, there are powerful demonstrations that the continuous selection of a certain target feature determines long-lasting attentional bias toward the feature per se, causing its involuntary selection even when it is no longer relevant for the task (Awh, Belopolsky & Theeuwes, 2012). An elegant demonstration comes from the study of Lin, Lu and He (2016), in which they split experiments into distinct phases: an initial training session and a subsequent test session. During the training, participants had to detect and discriminate the orientation of a "T" target letter presented among three "L" non-target letters. All the letters were presented inside differently colored circles and, unknown to the participants, the target was always inside a specifically colored circle (e.g., green). During the test phase, the above-mentioned color could be present or absent but, critically, it was never associated with the target. The authors found that response times in the test were slower when the color was present than when it was absent, suggesting that observers still attended to it. Such a paradigm is elegant in showing, in a simple way, how stimuli are unintentionally prioritized on the basis of past experience, knowledge and expectation of the observer (i.e., her/his internal state). Thus, such attentional bias – operationalized as "selection history" (Awh et al., 2012; Theeuwes, 2018)- resembles the contingent attentional capture in that both are suggested to be mediated by some involuntary processes of top-down control (Gaspelin & Luck, 2018; Egeth, 2018; Wolfe, 2018).

The conclusion that target features are prioritized over time is supported by parallel studies using explicit cues to signal the target feature on a trial-by-trial basis. From this literature (e.g., Bundesen, 1990; Bundesen, Habekost & Kyllingsbæk 2005), it has been proposed that the top-down guidance of attention to target objects requires mechanisms of attention to select objects containing the target features. Thus, a representation of what the target is expected to be is established with experience and this *attentional template* is used to set sensory gain, guide attention, and eye-movement.

1.3.1. Experience with distractor stimuli

The studies discussed in the previous section clearly show that experience plays a crucial role in multi-item scenes in which task-relevant objects compete with salient task-irrelevant objects, and research has shown that the brain has mechanisms for prioritizing further occurrence of the task-relevant stimulus and improving performance. Yet, these studies did not explicitly address whether exposure to salient task-irrelevant stimuli is important in order to attenuate distraction, and hence improve performance. In other words, is an experience with a target feature sufficient to improve task performance or is an experience with distractor stimuli necessary to configure attention away from salient irrelevant features?

One of the most interesting demonstrations that we are able to use distractor information in order to prevent distraction is provided by Arita, Carlisle and Woodman (2012), who showed that observers use cues signaling task-irrelevant features to the same extent to which they use cues signaling task-relevant features. Specifically, by giving observers a pre-cue indicating the color of the target (e.g., red), the distractor (e.g., blue), or a control cue that showed features different from those of both the target and the distractor (e.g., green) before the search display, they found not only the shortest RTs with the target cue but, more interestingly, also shorter RTs with the distractor cue compared to the neutral cue. The authors suggest that the negative cue was used to quickly instantiate a distractor template (‘*template for rejection*’) that reliably facilitated the search by avoiding distractor processing. In view of this concept, just as ‘knowing what to look for’ can be used to bias attention toward relevant information, ‘knowing what not to look for’ is effectively used to bias attention away from irrelevant features.

In the next section, I will review studies that have aimed to investigate how susceptibility to distraction is affected by an observer’s experience with salient task-irrelevant stimuli and the subtended cognitive mechanisms, before converging their findings into common theoretical frameworks. Altogether, they provide evidence that different types of experience with salient distractors, namely (i) repetition of the same stimulus, (ii) frequency of occurrence of the stimulus, and (iii) extensive exposure to variable stimuli, are effective in attenuating their distracting effect, suggesting that the attention allocation system learns to reject distractors over time and, hence, our brain has mechanisms for adaptively preventing the unwanted reiterated distraction.

1.3.1.1. Exposure to the same distracting stimulus

I. Experience as repeated exposure (practice) to a stimulus

For decades, it has been well-known that the repeated presentation of a stimulus results in a reduction in the physiological response to it (Sokolov, 1963). However, only recently have investigation begun into whether the strength with which a salient stimulus captures attention is reduced as a result of its repetition, and, as a consequence, whether its interference effect on a concurrent task is attenuated.

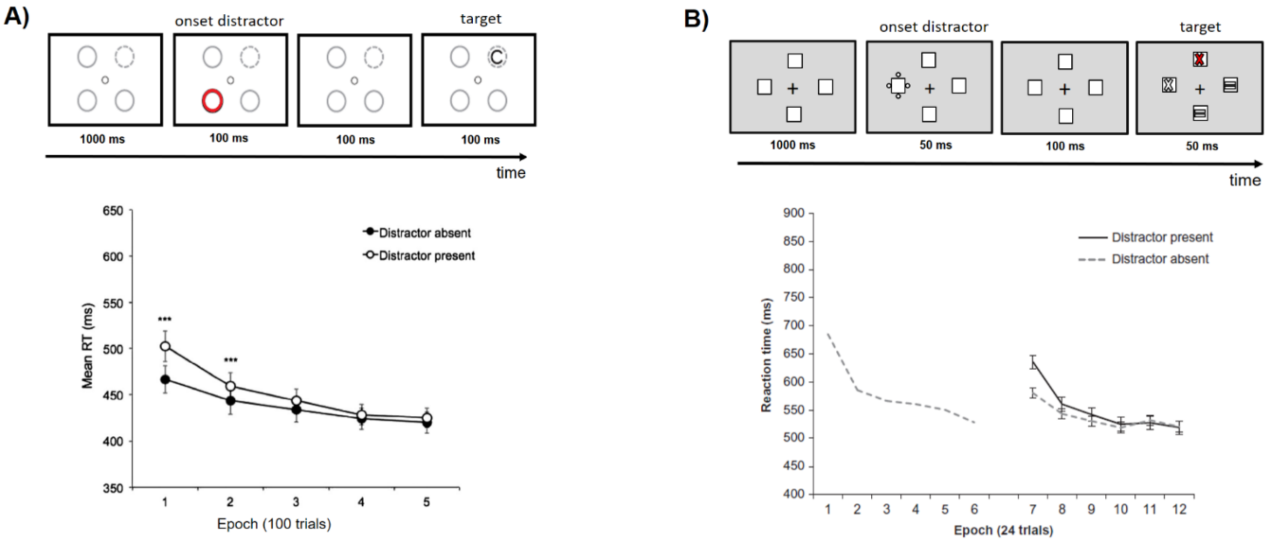

Figure 1.2. Upper: Schematic representation of trial sequence of (A) Turatto and Pascucci's paradigm with focused attention (2016, Experiment 2), and the spatial cueing paradigm used by Vecera et al. (2014, Experiment 2B). Below: In each study, mean RTs for distractor present and distractor absent trials split by epoch.

For example, in Turatto and Pascucci's study (2016; Experiment 1) (Fig 1.2a), participants were required to report the orientation of a target whose position was signalled in advance by a cue. In half of the trials, before the occurrence of the target – and after the cue - the abrupt onset of a bright annulus was presented. Authors found that attention was initially captured by the abrupt onsets, indicating that the processing of salient information was prioritized in a way that such capture could not be prevented even by strongly focusing attention on the task-relevant location; critically, however, distractor interference in the ongoing task reduced rapidly over time.

Similar findings have been found using a spatial cueing paradigm (Folk et al., 1992; see paragraph 1.2 for the description of the paradigm and main results) in a series of studies by Vecera, Cosman, Vatterott & Roper (2014; Experiment 1 a, b). The authors found that the presentation of an irrelevant distracting cue affected the rapidity with which participants detected a target, even though it did not match the target feature. However, the cueing effect varied throughout the experiment, with the greatest cueing effect at the beginning and no effect when participants performed a practice phase with the task, indicating, importantly, that searching consistently for a specific target feature over several blocks of trials was not sufficient to prevent attentional capture (fig. 1.2b); only repeated exposure to the distractor was able to do this (Vecera et al., 2014 – Experiment 2a,2b). Therefore, the specific experience with the salient distracting stimulus is determinant for attenuating distraction, rather than a mere experience with the task or with the target feature.

The experimental approaches that I have briefly reviewed are very interesting because they demonstrate an attentional capture by salient onset distractors in two paradigms that were traditionally employed for empirically supporting top-down theories of attentional control. As described in the previous paragraph (par. 1.2), the failure to find distractor interference in paradigms in which target and distracting features do not match (Folk et al., 1992) was considered to be evidence that stimuli do not have the intrinsic ability to capture attention and are involuntarily selected only if they match the current top-down attentional set. Similarly, the attenuation of interference in paradigms in which attention is fully focused in advance (e.g., Yantis and Jonides, 1990), or in paradigms that incentivize a feature search mode, supports the idea that attentional capture is prevented when there is an active attentional set, and hence it is neither top-down impenetrable nor mandatory. The crucial point is that Turatto and Pascucci (2016) and Vecera et al. (2014) adopted these paradigms but did not examine only aggregate data as done in previous studies; they tracked the participant's performance over time by epoching the data in bins of trials. In so doing, they have demonstrated that an abrupt onset captures initial attention even in the presence of an active attentional set. Thus, these studies offer a possible appealing resolution to the attentional capture debate in that they show that attentional capture is initiated only in virtue of the intrinsic properties of the stimuli; it is only later that the attention allocation system adapts by learning to ignore stimuli that, given the current priority of the observers, are irrelevant.

Nonetheless, in contrast with all these findings, Theeuwes (1992) showed that during a visual search task a color singleton distractor interfered with search performance, and distractor interference did not show any significant reduction in function of stimulus experience (early, middle, late section of task performance) – although there was the suggestion of a decrease from the first to the second section. Theeuwes concluded from this persistent interference that attentional capture by highly salient color contrasts is otherwise top-down impenetrable.

II. Experience as frequent exposure to the distractor

Recently, a growing number of studies has begun to address the role of distractor experience by manipulating the frequency of distractor occurrence across blocks.

Representative evidence of the phenomenon comes from Neo and Chua (2006) who showed that when a cue pre-signaled the target location, an abrupt onset retained the ability to capture attention when it occurred rarely in a given block of trials (18% or 25% of the trials), and, accordingly, caused interference in the concurrent task. However, such interference was strongly attenuated when it occurred frequently (i.e., in almost every trial). Similar to Turatto and Pascucci's findings, this study confirms that abrupt onsets are able to divert attention even when observers have an active attention set, nevertheless, such ability is modulated by the degree with which observers are exposed to them, indicating that their processing is not mandatory.

Having found this frequency effect, Folk and Remington (2015) challenged the contingent capture theory. They speculated that distraction is prevented not only when observers know exactly what to search for, but also when they have information about the distractor. Thus, in conditions in which there is the possibility to develop a positive set for the target properties, frequent presentation of a distractor stimulus (as opposed to infrequent presentation) is critical for generating a set that includes the irrelevant properties to avoid, and hence prevent distraction efficiently.

Interestingly, Muller and coworkers (Muller, Geyer; Zehetleitner & Krummenacher, 2009) demonstrated the frequency effect by gradually varying the proportion of distractor present trials across blocks; on one hand, they found that after an initial practice block in which distractors were never presented (0%), the distractor interference in the subsequent experimental block decreased when the probability of distractor occurrence increased (20% --> 50% --> 80%). On the other hand, after a practice session in which distractors appeared in every trial (100%), the distractor interference in the experimental phase did not vary with distractor probability (80% --> 50% --> 20%). Following these observations, the authors suggested that the persistence of distraction demonstrated in Theeuwes' study (1992) might have indicated that distractor interference cannot be down-modulated below some minimum value but not that attentional capture by color singletons is top-down impenetrable. Indeed, in Theeuwes's study, participants were exposed to an initial practice block with a distractor in each trial, and so they might have learned to reject the distractor as much as possible. Thus, in the subsequent experimental block, where, again, a distractor always appeared, observers could not further reduce the distractor interference. However, in Muller et al.'s view, this interference value indicated only the end of a continuum of top-down attentional control, and theoretically, the magnitude of this interference would have been greater if distractors had been presented in only a small, as compared to a large, proportion of trials within blocks.

It is worth noting that the frequency effect has also been demonstrated in the field of the "perceptual load theory". According to this theory, attentional capture depends strictly on the perceptual load of the task at hand: distractors capture attention, and therefore interfere with performance, only when there are enough attentional resources for processing other stimuli beyond those that are task-relevant (see Lavie, 2005 for a review). Numerous studies have supported this theory by manipulating the perceptual load task (i.e., by increasing the number of different-identity items that need to be perceived, or by making the perceptual identification of the same number of items more demanding) and have found a distractor interference effect under low perceptual load conditions but not under high perceptual load conditions. Given that the load effect has also been shown for abruptly appearing distractors (Cosman & Vecera, 2009) and distractors that move or loom (Cosman & Vecera, 2010a), the perceptual load studies gave some compelling evidence that attentional capture is not automatic. Interestingly, Cosman and Vecera (2010a, b) support and challenge this conclusion in part, by showing that abrupt onset distractors interfere with task performance even in high perceptual load conditions when they represent rare events, but not when they are frequent. These findings corroborate the idea that experience with salient distractors is necessary for preventing its attentional capture, and the high perceptual load by itself is not sufficient.

Evidence that frequency of presentation modulates attentional capture has been robustly reported using a variety of paradigms, with irrelevant abrupt onsets, highly salient color contrasts and, recently, moving object distractors (Folk & Remington, 2015; Geyer et al., 2008; Marini, Chelazzi & Maravita, 2013; Marini, Demeter, Roberts, Chelazzi & Woldorff, 2016; Muller et al., 2009; Neo & Chua, 2006; Pascucci & Turatto, 2015; Retell, Becker & Remington, 2016; Turatto & Pascucci, 2016). In short, these reports underscore the effect that distractor frequency exerts on attentional capture, and the degree of generalizability and universality of the frequency effect.

III. Cognitive mechanisms of distractor rejection

Previous studies converge to indicate that repeated or frequent exposure to the same stimulus are determinant for learning to reject irrelevant salient distractors. How does the brain prevent the reiterated counterproductive distractions?

Over the years, numerous authors have noticed that the reduction of the interference effect with stimulus exposure strictly resembles the habituation of the orienting response. The phenomenon of habituation occurs for virtually all behavioral responses, from a simple muscle response to a complex exploratory behavior, and it is operationally "a response decrement as a result of repeated stimulation" (Harris, 1943). Given that it is widespread among all living creatures, from amoeba to humans, it is considered the simplest and most basic form of experience-dependent plasticity (Thompson, 2009; Rankin et al., 2009).

As early as 1963, Sokolov demonstrated that habituation is also a defining feature of the orienting response (OR). The orienting response is a collection of autonomic and cortical modifications that are elicited by environmental changes, such as the appearance of a novel, unexpected, or significant event. Although the functional significance of the OR is still debated, there is a consensus that it serves to direct attention to a stimulus in order to enhance its processing and prepare a prompt behavioral response. From an evolutionary perspective, a rapid detection of an environmental change is critical because it may represent a potentially dangerous (e.g., predator) or beneficial (e.g., mate) event for the organism’s survival. At the same time, when an innocuous event occurs repeatedly, the OR to it habituates because it is unnecessary to continue to enhance its processing. The investigation of the OR started with Pavlov (1927) who, by attempting to demonstrate conditioning to visiting colleagues, noticed that the dog did not attend to the relevant conditioned stimulus as it always did, but instead directed its attention to the unfamiliar visitor. The set of behavioral changes in which the animal's receptor organs (eyes, ears, etc.) were oriented toward the novel stimulus was defined as an "investigatory reaction" and, later, "orienting reflex" or more colloquially the "what is it response". Subsequently, Sokolov noted that a novel event induced a series of physiological changes in the body– such as changes in the skin conductance level, and in the heart rate, as well as in the alpha blocking of the electroencephalogram (EEG) – that he named, indeed, “orienting response” (OR); these changes were gradually inhibited with stimulus repetition (habituation phenomenon), that is, as the stimulus became more familiar. From these physiological observations, Sokolov developed one of the most influential models of habituation: the Stimulus-Model Comparator theory. The basic notion is that repeated exposure to a certain stimulus forms a “neural” model in the cerebral cortex, which represents events in the environment at any given instant. In addition, there is an amplifying system in the midbrain region that subserves the behavioral output. When the environment changes (e.g., a novel stimulus appears suddenly), the cortical representation - which includes the stimulation from this new stimulus - fails to match the neuronal model, and an OR - mediated by the amplifying system - is elicited toward it. After several repetitions, the stimulus model develops and gradually integrates the novel stimulus, and it exerts increasing inhibition to the amplifying system, thus yielding habituation of the OR.

Besides the physiological changes, Horstmann (2002, 2005) showed that a novel, unexpected color stimulus also induced a slowing down of search times, a phenomenon that he called *surprise capture*. He concluded that surprise capture was triggered by a mismatch between the color of the object and the observers’ expectation regarding the color of the stimulus. The sensitivity of the attentional allocation system to a mismatch is similar to the neural model of Sokolov.

Coming back to the mechanisms that underline the effect of distractor repetition and distractor frequency, several studies posit that both these effects reflect a form of *stimulus novelty* in Sokolovian terms (e.g., Folk & Remington, 2015; Muller et al., 2009; Neo & Chua, 2006; Turatto &

Pascucci, 2016), similar to surprise capture. Within this perspective, as observers implicitly learn about the sequence of events that make up each trial during an experiment, an internal representation of how a typical trial should unfold over time is soon established (a sort of neural model). During its first few repetitions, or if it occurs rarely over a block of trials, a distractor is not likely to be incorporated into the representation and it attracts attention because it violates the observer’s expectations. On the other hand, when the salient distractor is repeated several times or occurs frequently (i.e., in almost every trial) it is integrated into the representation, and fails to capture attention as a result of habituation. Thus, attentional capture adaptively decreases with stimulus exposure because further stimulus intake is not necessary, and a reiterated distraction could be dangerous for the organism’s survival.

In parallel, several studies have given some indication that the effect of distractor exposure cannot be exclusively explained by the Sokolovian account (Folk & Remington, 2015, Marini et al., 2013; Muller et al., 2009). A clear evidence has been recently provided by Turatto and collaborators (2018), who showed that a prior passive exposure to a repeating visual onset was sufficient to attenuate the onset interference when presented within the context of an active task, but such exposure was not enough to eliminate it. Critically, the interference disappeared rapidly during the task, suggesting that an active top-down mechanism was specifically engaged in order to inhibit the distractor information and shield target processing from interference.

Conforming to these findings, in post hoc analyses, Folk and Remington (2015) showed that the magnitude of the interference of a rare onset was not modulated by the time interval between consecutive onset presentations. Theoretically, a system designed to detect unexpected stimuli or environmental changes should be sensitive to an infrequent onset only when the interval separating successive presentations is sufficiently long that the event is not integrated into the neural model, and so is generally unexpected. Accordingly, it has been demonstrated that the orienting reflex is sensitive to the temporal spacing between the occurrence of successive stimuli (ISI) (Romero & Polich, 1996; Polich, 1990). Considering that distractor inhibition is effortful, the authors suggested that the reduction of distractor interference reflects an adaptive inhibition strategy; in a context in which distracting stimuli are rare it would be inefficient to set attention so that distractor interference is reduced in a few trials at the expense of the majority of trials. On the other hand, when distractors occur frequently it is crucial to inhibit them in order to avoid a deterioration of performance in almost every trial, and hence an overall reduction in task efficiency.

Although the strategic suppression account has been supported by other studies (e.g., Muller et al., 2009), interestingly none of these studies rules out the role of *stimulus novelty* completely. For instance, in the study by Muller and collaborators (2009), participants started with extensive practice in a visual search task in which a distractor color singleton appeared in every trial, and then performed an experimental block in which a singleton distractor was presented in almost every trial (80%). Critically, in the distractor-present trials, the distractor was defined by a frequent feature in 70% of the trials (e.g., red singleton) and with a rare feature in 10% of the trials (e.g., blue singleton or bright singleton). Although participants gained experience with salient task-irrelevant stimuli and were incentivized to adopt a suppressive strategy in order to inhibit the too-frequent distractors, only the interference of the frequent feature was eliminated while the rare feature continued to cause a large interference effect. Thus, the rare distracting feature captured attention in a mandatory manner in virtue of its novelty and unexpectedness, while attention to the frequent familiar feature was inhibited as the result of a stimulus-specific habituation process. The notion of stimulus specificity is consistent with the notion that the habituation of the OR serves to reduce attention to innocuous stimuli while still leaving the organism responsive to novel stimuli.

Overall, all the studies converge toward the conclusion that the experience effect is mediated by the combination of stimulus novelty and the suppressive strategy. Is there a different mechanism from the habituation of the OR that underlies the attenuation of distraction? In other words, are we able to ignore salient task-irrelevant stimuli even if novel and unexpected?

1.3.1.2. Extensive experience (practice) with variable distractors

Until now, the majority of the studies presented above provide evidence for a modulation of the attentional capture phenomenon due to an exposure to the same salient task-irrelevant stimulus, making it difficult to disambiguate whether a different mechanism from the habituation of the OR could subtend the attenuation of distraction. Overall, they suggest that a specific experience, or practice, with a given distractor promotes a stimulus-specific learning process (e.g., the colored distractor seen during the previous practice session) rather than general learning to reject task-irrelevant stimuli (e.g., a general color feature or singleton items).

With this consideration in mind, more thorough investigations have begun into the conditions under which the learned control over distractors can generalize to new conditions. Starting from the evidence that other high-specific forms of learning - such as skill learning - generalize to novel environments when practice is variable (Schmidt & Bjork, 1992), attentional studies have analogously examined whether attentional capture is similarly affected by extensive practice with variable distractors. That is, if we are trained to ignore distractors, are we able to subsequently reject a distractor that has never been seen before? This issue is relatively new and less investigated.

The first evidence that distractor rejection can generalize beyond the specific ignored stimulus came from the work of Dixon, Ruppel, Pratt & De Rosa (2009). In their study, participants were asked to identify which one of a pair of objects belonged to a previously defined target set.

During priming blocks, subject had to repeatedly attend to the stimulus color in order to identify targets (e.g., pink target and purple distractors), while ignoring the uninformative shape information. During the following probe blocks, subjects were otherwise required to attend to the shape of the stimuli (e.g., differentiate a cross target from triangle distractors) while ignoring the color. Interestingly, participants were not only slower to respond to the shapes in the probe blocks after the priming blocks but, critically, a larger decrement in performance was found when the shapes were previously ignored across multiple-color target contexts, compared to a single-color-target context, indicating a generalized rejection strategy from a specific item (e.g., a circle) to a feature (e.g., shape).

More importantly for the focus of this thesis, two subsequent studies demonstrated a generalization of the practice effect when presented with salient distracting stimuli that were perceptually decoupled from the relevant stimulus rather than in response to irrelevant features belonging to the to-be-attended-to object (Kelley & Yantis, 2009; 2010; Vatterott, Mozer, & Vecera, 2018). These studies used paradigms consisting in an initial training phase in which participants practised rejecting salient distractors and a test phase in which distractors were presented that had not been previously presented in the training session.

Using an additional singleton paradigm, Vatterott and collaborators (2018) showed that a variable practice session with different color singleton distractors that appeared intermixed in the same block (heterogeneous training) was effective in preventing the interference effect of a novel color singleton during the subsequent test phase. In contrast, practice with distinct color distractors presented separately within each block (homogeneous training) was not sufficient, and the interference effect recovered immediately when a novel color distractor appeared after the training session. The authors suggest that participants learn to reject distractors by implicitly building a distractor template, and the more variable the practice the broader the “tuning” to distractor features, allowing a generalization of the distractor rejection strategy to novel irrelevant, but otherwise salient, stimuli (see also Won & Geng, 2018).

Regarding the target template, these results shed light on how attentional mechanisms involved in target selection and distractor rejection are differently affected by stimulus experience, suggesting that distractor rejection is mediated by separate processes. In fact, while variable distractor practice generates a broadly-tuned, less precise distractor template, that increases target search efficiency by generalizing to distractors that have not been experienced, practice with variable target features results in a broad target template that increases the number of false positive target selections, and hence reduces search performance.

In addition to previous findings, Kelley and Yantis (2009, 2010) used highly variable (never repeated) figure ground images that appeared in a completely irrelevant spatial position with respect to the central task, and demonstrated that variable practice is also effective in reducing attentional capture by novel, perceptual complex images. Given the perceptual complexity of the distracting stimuli, Kelley and Yantis (2009) hypothesized that the reduction in the distractor effect and the transfer to new spatial positions was the result of an improvement in the allocation of attention more than a habituation of the orienting response. Specifically, they proposed that distractor rejection requires the inhibition of the cortical areas corresponding to the representation of the object or to its spatial position. When the same distractor is repeated (as in homogenous practice), only a few areas need to be inhibited, and the process is quickly and constantly reinforced over time. On the other hand, when various and complex distractors are presented, different information is given over time, with the result that inhibitory interactions have to be established among a variety of visual processing areas. This broad filtering mechanism takes longer to be formed compared to specific filtering, but it can be applied in many different conditions.

Besides evidence of the generalization of distractor learning rejection is still scarce and the underlying neural processes unknown, it is likely that this skill determines performance benefits in complex tasks, such as driving, where observers must quickly learn “what to attend to” and “what to ignore”. Thus, the studies reviewed above are crucial because the paradigms contained therein resemble typical real-life situations in which we are often intensely exposed to salient and complex stimuli that differ from each other regarding location of occurrence, physical appearance, and meaning.

1.3.2. Integration and conclusion

As discussed in the previous sections, several years of research on the control of visual attention has resulted in a wealth of information regarding the condition under which attention is involuntarily diverted by salient stimuli, as well as the extent to which such “capture” of attention is cognitively impenetrable, meaning that it is immune from modulation by top-down control.

Investigation into the effect of distractor experience has been crucial in that it has offered a possible resolution to the attentional control debate. In accord with bottom-up theories, findings indicate that certain classes of events do have the intrinsic power to capture involuntary attention, but this capture is effectively prevented with repeated distractor exposure, indicating that it is not immune to top-down control, as supported by the top-down theories.

Taken together, all these findings have been conceptualized in the “**experience-mediated attentional tuning**” framework of Vecera et al. (2014). As shown in Fig. 1.3, the authors suggest that the attentional control debate can be resolved by embracing the idea that stimulus-driven and goal-directed control are not dichotomous processing modes; they lie on a continuum of processing in which experience and learning hold the balance of power by determining the extent to which attention will be captured by stimuli or not. With less experience, attention is allocated in a stimulus-driven mode, but, when experience increases, attentional control becomes goal-directed ("*learned control*"). In this learned control view, bottom-up control is the default mode, but top-down control is ultimately the most frequently used. Yet, although experience moves control from stimulus-driven to goal-driven, other factors might restrict the influence of experience, preventing control from becoming completely goal-driven, such as the perceptual load. For example, a task-irrelevant distractor will continue to draw attention in tasks of low perceptual load, suggesting that attentional control cannot become completely goal-driven in such conditions and is unable to prevent capture, even though this capture will be attenuated during the experiment as the result of increased experience.

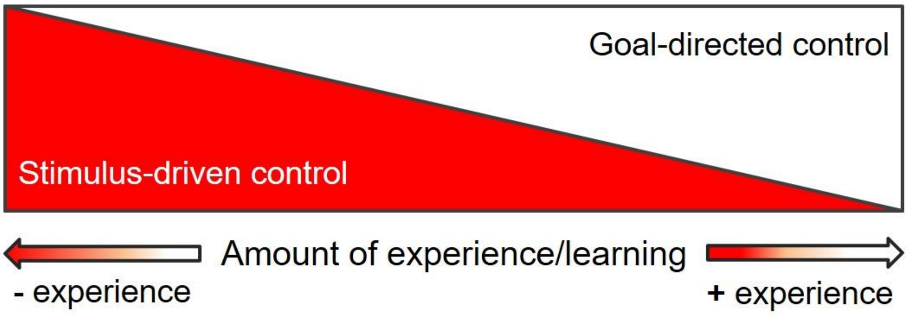

Figure 1.3. The "experience-based attentional tuning" framework. Modified from Vecera et al., 2014

Thus, the experience-mediated attentional tuning explains daily life situations more satisfactorily; in fact, almost every day we hear about the dire consequences resulting from failure to remain concentrated on a given task in daily life (e.g., a car accident may occur if we do not pay careful attention to the road and to the traffic signs while driving) and we are conscious of how easily we get distracted by certain events despite severe consequences, yet, if we consider the huge amount of salient information and the sheer number of salient events that happen constantly around us throughout our waking day, it is surprising how rare distraction is compared to what we may expect from lab findings.

1.4. Attention and Emotion

The *attentional capture* phenomenon has traditionally been associated with perceptual salience, which is computed on the basis of the detection of visual features that significantly differ in space (e.g., high color contrast, brightness, orientation) or over time (e.g., abrupt onset, motion) from the surrounding stimuli (Itti & Koch, 2001). Although these studies have provided an enhanced knowledge of the many facets of selective information processing, there are stimuli that are able to capture attention due to their emotional significance and despite their low-level physical properties. These stimuli are conditioned stimuli (i.e., stimuli that acquire a motivational value) and intrinsically motivational stimuli, such as images with an emotional content.

From an evolutionary perspective, the detection of potential opportunities and dangers are critical for the survival of individuals and their progeny, and environments in which those significant stimuli are unpredictable in time and space foster the evolution of mechanisms for attending to them reflexively, and responding rapidly if necessary. Thus, in a similar way to animals that selectively respond to stimuli on the basis of their inner motivation – such as hunger, threat of harm and sexual needs – human attention tends to be preferentially allocated to emotional/motivational events rather than to those that are routine and neutrally affective (Lang, Bradley & Cuthbert,1997). With a reference to its natural state, this form of attention is referred to as "**motivated attention**".

In the laboratory, the occurrence of an emotional cue sets off a cascade of brain responses. Several studies suggest that emotional stimuli engage cortico-limbic appetitive and defensive circuits, which, in turn, (i) enhance attention allocation to facilitate the perceptual and evaluative processing of the stimulus, and (ii) trigger a series of reflex responses to prepare the organism for action (Anderson, Laurent & Yantis, 2011; Gottlieb, 2012; Hickey, Chelazzi & Theeuwes, 2010; Lang & Bradley, 2010; Lang, Bradley & Cuthbert, 1997; LeDoux, 2012; Pourtois, Schettino & Vuilleumier, 2013; Raymond & O'Brien, 2009). Engagement of these systems is mediated by *stimulus significance,* which is computed in terms of valence – indicating which system is activated – and arousal – indicating variation in the "intensity" of the activation (e.g., Bradley, Codispoti, Cuthbert & Lang, 2001).

1.4.1. Attentional capture by conditioned stimuli

Findings regarding the influence of emotional stimuli on attentional control come primarily from animal and human research using conditioned stimuli. Specifically, stimuli that have acquired an emotional significance (motivational value) through an association with a reward or punishment are suggested to be automatically prioritized by the attentional allocation system (e.g., for a review see Failing & Theeuwes, 2018; Le Pelley, Mitchell, Beesley, George & Wills, 2016). Evidence of this is shown in numerous studies that report performance benefits when the stimulus signaling reward or threat are either the target or relevant for task-performance (e.g., bound to the spatial location of the target). For example, in Kiss, Driver and Eimer (2009), participants were rewarded for searching for a singleton whose color signaled the magnitude of the reward that could be obtained. Although the color singleton varied trial by trial, meaning that participants were uncertain about the incoming reward until the target was presented, the results showed faster identification for high-rewarded targets than for low-rewarded targets, suggesting that reward modulates the efficacy of top-down control.

However, the powerful capacity that conditioned stimuli have to attract attention has been clearly shown by studies in which reward or threat-signaling stimuli compete with other attentional control processes for attentional selection. One of the most intriguing experimental paradigms demonstrating that conditioned stimuli capture attention independently of our control has been designed by Le Pelley and collaborators (2015). In a version of the additional singleton task (Theeuwes, 1992), participants searched for a shape singleton while ignoring a color singleton that appeared in two thirds of the trials. The critical manipulation was that the singleton was presented throughout the experiment in three different colors and each color signaled a different amount of reward that could be earned if participants gave a correct response within a given time limit. Crucially, the stimulus that signaled a reward was never required to be selected in order to obtain the reward and, more importantly, its selection could determine a slowing down of responses and hence the consequent loss of the reward. Nevertheless, the results showed that response times were slower when the color distractor was present compared to when it was absent, and the degree of attentional capture was larger when the distractor signaled a high reward compared to a low reward - ruling out the possibility that attentional capture was due only to distractor salience. Moreover, distractors signaling a high reward produced a large oculomotor capture, indexed by saccade latencies, compared to low-reward distractors. Considering that participants were not explicitly informed of the relationship between distractor color and reward magnitude, these findings demonstrate that conditioned stimuli capture involuntary covert and overt attention even when they are entirely irrelevant for the task and, more importantly, even when attending to them is counterproductive for obtaining the reward.

Similarly, an automatic attentional and oculomotor capture has also been found for threat-signaling distractors (e.g., Schmidt, Belopolsky & Theeuwes, 2015a,b; Nissens, Failing & Theeuwes, 2017). For example, Nissens and co-workers (2017) found that participants attended to a threat-signaling, but non-physically salient, distractor even though they had been warned that attending to it would lead immediately to the release of a shock.

Corroborating evidence has also been found using very different paradigms and with perceptually complex conditioned stimuli (Failing & Theeuwes, 2015; Reynolds & O'Brien, 2009), emphasizing the generalizability and universality of findings of attentional capture by conditioned stimuli. For example, Failing and Theeuwes (2015) found that participants' sensitivity in detecting a target image (e.g., an image depicting a forest) among a fast-presented stream of different images (e.g., images of a field) decreased when a picture that had previously been associated with a reward was presented. Moreover, the semantic category of natural scenes associated with a high reward caused more interference in target detection than the semantic category associated with a low reward. A similar effect was found when using conditioning images associated with a loss of money, showing a decrement in target detection when an image previously associated with a high loss, compared to a small loss, preceded the target.

Conjointly, these studies suggest that the extent to which attention is allocated to conditioned stimuli does not depend on the valence of the stimulus – that is, whether it is associated with a positive (reward) or a negative (threat or loss of money) value – but rather on its arousal, that is, the amount of reward or loss associated with the stimulus itself.

1.4.2. Attentional capture by emotional images

Differently from conditioned neutral images, natural scenes with an emotional content – such as erotic and violent images - are shown to have the intrinsic power to elicit measurable attention and orienting responses. Picture viewing is a ubiquitous human activity, and with the importance that the mass media has assumed, we are now, more than ever, continuously exposed to pictures through television, newspapers, billboards, or banner advertising on websites. Images that are emotionally charged, but also films and stories, prompt patterns of bodily change in observers even though they are mere representations and not actual events, and their impact on our behavior is well-known in daily life. For example, just think how the movie "Jaws" caused a fear of swimming in the sea in a generation of people (Cantor, 2004) and that, recently, billboard advertisements for women's lingerie were removed from some main cities because they captured drivers' attention, impacting negatively on road safety.

1.4.2.1. Orienting in free picture viewing

In the psychology laboratory, one very intriguing way in which attention has been linked to these emotional stimuli has been by highlighting analogies existing between the bodily changes that occur when individuals process these "significant" events and when they process "novel" events, which are the stimuli that were initially found to elicit an orienting and attentional response (Bradley, 2009).

To evaluate these analogies empirically, stimulus "significance" has to be categorized in terms of subjective ratings of valence and arousal; specifically, when observers rate a set of pictures that depict a variety of common objects and daily life situations in terms of pleasure (ranging from pleasant to unpleasant) and arousal (ranging from calm to aroused), the result is a two-dimensional space like the one illustrated in Fig. 1.4a (e.g. Bradley, 2009). This distribution of pictures is consistent with the idea that judgments of their significance reflect the underlying activation of the motivational systems: when activation is minimal, pictures are rated as being low-arousing and are usually labeled "neutral" or "unemotional", on the contrary, when the activation gradually increases, pictures are rated as more arousing, and are defined differently, as being "emotional". From a motivational perspective, neutral events indicate a weak tendency to action and little energy mobilization, while emotional ones are linked to metabolic requirements for preparing motor action.

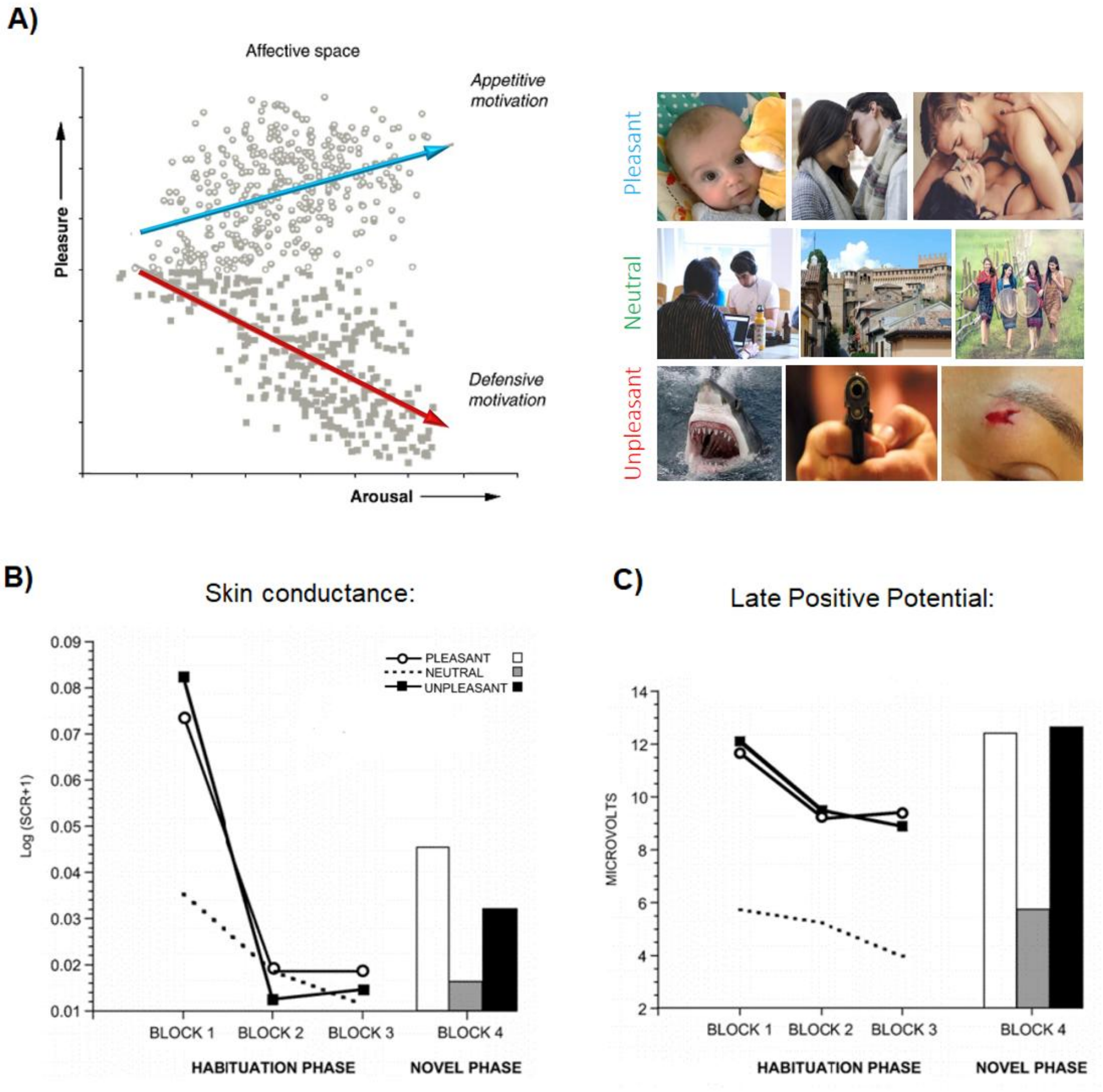

Figure 1.4. A) On the left, this representation of the distribution of pictures in a two-dimensional space defined by mean rating of judged pleasure (y axis) and arousal (x axis) is consistent with the hypothesis that evaluative judgements reflect the level of activation in appetitive and defensive systems. Modified from Bradley (2009). On the right, examples of the picture categories rated by participants. Below, skin conductance changes (B) and Late positive potential amplitude (400-800 ms) elicited when repeatedly viewing the same pleasant, neutral, and unpleasant pictures through three blocks (habituation phase), and a novel set of emotional and neutral pictures (novel phase). Modified from Codispoti et al. (2006)

As stated in a previous paragraph (1.3.1.1), the orienting response is a collection of different physiological, neural and motor responses - including heart rate deceleration, skin conductance change and EEG activity - which were initially linked with attention allocation to novel, unexpected events. Hence, in order to appreciate the effect of the significance of a stimulus on the OR, it is useful to concentrate on the main findings derived from physiological studies in which participants passively viewed significant (arousing pleasant or unpleasant) pictures that were novel or repeated. Specifically, during the picture viewing paradigm, it has been found that: (i) all pictures elicit an OR during their initial presentation, hence when they are “novel” (i.e., never repeated, as in the Sokolovian sense of the word), (ii) the significance of the stimulus, both pleasant and unpleasant, increases the magnitude of the OR, and (iii) the different components of the OR habituate at different rates with repeated presentation of the same picture, suggesting that the OR is a complex combination of responses rather than a unitary process. With these findings as a starting point, evidence regarding the modulation of the main components of the OR will be described in a more exhaustive way in order to shed light on the extent to which emotion affects attention (Bradley, 2009; Codispoti, Ferrari, De Cesarei & Cardinale, 2006).

Regarding the peripheral physiological components of the OR, when observers passively look at pictures, heightened skin conductance (Fig 1.4b) and relatively prolonged cardiac deceleration are elicited during the initial presentation, and this is true for all novel pictures including those that are neutral. The magnitude of these measures is affected by stimulus significance, showing an increased skin conductance response and a more pronounced heart rate deceleration for emotional, compared to neutral pictures. However, the pattern of the affective modulation for the two components is different, with a larger skin conductance for both pleasant and unpleasant, compared to neutral pictures; a larger heart rate deceleration, on the other hand, is seen for unpleasant, compared to neutral and pleasant images.

Concerning the neural physiological components of the OR, different event-related potential (ERP) components are modulated by stimulus novelty, such as an early mismatch negativity (Naatanen, 1979) and the later N2b and P3a (e.g., Courchesne, Hillyard & Galambos, 1975; Rohrbeaugh, 1984). Several other ERPs are modulated by stimulus significance, including the centro-parietal P3b that is especially tied to the attentional allocation to task-relevant stimuli, and a similar slow positive centro-parietal component called Late Positive Potential (LPP; Cacioppo, Crites, Gardner & Berntson, 1994). As shown in Fig. 1.4c, similar to the skin conductance response, pleasant and unpleasant pictures elicit a more pronounced LPP compared with neutral pictures; the LPP magnitude does not differ between pleasant and unpleasant pictures. This modulatory effect, that is referred to as **affective modulation of the LPP**, has been reported in numerous studies and it is considered a reliable index of attention allocation and emotional significance and, for the aims of this study I will subsequently describe it in more detail.

These components habituate at different rates. For example, changes in electrodermal activity disappear when the same neutral images are presented after a week, while emotional images continue otherwise to elicit a larger orienting. However, when pictures are consecutively repeated within and across-blocks of trials, the skin conductance response does not discriminate between emotional and neutral pictures after approximately 20 repetitions. On the other hand, the general prolonged cardiac orienting to pictures, and the specific differences in heart rate change found for unpleasant pictures, disappear both when the same images are presented after a week and when they are repeated about 10 times. Although skin conductance and heart rate changes disappear completely with picture repetitions, a new set of pictures elicits the reinstatement of both these changes when presented after the habituation process.

In contrast, although the overall LPP amplitude decreases with stimulus repetition, the affective modulation of the LPP is fairly resistant to habituation, as shown by the fact that it does not diminish, neither when the same emotional images are repeated after a week nor when they are repeated numerous times within the same block or for subsequent blocks, remaining invariant for up to 90 image repetitions (Fig. 1.5c) (Bradley, Lang & Cuthbert, 1993; Codispoti et al., 2006). Thus, heart rate habituates faster compared to skin conductance, while the affective modulation of the LPP seems to be unaffected by habituation. Taken together, these data indicate that the traditional indices (heart rate, skin conductance, and LPP) are differently modulated by repetition and stimulus significance, suggesting that they might reflect different facets of orienting. Nonetheless, all the components of the OR work jointly to promote the survival of the organism by directing its attention, thus alerting it, to unusual events that might be potentially relevant (e.g., a potential predator from which it is necessary to escape or a mating partner that it is beneficial to approach).

The survival function of the OR is easily appreciable in conditioned contexts, in which novel stimuli are associated with electric shocks or money, however, it is not so readily perceivable in the classic repetition/change paradigms where novel stimuli are neither clearly motivational nor completely novel. Novelty may be defined in several ways, and distinct types of stimuli have been considered novel. In reality, a stimulus is **truly novel** only when it has never been experienced before, and when it does not match with any long-term memory representations. This kind of novelty is difficult to study in human adults since most, if not all, stimuli used in laboratory experiments are “familiar”, even when presented to the participants for the first time, given that they will at least bear some resemblance to something that has been experienced during the course of life. It is worth noting that some indication as to the effect of viewing a truly novel stimulus is provided by studies on non-human primates; these studies found that the initial reactions were always defensive and protective, even though the stimuli used were inoffensive, and sometimes inanimate, objects (Dolin, Zborovskaya, Zamakhovev, 1965). Novel stimuli reflexively engage the defensive system that, in turn, mediates a prolonged heart rate deceleration to prompt perceptual intake and attention, and a subsequent enhancement of skin conductance to prepare the organism for action when the stimulus represents a real danger. Only after information is stored regarding the safety of the stimulus are traditional “orienting” behaviors of exploration actualized. As suggested in animal literature, this selective habituation – “learn what not to fear” – is the most conservative and advantageous strategy that animals can pursue, since they approach, sniff, and handle the novel stimulus only after answering the questions “What is that?” and “What should I do?”. This behavior therefore saves their life when the stimulus is effectively dangerous, such as a predator, entailing the cost of losing a meal or a mating opportunity when the stimulus is ultimately appetitive.

A different way to study novelty in human adults is by considering stimulus novelty as in the Sokolovian account in which a stimulus is novel when it does not match the representations that are currently active in the short-term memory (STM) – Sokolov’s “neuronal model”. In the laboratory, a short-term aspect of novelty is **deviance;** this term is applied to a rare stimulus change (i.e., deviant) that occurs in an otherwise repetitive sequence (i.e., standard). In this case, the conspicuous repeated presentations of the standard result in a strong match in the STM with little evidence of orienting in skin conductance, heart rate, or LPP (e.g., Simons, Graham, Miles & Balaban, 1998; Simons, Rockstroh, Elbert & Fiorito, 1987), while the infrequent occurrence of the deviant - and the long lapse between its consecutive occurrence - decreases the probability of a match, and increases the OR response as a consequence (e.g., Escera and Malmierca, 2014; Gatchel & Lang, 1974). Alternatively, the stimulus can be novel when it is presented only once and never repeated within the experiment, therefore becoming less easily identified or categorized. In terms of ERPs, for instance, it is found that in oddball paradigms the orienting response is enhanced for novel (i.e., never repeated rare changes) compared to deviant stimuli (i.e., the same rare change) (Courchesne et al., 1975), and behavioral data show that, compared to a standard distractor, participants are slower at responding to a task when a novel, rather than a deviant, stimulus appears, suggesting that more attentional resources are diverted to novel stimuli (e.g., Schomaker and Meeter, 2014). According to the mismatch model (Sokolov, 1963), these findings suggest that the degree to which stimuli elicit an orienting response depends on their degree of novelty that, in turn, depends on the degree of similarity between the stimulus features and the current STM representations. Thus, orienting will be largest for stimuli that do not share features with STM representations (i.e., novel stimuli) compared to stimuli with a low featural match (i.e., deviant stimuli), and will be minimal for stimuli with substantial overlapping features (i.e., standard stimuli). This continuum can be similarly proposed for the long-term memory (LTM) representation with the largest OR to truly novel stimuli and no OR for extremely familiar stimuli.

As far as emotional pictures are concerned, both pleasant and unpleasant images match existing representations in LTM to some extent, even when presented for the first time during picture viewing paradigms. For example, a picture of an attacking dog that has never been seen before matches a LTM representation of previously seen dangerous dogs. Unpleasant pictures match existing associations with the defensive motivational system that, as previously described for truly novel stimuli, initiates increased perceptual processing (cardiac deceleration) and preparation for action (skin conductance change), because past memories lead us to consider the unpleasant stimulus as dangerous. Pleasant pictures, on the other hand, include associations with the appetitive motivational system and, though novel, are considered potentially non-threatening or even rewarding, generating a reduced cardiac deceleration and a heightened skin conductance change inducing the approach tendency (Lang, 1984). Through their natural associations with motivational systems, pleasant and unpleasant familiar pictures prompt a similar enhanced late positive potential, whose magnitude is presumed to reflect both the allocation of attentional resources to these stimuli and the activation of the motivational system. Considering that the affective modulation of the LPP is fairly insensitive to habituation, the general idea regarding LPP is that the repetition of the same emotional images does not eliminate the associative connection with the motivational systems (e.g., Rescorla, 2001), but reduces the necessity of an enhanced perceptual processing and/or of an immediate reaction - as indicated by the rapid habituation of the heart rate and skin conductance change, respectively.

In summary, the different components of the OR mediate different adaptive reactions to novel and significant events, and therefore their habituation rate can be considered a reliable “tool” for examining the state of engagement of their subtended processes (Bradley, 2009).

1.4.2.2. The Late Positive Potential (LPP)

Event-related potentials (ERPs) are modulations of the electrical activity of the brain, which are traditionally analyzed in terms of components, defined as deflections of the ERP wave occurring at a certain latency. Thanks to its excellent temporal resolution, the ERP technique is quickly becoming the primary tool in cognitive neuroscience, providing a reliable narration of neural processes as they unfold, millisecond by millisecond.

In terms of ERPs, it has been observed that the viewing of emotional content affects the amplitude of a late slow positive potential during a passive picture viewing, named the Late Positive Potential (LPP). As shown in Fig. 1.5, the LPP is an enhanced centroparietal positive signal that begins around 300 – 400 ms after the onset of emotional, compared to neutral, pictures, and that persists after the disappearance of the image for up to 6 s. This cortical modulatory effect seems to be greater for pictures rated highest in emotional arousal, compared to low-arousing images, regardless of whether they are pleasant (e.g., erotica) or unpleasant (e.g., mutilation) (Cacioppo et al., 1994; Cuthbert, Schupp, Bradley, Birbaumer & Lang, 2000; Schupp et al., 2000; Schupp, Flaish, Stockburger & Junghöfer , 2006; Schupp, Junghöfer , Weike & Hamm, 2004).

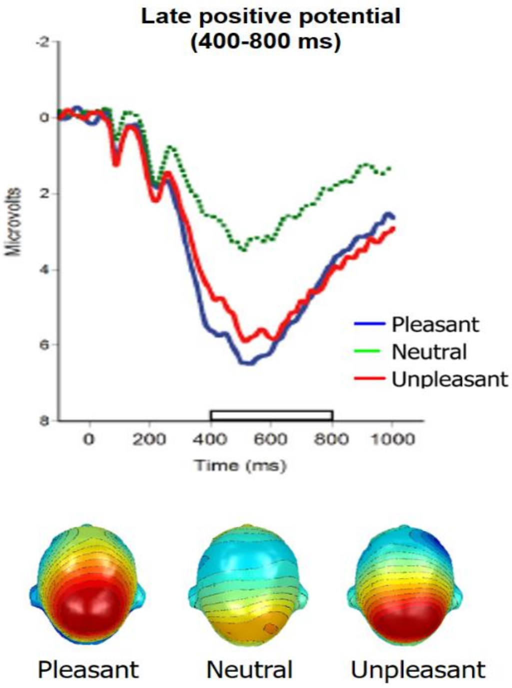

Figure 1.5. Example of the emotional modulation of the LPP during Picture Free Viewing.

Crucially, the affective modulation of the LPP does not rely on voluntary evaluation of the hedonic content and is relatively unaffected by task demands; for example, Cuthbert et al. (1995) found a similar modulation when comparing the magnitude of the LPP elicited during passive viewing to when an evaluative task was performed, suggesting that passive viewing elicits similar cortical processing to that elicited by an explicit evaluative task. Moreover, several behavioral studies have found involuntary semantic processing of affective stimuli (McKenna & Sharma, 2004; Pratto & John, 1991; Stenberg, Wiking & Dahl, 1998), and have also discovered that affectively congruent stimuli prime both pronunciation and lexical decisions, in the absence of an explicitly evaluative context (Bargh, Chen & Burrows, 1996; Giner-Sorolla, Garcìa, Bargh, 1999; Hermans, Houwer & Eelen, 2001; Wentura, 1998).

These results give rise to the idea that intrinsically motivational cues are selectively processed, because they naturally engage attentional resources, as reflected in the LPP modulation (Lang et al., 1997).

Even more convincing evidence of the automaticity of emotional processing was provided by Codispoti and colleagues (Codispoti et al., 2006; Codispoti, Ferrari & Bradley, 2007; Ferrari, Bradley, Codispoti & Lang, 2011). In these studies, using a free viewing paradigm, the same picture was presented for as many as 90 trials within the same experimental session. The authors found that the overall amplitude of the LPP decreased to some extent with repetition, but, critically, the affective modulation of the LPP remained unvaried until the last picture presentation. The persistence of this cortical modulation, notwithstanding the massed repetitions, led the authors to interpret the emotional modulation of the LPP not only as an index of attentional allocation but also of motivational engagement. This hypothesis was supported by a further study that found an enhanced LPP even when pictures were presented for only 25 ms that persisted for seconds after the picture itself was no longer on the screen, ruling out the possibility that it reflected a continuing perusal of the sensory array (Codispoti, Mazzetti & Bradley, 2009).

Over the years, numerous findings have converged to indicate that the LPP component reflects the emotional processing of the semantic properties of the pictures, rather than the perceptual properties (Codispoti, Bradley & Lang, 2001; Codispoti, De Cesarei & Ferrari, 2012; De Cesarei and Codispoti, 2006; 2011). For example, it has been intuitively proposed that both color and picture size could facilitate the recognition of the emotional content of a natural image under challenging perceptual conditions (e.g., red, mutilated bodies, or pink, naked bodies). Nonetheless, a similar modulation of the LPP was found for color and greyscale images regardless of the very brief image presentation (24 ms) (Codispoti et al., 2012), and was not dampened by picture size reduction (De Cesarei and Codispoti, 2006). Moreover, when progressively revealing the content of initially degraded pictures by manipulating the spatial filtering effects of the image, the affective modulation of the LPP varied with picture identification similarly for low- and high-pass filtered pictures, and hence is not affected by the compositional content of the image itself (De Cesarei and Codispoti, 2011). Taken together these findings rule out the possibility that LPP affective modulation is merely due to bottom-up perceptual factors.

In light of all these findings, the affective modulation of the LPP is considered to be an index of the semantic identification of motivationally significant pictures, and of the activation of motivational systems, and it is not due to mere perceptual factors, such as exposure time, color, picture size or spatial frequencies (Ferrari et al., 2011; Lang et al., 1997; Schupp et al., 2006).

1.4.2.3. Emotion counteracting top-down processes

In the studies reviewed in the previous section, attention to emotional cues was examined in a free-viewing context in which the emotional content of the pictures was the most salient aspect of the stimulus to process (e.g., Bradley, 2009). In this type of situation, orientation of attention toward emotional images has been associated with several autonomic changes, such as the increase in skin conductance. In everyday life, however, it rarely happens that we monitor the environment passively; more often than not we are engaged in a task. How is attention allocation affected when attending to an emotional stimulus is counterproductive for performing the task at hand? In other words, when participants are actively engaged in an unrelated task, and hence the amount of attentional resources that can be committed to the evaluation of affective stimuli is constrained, do motivationally salient distractors compete with task-relevant stimuli for attentional selection?

As discussed in previous paragraphs, attentional capture by a perceptually salient stimulus is traditionally measured in terms of the detrimental effect that it causes on the concurrent task, such as the elongation of reaction times and/or increment in errors. In a similar way, research has converged in showing that emotional pictures engage attentional resources, causing a poorer processing of the task, and hence worsened performance. For instance, a classic paradigm adopted to demonstrate the emotional attentional capture is the one adopted by Erthal and collaborators (2005) in which participants had to discriminate the orientation of two bars that appeared on the left and right sides of a simultaneously-presented central picture. Although the pictures were task-irrelevant, and participants were required to ignore them, authors found slower response times when high-arousal unpleasant scenes, compared to neutral scenes, appeared. A similar disruption in a simple discrimination task has also been demonstrated using high-arousal pleasant pictures (e.g., Gupta et al., 2016). The emotional interference effect is measured as the quantitative difference between the disruption caused by pictures with an emotional meaning compared to pictures with a neutral meaning. Importantly, Calvo and collaborators (Calvo, Gutiérrez-García & del Libano, 2015) demonstrated that emotional images still caused an interference effect when the low-level perceptual properties between neutral and emotional pictures were controlled, confirming that the emotional attentional capture phenomenon is determined by the semantic picture content, rather than by mere bottom-up factors. Moreover, the authors found that emotional pictures interfere with performance also when presented in peripheral vision, that is, under challenging perceptual conditions.

Further evidence of the emotional prioritization is provided by studies in which attentional resources are temporally constrained. One of the most often used methods of examining temporal attention involves the attentional blink phenomenon (AB; Chun & Potter, 1995; Raymond, Shapiro & Arnell, 1992). In an AB task, participants are exposed to a stream of stimuli in which each stimulus is only briefly presented, and they are required to detect or discriminate between the identity of two consecutive targets embedded in the stream. Typically, the attentional blink consists in a poorer performance for the second target (T2) when it appears very soon after the target that was previously attended to (200 ms versus 800 ms), because of the limits of available attentional resources across time (e.g., Shapiro, Raymond & Arnell, 1997). Interestingly, it is found that the AB effect is modulated by motivational significance, with enhanced accuracy in recognizing T2s at short intervals when they are emotionally-charged rather than neutral, suggesting that emotional stimuli gain priority in attentional processing regardless of the temporally constrained processing. It is fascinating to note that pleasant and unpleasant pictures capture and hold attention to an extent that they induce a “spontaneous AB”. Specifically, participants are worse at detecting target images that are presented after high-arousal pleasant and unpleasant pictures compared to neutral images, an effect that is operationalized as “emotion-induced blindness” (EIB) (e.g., Most, Chun, Widders & Zald, 2005; Most et al., 2007; Piech et al., 2011). Thus, in constrained conditions, emotional prioritization can lead to two opposing effects: on one hand, emotional stimuli behave as distractors that deteriorate the temporal processing of targets, and hence cause an AB, and on the other hand, emotional targets are empowered to overcome the AB.

Besides natural scenes, attentional capture by emotional stimuli has been observed in paradigms using faces and words, showing that angry or happy facial expressions and emotionally-charged words interfere more with performance compared to neutral stimuli. The interference effects that are induced are usually smaller compared to those caused by natural scenes, but nonetheless they add evidence that intrinsically motivational stimuli enjoy a special status in the attentional allocation system. It is worth noting that, independently of the nature of the stimulus, attentional capture seems to be specifically sensitive to its arousal, independently of the valence. For example, when comparing stimuli rated with different levels of arousal, Calvo and colleagues (2015) found that the more unpleasant and pleasant images were arousing, the more performances in a perceptual task were impaired. Also, Keil and Ihssen (2004) confirmed these findings using an AB task; the authors observed that only pleasant and unpleasant words that were rated high in arousal overcame the AB, while low-arousing emotional stimuli behaved similarly to neutral stimuli. Comparable results are found for conditioned stimuli (section 1.4.4.1), in which stimuli associated with a high amount of reward or loss disrupt performance to a greater extent compared to stimuli associated with a low or zero amount, converging to indicate an attentional prioritization for high-arousing stimuli. Recently, Padmala and co-workers (2018) have shown that the simultaneous presentation of two high-arousing distractors, independently of valence congruence (pleasant-pleasant, unpleasant-unpleasant or pleasant-unpleasant), cause greater interference compared to one high-arousing emotional image associated with a neutral one, which, in turn, interfere more compared with the presentation of two neutral images. These data have been interpreted as a modulation of the emotional interference as a function of stimulus significance. Consequently, variation of the interference effect with stimulus arousal - indexed by reaction times and/or accuracy – might bear a close resemblance to the LPP and skin conductance components of the orienting response: in a free viewing context, in fact, viewing of the highest arousing pictures elicits the largest LPP and the most pronounced SC changes (Codispoti et al., 2006; Codispoti and De Cesarei, 2007; Johnston, 1986; Radilova, 1982; Schupp et al., 2004). Thus, behavioral measures that are considered as the index of attentional capture, and physiological measures that are considered to be indexes of orienting, converge to suggest that the more a stimulus is arousing, and the more it engages motivational systems, the more it captures attention.

In summary, emotional interference effects have been demonstrated using a variety of visual and acoustic tasks (e.g., Calvo et al., 2015; Ferrari, Mastria, Bruno, 2014; Gupta, Hur & Lavie, 2016; Harris and Pashler, 2004; Hartikainen, Ogawa & Knight, 2000; Shimmack, 2005; Vuilleumier, Armony, Driver & Dolan, 2001) and all these findings have converged to indicate that emotional stimuli are prioritized by the attention allocation system in such a way that they are selected over task-relevant stimuli even when they are entirely irrelevant for the task in terms of spatial position, semantic content and sensory modality of presentation. Overall, the interference produced by emotional distractors has been interpreted as evidence that the processing of emotional stimuli is not only prioritized, but that it occurs in a fairly mandatory fashion (Vuilleumier et al., 2001)

I. To be or not to be (mandatorily attended)

Recently, the hypothesis of an obligatory emotional processing has been challenged by findings which show that there are factors that are able to attenuate or even prevent the emotional interference effect. However, evidence does not converge toward a unique conclusion.

One of the most fascinating pieces of evidence in support of a mandatory attentional capture by emotional stimuli is provided by Augst and collaborator (2014), demonstrating the incapability of individuals to voluntarily reject significant stimuli. Specifically, the authors showed that the presentation of emotional images always interfered during a simple discrimination task, even when participants were informed in advance as to what kind of distractor would appear in a given trial, and so could have prepared themselves to ignore it. Contrasting evidence, however, demonstrates that the emotional interference effect disappears when individuals are rewarded to perform better in a task, indicating that emotional distractors can be voluntarily ignored when there is sufficient motivation to do so, and hence the processing of emotional stimuli is not obligatory (e.g., Padmala and Pessoa, 2014; Hu, Padmala & Pessoa, 2013). Overall, the hypothesis that attentional capture by emotional stimuli can be controlled by volitional, top-down control processes is still debatable.

Another line of research that argues against an automatic attentional capture comes from the field of the perceptual load. On the whole, these studies indicate that emotional interference is not only reduced, but even eliminated, in those strict conditions in which not only emotional stimuli are task-irrelevant but also in which the main task requires a high level of perceptual load (e.g., Erthal et al., 2005; Mitchel et al., 2007; Pessoa, 2002; Silvert et al., 2007). For instance, in the study of Erthal et al. (2005), participants were presented a foveal image while simultaneously performing a discrimination-orientation task in which they were asked to decide whether two bars with an angular difference of 90° (low perceptual load condition) or 6° (high load condition) had the same or a different orientation. The results indicated that while emotional, compared to neutral, pictures slowed down response times in the low perceptual load condition, this interference effect disappeared in the high load condition. These findings are consistent with Lavie's (1995; Lavie, Hirst, De Fockert & Viding, 2004) proposal that if the processing load of a target task exhausts available resources, stimuli that are irrelevant to the task will not be processed. Therefore, emotional processing is not mandatory because emotional stimuli can capture attention only when there are spare resources left from the processing of task-relevant information.

Interestingly, a different panorama has been observed when the focus of investigation is not behavior but activity at a neural level. Focusing specifically on ERPs, Codispoti and collaborators

(2006) found that the modulation of LPP was unaffected by the load of the foveal task; in fact, peripheral emotional images elicited a more pronounced LPP compared to neutral stimuli in the low load condition, and this differential modulation still persisted in the high load condition, indicating that the emotional content of stimuli continued to be processed in the brain.

To summarize, emotional stimuli seem to be quite special in their ability to capture attention, engaging motivational systems and drawing attentional resources even under challenging conditions. As argued by Carretiè (2014), “from an evolutionary perspective, the fact that emotional, biologically salient distractors capture attention also during highly demanding tasks seems a reasonable strategy”. However, because human beings are not slaves to their instinct and reflexes, an intriguing issue is the extent to which it is possible to resist their distracting effect. Some evidence indicates that when capture becomes too detrimental for task performance – for example, obstructing the possibility of reaching an amount of money (Padmala and Pessoa, 2014; Hu et al., 2013) - one can voluntarily ignore emotional distractors. Thus, an interesting question is whether experience with emotional stimuli that are clearly inconsequential should involuntarily lead to their effective rejection.

1.4.3. Experience with emotional distractors

Observations of animal behavior in natural environments have provided the most engaging evidence of the importance that experience and learning have in the perception of significant events. Considering that the “emotional attentional capture” phenomenon has been framed within an evolutionary perspective, it seems interesting to draw a brief parallel with animal research.

In the animal world, predation is a major force in shaping animal behaviors, so that precise identification of predators is beneficial for the survival of animals that serve as food for others. A predator image that is too specific leads to missed detections of predators - and hence poses a risk to life - but an over-general predator image generates fitness costs because animals waste time and energy responding to a harmless cue. In the absence of innate predator recognition, experience and learning allow prey animals to modify the image of a predator. As a result, prey can fine-tune anti-predator behavior to match the current risk, and balance the cost of predator avoidance with fitness-promoting behaviors, such as foraging and mating, thus increasing both their survival and fitness (e.g., Lima & Dill, 1990; Lima & Bednekoff, 1999). Interestingly, it has been found that species that live in situations in which cues associated with predators are highly variable or change in time tend to respond to all the unfamiliar cues and ignore harmless ones only when, with experience, they have learned that they do not represent a danger. Evidence of this is especially appreciable in the modulation of the anti-predator response of seals to whales’ vocalizations. By reproducing sounds of different populations of predator and non-predator whales, Deecke and co-workers (2002) found that seals responded strongly to both familiar-predator whales that habitually prey on them, and to harmless whales that live in distant areas, and hence to cues with which they had no prior experience; on the contrary, they did not respond to harmless whales living in the same area (i.e., familiar cues). Thus, the authors suggest that seals start out with a rather general predator image, interrupting their current foraging or mating activity to respond to all cues that could possibly be associated with a threat, but with experience, they remove harmless cues from the image, learning to ignore these significant, but otherwise inconsequential, stimuli. As a result, through a specific habituation process, they learn what not to fear.

In human beings, the effect of experience and learning on emotional attentional capture, as indexed by the behavioral interference effect, is still relatively unmapped. Regarding conditioned stimuli, for example, it has been shown that a stimulus that was previously associated with a reward initially captures attention despite being task-irrelevant and no longer associated with a reward, but this interference effect is larger in the first hundred trials and then diminishes gradually, indicating that as the learned stimulus-value associations are extinguished in the absence of a reward, so does attentional capture (Anderson et al., 2011).

Converging results have been found when investigating motivationally intrinsic stimuli. For example, Harris and Pashler (2004) clearly showed that an emotional word has a distracting effect in an unrelated concurrent task ("digit-parity task") only initially when its appearance is unexpected. After a few repetitions, however, it becomes less distracting, and acts more similarly to neutral stimuli. Therefore, the authors conclude that emotional stimuli are not so special after all in their ability to attract attention, and the interference that they cause apparently reflects a momentary response of surprise that habituates very rapidly.

However, besides the behavioral interference effect, at a cortical level, the affective modulation of the LPP tells us another story. Although RTs are mostly used as measures of attentional capture by distractors, recently studies have begun to incorporate ERPs to examine the effect of stimulus repetition on emotional distraction. Contrasting evidence derives firstly from a series of ERP studies (Ferrari, Codispoti, Cardinale & Bradley, 2008; Mastria, Ferrari & Codispoti, 2017). During explicit categorization tasks in which participants were presented a series of images (emotional and neutral) and were asked to categorize each of them according to a specified target (e.g., presence or absence of an animal), the authors found that pleasant and unpleasant images always elicited an enhanced LPP regardless of picture repetition. More importantly, this affective modulation of the LPP did not differ from that found during free viewing, suggesting that the picture emotionality remained the most salient aspect of the stimulus independently of task-instruction, despite the amount of resources that could be committed to the affective evaluation being reduced by the presence of an unrelated task. Thus, the results suggest that the evaluation of the emotional images and the engagement of motivational systems are independent from contextual factors, and occur in a fairly mandatory fashion.

Interestingly, behavioral and ERP findings were also found in a further study which investigated the effect of stimulus repetition on the processing of emotional stimuli, as reflected not only in the emotional interference but also in the neural activity (ERPs), while participants performed a parity judgment task (see experiment 2). As shown in fig 1.6, the experiment consisted of 4 testing blocks; in the first three “habituation” blocks, the same set of neutral and emotional images were repeatedly presented, and in the last “novel” block participants were exposed to a new set of images. As expected, the appearance of emotional stimuli, as opposed to neutral distractors, slowed down reaction times immediately and prompted an enhanced LPP modulation. Crucially, while the behavioral interference effect gradually diminished with stimulus repetitions until it disappeared (fig 1.6a), the late positive potential (LPP) amplitude, on the contrary, continued to be enhanced for emotional, compared to neutral, distractors during the entire habituation phase (fig 1.6b). On one hand, these findings closely resemble those of Harris and Pashler (2004) and generalize the exposure effect beyond the emotional words, that have been proved to be weaker distractors compared to other emotionally-charged stimuli, that is, high-arousal emotional images.

On the other hand, the authors showed that the LPP was not reduced even when emotional distractors were spatially decoupled in the task. Importantly, distraction recovered completely when new emotional images were presented, suggesting that the attenuation of emotional interference was specific for the stimulus experienced and observers cannot prevent distraction from previously unseen emotional stimuli. Consequently, the reduction of emotional interference seems to reflect the stimulus-specific habituation of the orienting response.

The authors conclude that the affective modulation of the LPP and the behavioral interference may represent different stages of emotional processing. On one hand, the emotional modulation of the LPP reflects the resources that are committed to the categorization of the stimulus: evaluation processes and engagement of motivational systems. In this way we evaluate all incoming stimuli to identify objects or individuals as potential threats or rewards, and the same stimuli are obligatorily evaluated at each presentation in order to be categorized as being previously encountered or not. On the other hand, when a stimulus is recognized and is “safe”, attentional processes are not important since the event does not require further processing or motor action. Thus, the attentional allocation system learns to ignore the specific objects to which it is repeatedly exposed in order to preserve the limited attentional resources and increase the efficiency of the information processing system.

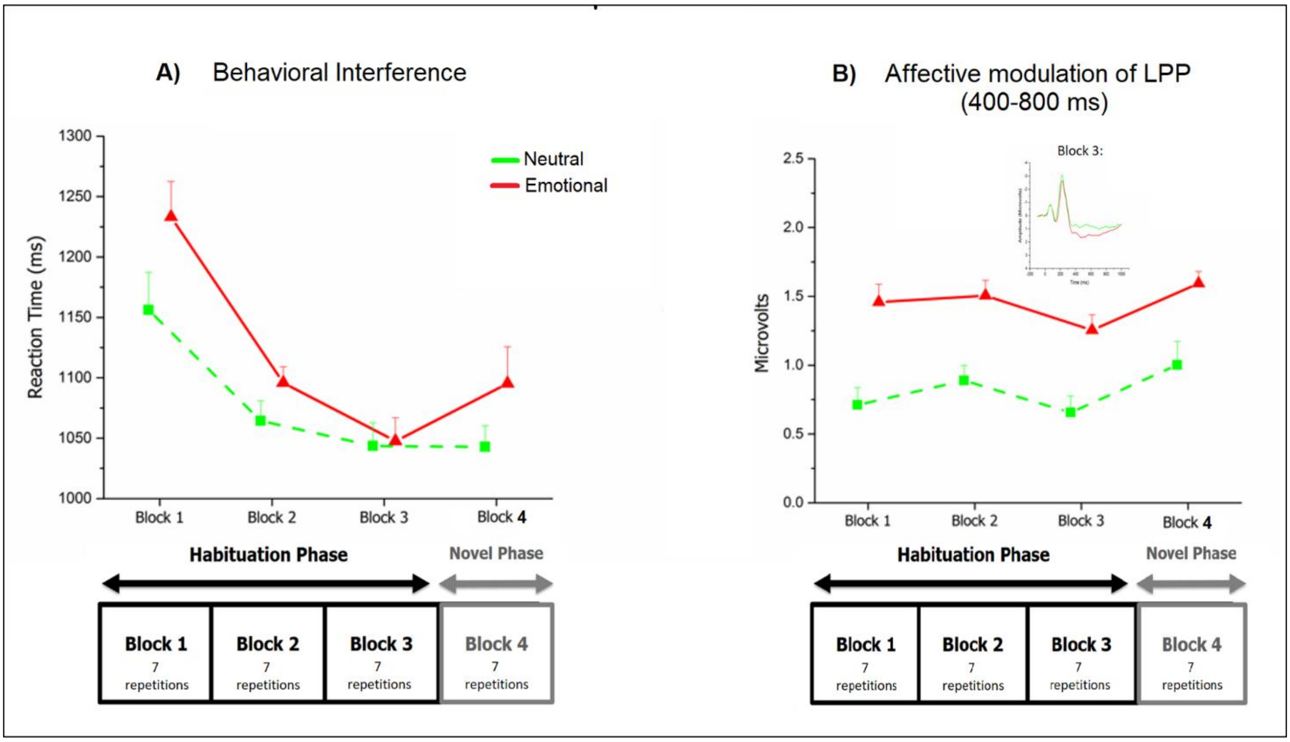

Figure 1.6. Effect of stimulus repetition on the behavioral interference effect (A) and the affective modulation of the LPP (B) during a parity judgment task. Modified from Codispoti et al. 2016

In conclusion, the attention system is naturally hard-wired to respond to emotional stimuli since these may indicate the presence of a danger or of a benefit. However, to continue to attend to emotional stimuli that are irrelevant is not only a waste of energy, but causes distraction, therefore reducing the efficacy with which we perform current tasks. When distraction is reiterated it becomes dangerous for the organism’s survival. As for perceptually salient stimuli, our brain has developed mechanisms to avoid the unwanted distraction. With experience, we learn to ignore emotional stimuli that we know to be inconsequential.

1.5. The research problem

What should be apparent from the brief review above is that certain stimuli have the intrinsic ability to capture attention. However, the attentional system may adapt by learning to ignore them when they revealed to be clearly inconsequential. Under this "learned control" view, the counter-action of top-down control over the counter-productive attentional capture is viewed as a skill that is acquired through experience, just like learning to drive a car or play chess.

This learning process is not always mediated by volitional processes and an exposure to the task and all its stimuli (task-relevant and task-irrelevant) is the major determinant of whether a stimulus will capture attention. When we have little experience with a task, our attention will be captured by salient distractors possibly because we have little or no prior knowledge about whether these stimuli entail some positive or negative consequences, and hence may require further processing and potentially a prompt reaction. If the stimulus is "beneficial" or "dangerous", the attention dedicated to it will be reinforced, and if not, the stimulus will be discounted and the processing of the task at hand will be prioritized. In either case, being exposed to the task and to the salient or significant stimulus is fundamental in order to learn "what to attend to" and "what to ignore". To this end, the brain has mechanisms that prevent or attenuate the unwanted distraction.

Until now, *experience-mediated attentional learning* has mostly been investigated with perceptually salient stimuli. What about significant emotional stimuli? Two previous studies indicated that the interference effect of emotional events (i.e., slowing of reaction time) on the concurrent task reduced with stimulus repetition, showing that attentional resources are preserved from being allocated to well-known inconsequential stimuli (Harris and Pashler, 2004; Codispoti et al., 2016). On the other hand, the persistence of the affective modulation of the LPP indicates an obligatory evaluative processing of the emotional content of the stimulus, demonstrating that repetition is not sufficient to eliminate the motivational engagement (Codispoti et al., 2016; Mastria et al., 2017).

It is of note that, so far, no studies have examined what happens when observers are exposed to heterogeneous emotional distractors, despite the fact that in the real-world environment we are inevitably surrounded by varied distractors. On one hand, emotional interference disappears with stimulus repetition but recovers when novel emotional stimuli are presented, suggesting that the inhibition of emotional distractors is mediated by stimulus-specific habituation processes (Codispoti et al., 2016). On the other hand, the elimination of the interference of variable emotional distractors with a reward incentive (Padmala and Pessoa, 2014; Hu et al., 2013) seems to reflect a general habituation of the processing of task-irrelevant emotional stimuli that occurs without a direct distractor experience.

The specific aims of this thesis are:

- to examine whether frequency of exposure to task-irrelevant stimuli modulates the interference of all variable (i.e., never repeated) emotional distractors and, if so, whether it is a long-lasting attentional modulation or not.

- to investigate whether extensive practice with heterogeneous distractors modulates the interference of novel emotional distractors, that is, whether a “learned control” can generalize to emotional stimuli that have never been seen before.

- to shed light on which stage of the emotional processing is affected by the “distractor-experience” effect – stimulus frequency and extensive practice - by comparing behavioral (response times and accuracy) and cortical (LPP) measures.

Chapter 2

Experience-mediated attentional learning and emotional distractors

Experiment 1: Distractor frequency and emotional attentional capture

The goal of Study 1 was to examine the effects of the frequency of occurrence of distractor stimuli that were novel emotional pictures, as reflected in both behavioral interference (RTs) and neural activity (LPP), while participants were actively engaged in an orientation discrimination task with a central gabor stimulus; all pictures, that varied in emotional content (emotional and neutral), were always task-irrelevant stimuli.

1. The attenuation of the emotional interference (slower RT for emotional compared to neutral stimuli) found in response to repeated stimuli might indicate that the attentional allocation system learns to ignore emotional stimuli over time, and hence attentional capture by emotional stimuli is sensitive to an observer's experience (Harris and Pashler, 2004; Codispoti et al., 2016). (a) If so, we might expect the interference effect prompted by novel emotional pictures to be reduced in a block in which distractors occur frequently (80% of trials) compared to a block in which they appear only rarely (20%); on the other hand, it is also possible that the frequency with which observers are exposed to distractors does not influence the emotional interference effect, indicating that the attentional system may not ignore emotional stimuli when they are all novel, that is never repeated before.
2. The persistence of the affective modulation of the LPP regardless of stimulus repetition and in the presence of a task (Codispoti et al., 2016; Ferrari et al., 2008; Mastria et al., 2017) has been

interpreted as evidence that the evaluation processes, and the engagement of motivational systems, occurs mandatorily. Therefore, here we recorded ERPs to clarify which stage of emotional processing might be affected by the frequency effect, and we might expect the affective modulation of the LPP to remain unchanged when participants are frequently exposed to distractors, confirming that contextual factors do not affect motivational engagement. However, we cannot exclude the scenario of a gradient of modulation of the LPP when varying the frequency of distractor occurrence across blocks. Accordingly, assuming that the affective modulation of the LPP cannot be down-modulated below some minimum value, as shown by habituation studies, we might expect the magnitude of LPP affective modulation to be greater when distracting stimuli are presented in only a small, as compared to a large, proportion of trials within a block.

3. Moreover, we are interested in examining whether “learned control” could be protracted over time or whether it is context-specific. In the first case, if frequent exposure to distractors exerts a long-lasting effect on attentional capture by emotional stimuli, then we should expect a reduced emotional interference in the 20% block for participants (run-down group) that performed it after the 80% block - in which they should have had the opportunity to learn to ignore emotional distractors - compared to those who performed this block first (run-up group). If, on the other hand, frequent exposure to distractors is the prerequisite for reducing the emotional interference effect, and thus induces a rather short-lasting bias of attention, we expect the “learned control” not to last, and hence we should not find any cross-over effects in the 20% block for the run-down group.

Experiment 1a

Method

Participants

A total of 24 healthy students (10 females) of the University of Bologna (Italy) participated in the experiment as volunteers. The mean age was 20 years, and all participants had normal or corrected-to-normal visual acuity.

The study was approved by the Ethical Committee of the Department of Psychology at the University of Bologna, and prior to participating, all subjects signed an informed consent.

Participants were randomly assigned to the run-down (n= 12) or run-up (n= 12) condition order. Due to technical problems, EEG data from one male participant were excluded from the analyses.

Materials and design

As distractor stimuli, a total of 300 pictures were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008), and from public domain pictures available on the Internet. The pictures included 75 pleasant (heterosexual erotic couples), 75 unpleasant (mutilated bodies), and 150 neutral (people in a variety of daily activities in both enclosed spaces [n=75] and outdoors [n=75]).

To maintain some homogeneity across emotional and neutral contents, all scenes depicted people. This “homogeneity” is somewhat important given that several studies have underlined the importance of distinguishing between scenes involving human beings and others (e.g., inanimate objects), in order to avoid the confound of the processing of emotional stimuli being facilitated by the presence of humans due to empathy (Colden, Bruder & Bradley, 2008; Groen, Wijers, Tucha & Althaus, 2013; Calvo et al., 2015).

In pilot studies, subjective, autonomic and cortical responses to each of these pictures were collected in a new sample of undergraduates. Participants (n= 60; 30 female) rated each scene valence (on a 1- unpleasant- to 9- unpleasant- scale), and arousal (on a 1-calm-to 9-tension – scale), using the standard SAM (self-assessment mannequin) procedure (Lang, Bradley & Cuthbert, 2008), while skin conductance changes were recorded. For the same images, EEG were recorded in another sample of participants (n=24; 12 female) while they were passively viewing pictures. Each participant saw one picture at a time on a computer screen in a self-paced mode. As shown by analyses, unpleasant pictures were judged significantly less pleasant (M= 2.21) than neutral pictures (M=5.01), p< .001, which were, in turn, rated less positively than pleasant pictures (M=6.92), p< .001. Regarding the subjective rating of arousal, emotional pictures were rated as more arousing (pleasant: M= 6.11; unpleasant: M= 6.12) compared to neutral pictures (M= 2.52), p_s< .001, and pleasant stimuli did not differ from unpleasant stimuli, p= .701. At a cortical level, emotional pictures elicited a more pronounced LPP (M= 2.49) compared with neutral pictures (M= 0.14), p_s<.001, and the LPP amplitude for pleasant and unpleasant pictures did not differ, p= .114. Moreover, skin conductance replicated the typical arousal effect with larger changes when viewing emotional (M= .059), compared to neutral, stimuli, p_s< .002; no differences were found between pleasant and unpleasant contents, p=.163.

Images were displayed on a gray background of a 16-in. monitor at 1,024 × 768 resolution (refresh rate of 120 Hz), controlled by an IBM computer. Each scene subtended 14.3° horizontal by 10.8° vertical degrees of visual angle and was positioned either to the left or to the right of a central Gabor patch. The Gabor patch (sinusoidal gratings with a Gaussian envelope), used for the orientation discrimination task, subtended a 5.3° x 5.3° visual angle and it could be horizontally or vertically oriented. Gabor patches were generated using custom MATLAB software by overlapping two distinct Gabor filters with the same orientation but different frequencies (0.94 and 9.4 frequency x visual angle, respectively). The distance between the inner edge of the distractor image and the center of the Gabor patch was a 4° visual angle. All stimuli were equated in brightness and contrast to control for potential confounds resulting from low-level visual properties of the images.

Stimulus presentation and data collection were performed using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002).

For each participant, all of the 300 images (150 emotional and 150 neutral) were presented during the experimental session. The session consisted of two blocks of 300 trials; critically, in the two blocks the frequency of distractor presentation was set differently, and participants were not explicitly informed about this uneven distribution. In the 20% block, distractors appeared in 20% of the trials, meaning that a total of 30 distractors (15 neutral and 15 emotional) were presented. In the 80% block, distractors were displayed in 80% of the trials, for a total of 240 distractors (120 neutral, 120 emotional). In both blocks, therefore, half of the distractors were neutral and half were emotional (Fig 2.1). The order of block presentation was introduced as a between-subject factor with a group of participants that started with the 20% block (run-up group) and a second group that started with the 80% block (run-down group).

Across participants, each picture was randomly assigned to either the 20% (run-up group) or the 80% block (run-down group). Nevertheless, within participants each picture was never repeated across the experiment (i.e., it was novel).

Before the beginning of the experiment, participants performed a set of 100 practice trials, in which no distractors appeared, to familiarize themselves with the task. After a break, the two experimental blocks began with a short break in between.

The order of trial type (trials without distractor, emotional-distractor trials and neutral-distractor trials were pseudo-randomized with the following restrictions: (i) the emotional pictures occurred no more than three times consecutively, (ii) emotional pictures of the same valence were never presented one after the other, (iii) pictures did not appear more than three times consecutively on the same side. E-prime software synchronized the presentation of the stimuli and triggered EEG recording on each trial.

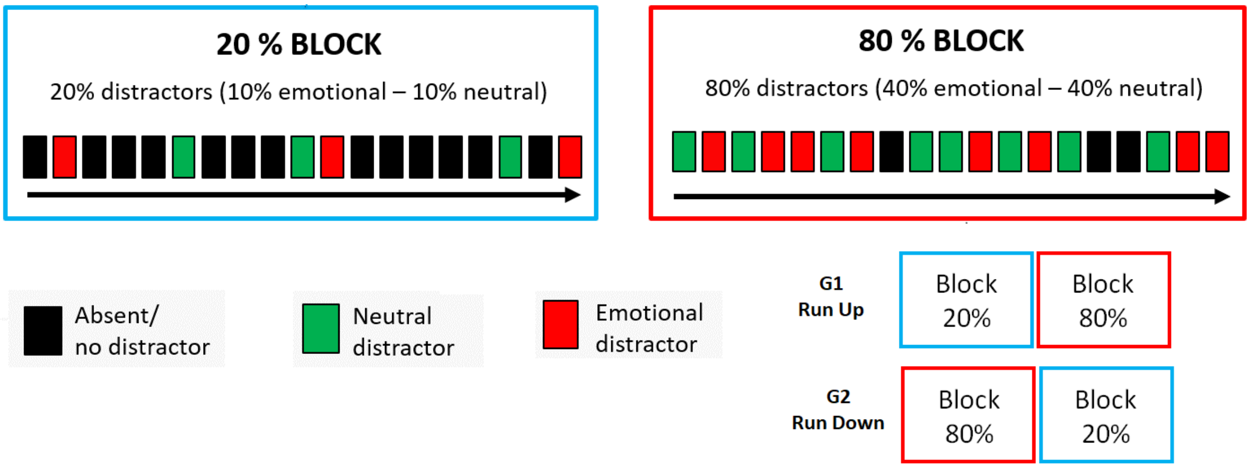

Figure 2.1. Experimental design in Experiment 1a.

Procedure

Upon arrival at the laboratory, participants signed an informed consent form. Participants were then seated in a recliner in a small, sound-attenuated, dimly lit room, and the EEG sensor net was attached. Participants sat in front of the computer monitor with their head supported by a chinrest. The distance between the eyes and the monitor was 60 cm for all subjects.

Figure 2.2 shows the sequence of events of the experimental paradigm. Each trial started with the presentation of a uniform gray background displayed for 500 ms. This was followed by the appearance of a Gabor patch in the center of the screen for 150 ms. The participant’s task was to determine, as quickly and as accurately as possible, whether the Gabor patch was vertical or horizontal by pressing one of two buttons on the keyboard (“v” or “b”) with the index finger of their dominant hand. In distractor-present trials, an image (either emotional or neutral) was presented simultaneously with the Gabor, appearing equally often in the left or right visual field. Participants were explicitly informed that there would be a peripheral distracting stimulus (i.e. the image) in some trials but that they had to maintain fixation on the center of the screen, focusing their attention exclusively on the Gabor patch while ignoring distracting images. Consecutive trials were separated by a gray screen for a variable amount of time ranging from 1000 to 1750 ms (intertrial interval, ITI). During this period, behavioral responses to the orientation task were collected.

Before the beginning of the experiment, participants performed a practice block of 100 trials in which distractors were never presented. During the experiment, the run-up group performed first the 20% block and then the 80% block; the order was reversed for the run-down group. Between each block, a 2-min break was given, and each block always started with 20 distractor-absent trials. The experiment lasted approximately 28 minutes.

In order to assess participants’ awareness of the manipulation of the frequency of distractor occurrence across blocks, directly following completion of the experiment they were asked to answer post-experimental questions about (i) whether and how the two blocks differed and, afterward, (ii) to indicate how frequently distractors had occurred within each block (from 1 in each trial –frequently - to 1 every 10 trials –rarely).

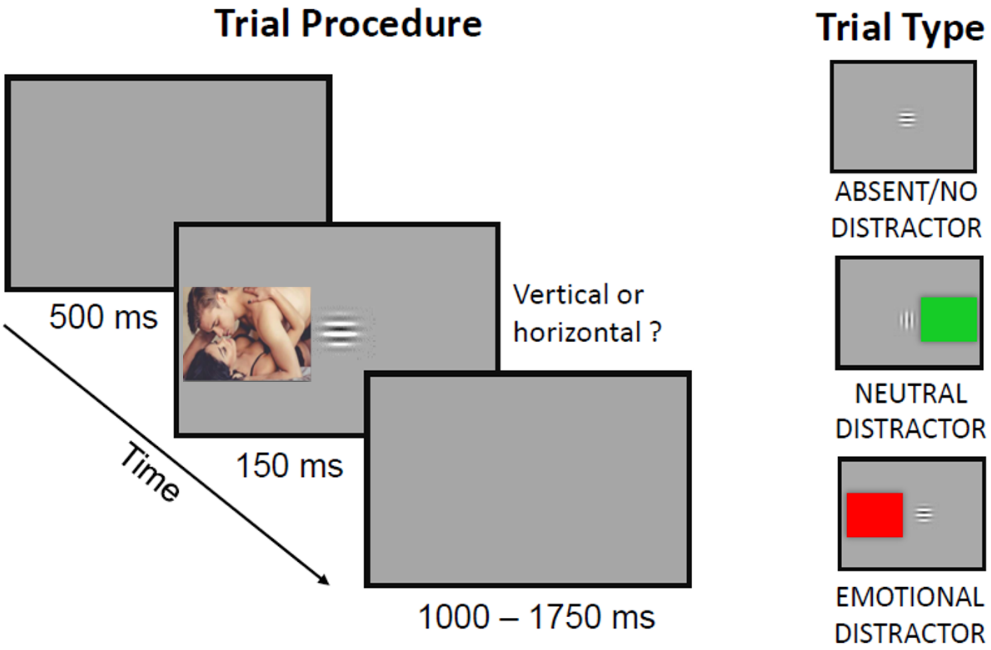

Figure 2.2. Sequence of events and trial type in Experiment 1a.

EEG recording and processing

Electroencephalogram (EEG) was recorded at a sampling rate of 512 Hz using the ActiveTwo BioSemi system (BioSemi, Amsterdam, The Netherlands), with a 62 dense sensor array. The EEG was referenced to an additional active electrode (CMS = common mode sense; with ground in additional electrode DRL = driven right leg) during recording. All data were re-referenced to the average of all scalp electrodes. Additionally, a sensor was attached below the left eye. For each trial, the EEG was corrected for blinks and eye movements using a regression technique based on the electrodes above and below the left eye, and to the left and right side of the eyes (Schlögl et al., 2007). Off-line analysis was performed using Emegs (Peyk, De Cesarei, & Junghöfer, 2011). First, data were initially filtered (40 Hz low-pass and 0.1 Hz high-pass). Then, trials and sensors containing artifacts were detected through a statistical procedure specifically developed for dense-array EEG (Junghöfer, Elbert, Tucker, & Rockstroh, 2000). Trials containing a high number of neighboring bad sensors were discarded; for the rest of the trials, sensors containing artifactual data were replaced by interpolating the nearest good sensors. Finally, data were re-referenced to the average of all sensors, and a baseline correction based on the 200 ms prior to stimulus onset was performed. Averaged ERP waveforms were calculated according to factors Block and Trial Type. Region and time interval of interest were selected based on an initial examination of the ERP waveforms and topography. The LPP was scored as the average of the ERP waveform in the 450 and 900 ms after stimulus onset at the parieto-occipital sensor group (see cluster of sensors in Appendix A) where the LPP amplitude was largest (Picton et al., 2000).

Data collection and analysis

Reaction times (RTs) and ERP analyses were performed only on accurate trials. Practice trials and the 20 distractor-absent trials before each block served to acquaint participants with the task and were not included in the analyses. Trials with RTs shorter than 250 ms or longer than 1350 ms were treated as inaccurate. In each participant, for each valence of each condition, response times above or below three standard deviations from the mean were discarded as outliers. These criteria removed 3.6% of the data.

These data were submitted to a repeated measures analysis of variance (ANOVA; using the Huynh-Feldt correction) for within-subject factors Block (two levels: 20%, 80%) and Trial Type (three levels: absent, neutral, emotional) to evaluate the overall frequency effect. Subsequently, an ANOVA on Block and Valence (two levels: neutral, emotional) was conducted to analyze, specifically, the effect of distractor frequency on the behavioral interference effect of emotional stimuli and on the affective modulation of the LPP. Also, an ANOVA with factors Block and Trial Type as within subject-factors and Condition Order (two levels: Run-Up, Run-Down) as between-subject factors was performed to test the possibility of crossover effects across subsequent blocks. For each ANOVA test, the partial eta squared statistic (η^2_p), indicating the proportion of variance that is explained by experimental conditions over the total variance, is reported.

Results

Behavioral measures

Reaction times (RTs). Participants were slower in the orientation discrimination task when distractor images appeared abruptly, and performance was especially disrupted when such images had an emotional, compared to a neutral, content. Critically, this emotional interference effect was attenuated in the 80% block in comparison with the 20% block (Fig. 2.3).

Statistically, analysis of RTs yielded a significant effect of Trial Type, F (2, 46) = 26.359, $p < .001$, η^2_p = .534, indicating slower RTs in distractor-present trials (neutral and emotional) compared to distractor-absent trials, F_s (1,23) > 41.514, $p_s < .001$, $\eta^2_{ps} > .643$, and in emotional-distractor trials compared to neutral-distractor trials, F(1,23) = 12.415, p = .002 , η^2_p = .351. The main effect of Block was not found, F (1,23) = 1.440, p = .242, η^2_p = .059. Importantly, a significant Block x Trial Type interaction was observed, F (2, 46) = 21.495, $p < .001$, η^2_p = .483. Following up on this interaction, the Block effect was tested in each type of trial: the appearance of emotional stimuli slowed down responses more in the 20% than in the 80% block, F(1, 23) = 9.753, p = .005, η^2_p = .298, while no difference was found between the two blocks for neutral distracting trials, F(1, 23) =1.150, p = .295, η^2_p = .048. In the 80% block (versus 20%), however, participants were slower to respond to the task in those trials in which no distractor actually appeared, F (1, 23) =5.460, p = .029, η^2_p = .192. More importantly for our experimental question, a subsequent ANOVA confirmed a significant Block x Valence (neutral, emotional) interaction, F (1, 23) =6.732, p = .016, η^2_p = .226. Pairwise comparisons confirmed that emotional stimuli interfered more than neutral stimuli in the 20% block (M=32.78), F(1, 23) = 11.369, p = .003, η^2_p = .331, and this emotional interference effect was still significant, but severely reduced, in the 80% block (M= 9.33 ms), F (1, 23) =4.902, p = .037, η^2_p = .176.

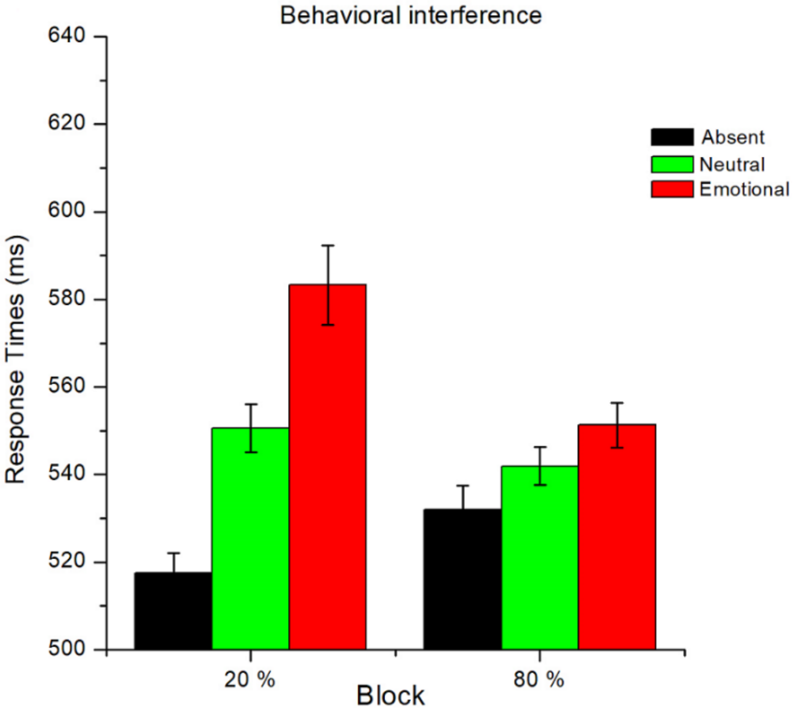

Figure 2.3. Effect of the frequency of picture occurrence on reaction times in Experiment 1a. Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014).

Although there was a reduction in emotional interference in the 80% block, participants who later performed the 20% block (run-down group) were not more effective in attenuating the interference of rare emotional distractors, compared to the participants who performed the 20% block first (run-up group) (Fig. 2.4), suggesting that the effect of frequent exposure did not last, and hence no carry-over effects were found. This was confirmed by the failure to find a significant Condition Order X Block X Trial Type interaction, F (2, 44) = .917, p = .384, η^2_p = .040, or a Condition Order X Block X Valence interaction, F (1, 22) = .758, p = .393, η^2_p = .033.

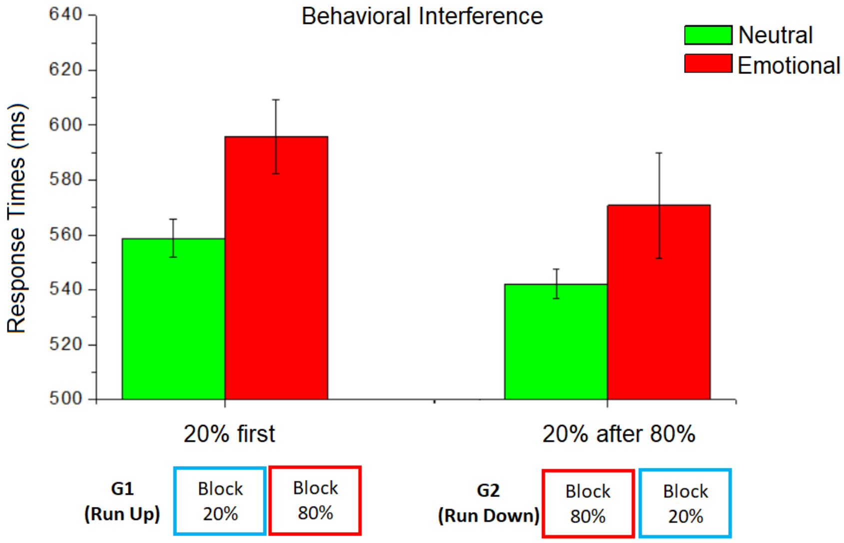

Figure 2.4. Effect of condition order on the emotional interference effect in Experiment 1a. Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014).

A further analysis was conducted to evaluate the possibility that the attenuation of the emotional interference effect reflected the number of times the participants were exposed to distractors, rather than frequency per se. Specifically, in the 80% block (300 trials), distractors appeared in 240 trials, whereas in the 20% block, they appeared in only 60 trials, making the alternative explanation possible: the cognitive system may require a minimum number of exposures to distractors in order to learn how to ignore them. To test this possibility, we analyzed only the first 75 trials which included the first 60 distractor-present trials (30 neutral and 30 emotional). If frequency was confirmed to be determinant, as suggested in literature on perceptually salient distraction, then we expected to still find a reduced interference effect in the 80% compared to the 20% block. Otherwise, if the number of distractors was the crucial factor, then the interference effect should not differ between the two blocks (the first 75 trials of the 80% block and the 60 trials of the 20 percent block). Results showed a significant Block x Valence interaction, F (1,23) =7.676, p =.011, η2p=.250, with an interference of emotional stimuli in the 20% block (p= .003) that completely disappeared in the 80% block (p= .771), thus supporting the importance of the rate of distractor presentation (frequency) in driving the difference in emotional interference between the 20% and the 80% blocks.

Accuracy. As expected, accuracy was generally high (M=97.4%), indicating that the discrimination task was perceptually easy (low load perceptual task); see Table 1 in Appendix A. An ANOVA with the same factors as above was conducted on accuracy, but only a main effect of Trial Type was found, F (1, 46) = 11.030, p =0.001, η^2_p = .324, indicating a larger number of errors when viewing emotional stimuli, compared to neutral ones, F (1, 23) = 11.429, p = .003, η^2_p = .332, and to distractor-absent trials, F (1, 23) = 15.005, p = .001, η^2_p = .395, but no difference in accuracy between neutral distracting trials and distractor-absent trials, F (1, 23) = .385, p = .541, η^2_p = .016. However, no significant main effect of Block, F (1, 23) = 1.557, p = .225, η^2_p = .063, or significant Block x Trial Type interaction, F (2, 46) = 3.091, p = .070, η^2_p = .118 were found, ruling out the possibility that the RT pattern observed was the result of speed-accuracy trade-offs.

Late positive potential (LPP)

As illustrated in Fig. 2.5, emotional stimuli elicited a larger positivity over parieto-occipital sensor sites in the 450-900 ms time interval. Yet, although the affective modulation of the LPP seemed to be somewhat smaller in the high frequency compared to the low frequency block, it continued to be significantly enhanced in both blocks.

Accordingly, the main effects of Block, F (1, 22) = 6.233, p = .021, η^2_p = .221, Trial Type, F (2, 44) = 22.577, p < .001, η^2_p = .506 and a Block X Trial Type interaction, F (2, 44) = 9.257, p <.001, η^2_p = .296, were significant. Following up on this interaction, distractor trials, both emotional, and neutral distractors, , elicited a more positive LPP amplitude when appearing rarely in the 20% block compared to the 80% block (F (1, 22) = 12.197, p =.002, η^2_p = .357, F (1,22) = 4.536, p =.045, η^2_p =

.171 respectively), and, no difference was found for distractor-absent trials between the two blocks, F (1,22) = 1.412, p=.247, η^2_p = .060. Moreover, the interaction Block X Valence (neutral, emotional) approached significance, F(1, 22) = 3.994, p = .058, η^2_p = .154, and the following simple main test effects showed that the LPP enhancement to emotional compared to neutral pictures was larger in the 20% block (M= 1.06 µV), F(1, 22) = 11.690, p = .002, η^2_p = .347; in fact, this cortical modulatory effect was only marginally reduced in the 80% block (M= 0.60 µV), F(1, 22) = 12.685, p = .002, η^2_p = .336. Further analysis showed that modulation of this cortical modulatory effect did not differ between the run-up and run-down groups of participants, indicating that it was not affected by the order with which the two blocks were performed. Indeed, an ANOVA on LPP amplitude, with Condition Order as between-subject factor and Block and Trial Type as within-subject factors failed to reveal any significant effects: interaction, F (2, 42) = .379, p = .687, η^2_p = .018.

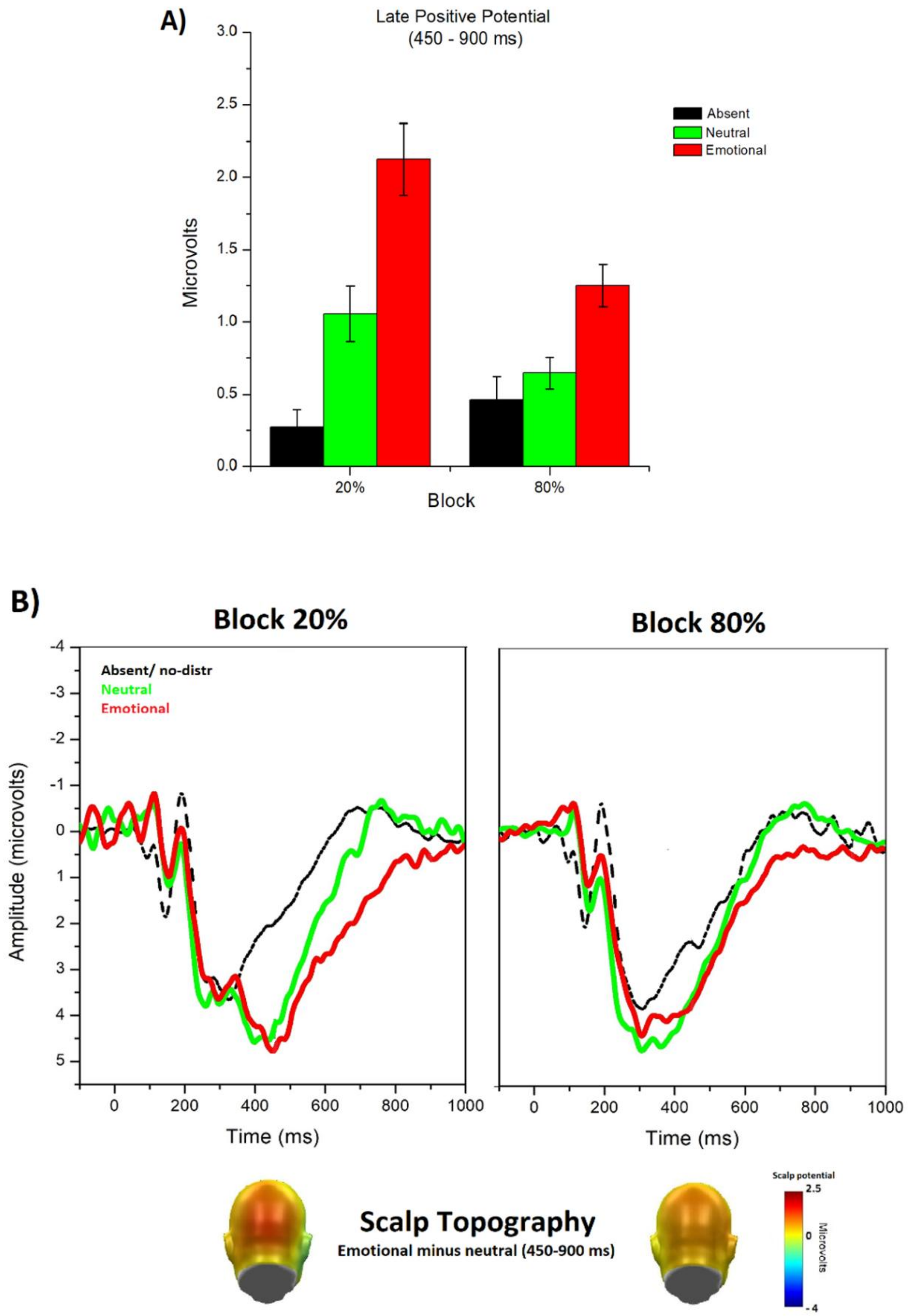

Figure 2.5. Effect of the frequency of picture occurrence on the (A) LPP amplitude in Experiment 1a. Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014). (B): Grand-averaged ERP waveforms averaged over parieto-occipital sensors used for the analysis of the LPP for neutral and emotional pictures in the 20% block and in the 80% block. Insets below each graph are the back views of the scalp topography (450–900 ms) of the difference between emotional and neutral picture processing.

Awareness of distractor frequency

We examined whether the reduced emotional interference in the 80% block vs the 20% block critically depended on participants having "recognized" the high frequency of distractor occurrence in the 80% block. To determine participants' awareness, we analyzed their responses to the general (post-experimental) query about whether the two blocks differed from each other. Ten of the 24 participants (42%) answered "no" and, after a brief interview with the experimenter, they reported not having noticed any change in the frequency with which distractors occurred between the two blocks. Subsequently, for the participants who were aware, we analyzed their response when asked to approximately indicate the frequency of distractor occurrence within each block; 10 of the 14 participants correctly indicated which of the two blocks was the one in which distractors occurred frequently, while 4 participants were completely wrong.

Moreover, we analyzed the results separately for those who were aware (n=10) and those who were unaware (n=14) of the frequency manipulation as a between-subjects variable. There were no interactions with the other variables, indicating that some awareness regarding the high frequency of distractor occurrence did not determine attenuation of the emotional interference effect, Group (aware, unaware) x Block (20%, 80%) x Valence (emotional, neutral), F (1, 22) =.700, p=.412, η^2_p = .031.

Discussion

As expected, the findings of Experiment 1 indicate that, despite observers being actively engaged in a focal task, pictures with an emotional content captured attention, even when appearing in an irrelevant peripheral location, as indicated by their general interference in task performance (i.e., slowing of RTs). Importantly, emotional distraction was drastically reduced when observers were frequently exposed to distractor pictures (80% of the trials versus 20%), indicating that the strength with which emotional stimuli captured attention was modulated by the frequency of exposure to distractors. Considering that the irrelevant images were all novel, the attenuation of the emotional interference seems to be ascribed to a general inhibition toward task-irrelevant emotional stimuli rather than a stimulus-specific mechanism. To better clarify which stage of the emotional processing was affected by the frequency effect, ERPs were recorded, showing an overall reduction of the LPP amplitude when the frequency of task-irrelevant images was increased, suggesting a reduced attentional allocation toward the irrelevant images. Critically, the affective modulation of the LPP – i.e., the larger positivity elicited by emotional compared to neutral pictures - was preserved in the high frequency context, showing only a trend toward reduction, despite the behavioral emotional interference in the primary task being strongly attenuated. Therefore, these findings, taken together, indicate that emotional distractors continue to activate the motivational systems, as suggested by the LPP affective modulation, even when attentional allocation to these stimuli habituates as indicated by the behavioral emotional interference.

The affective modulation of the LPP and behavioral measures – such as response times - have been widely used as indexes of attention allocation. While the LPP is considered to reflect both the engagement of attentional resources by emotional stimuli and the activation of motivational systems (e.g., Lang et al., 1997; Schupp et al., 2006; Ferrari et al., 2011), behavioral interference is, by far, the most widely used index for investigating the attentional capture phenomenon in research on emotional, salience, and deviance distraction. Specifically, in literature on perceptual salience, behavioral costs in target detection (elongation of RTs or lower accuracy) are considered to be reliable, indirect measures of the fact that the presence of a salient task-irrelevant stimulus captures involuntary attention, causing, consequently, a poorer processing of the task (Theeuwes 1992). However, response times represent the sum of many distinct mental processes that occur after the actual attention allocation to the stimulus, while the LPP represents a more temporally proximal measure of the evaluative processes involved. Therefore, several factors might affect the behavioral interference, eliminating it even as the brain continues to process the emotional stimuli. It is worth noting that affective modulation of the LPP has been investigated more often during free viewing when pictures are attended to without a task. However, recent studies that measured LPP in the presence of a task, and hence when attentional resources were constrained, did not find a reduction even after numerous repetitions of the same emotional image. It is significant that recent evidence similarly indicates that electrophysiological and behavioral measures of distraction (i.e., behavioral interference), can be dissociated since they reflect different processes. These works suggest that the affective modulation of the LPP might be an index of the engagement of motivational systems more than of attentional processes per se (Codispoti et al., 2016). Moreover, such a dissociation is not exclusively related to emotional distraction but has been reported even in literature on deviance distraction, in which the behavioral distraction induced by the appearance of a rare and unexpected sound (i.e., deviant) can vary widely in the absence of variation in the electrophysiological measures of distraction (e.g., P3a), suggesting that behavioral distraction is controlled by further, and presumably later, mechanisms (e.g., Schröger & Wolff, 1998; Wetzel, Schröger & Widmann, 2013). From these findings, it is possible that the attenuated emotional interference reported in the present studies is the result of inhibitory mechanisms that act after evaluation processes, and the engagement of motivational systems, have occurred, possibly with the aim of preventing limited resources from being allocated to inconsequential emotional stimuli.

These findings raise the question of which mechanisms may subtend the attenuation of behavioral interference. In the present study, by using only novel and heterogeneous pictures, it is hypothesized that the attenuation reflects more of a general inhibition of task-irrelevant stimuli rather than a stimulus-specific habituation (Codispoti et al., 2016). This decrease in emotional interference may be due to the occurrence of a generalization to features that are shared between individual scenes. Gati and Ben-Shakhar (1990) presented evidence that habituation can be based on the repetition of certain features across images, rather than the repetition of the images per se. Accordingly, in this experiment, specific features were presented among the different scenes (e.g., blood in mutilation scenes, or pink bodies in the erotic images) and so the OR could have habituated due to their repetition. If the habituation of the OR occurred, then the emotional interference should be expected to gradually decrease over time– with the greatest interference at the beginning of the 80% block when the features were relatively novel and the least interference at the end when the features had been widely repeated. To explore this possibility, a further analysis was conducted by splitting the 80% block into three mini-blocks of 100 trials: each mini-block contained 20 distractor-absent trials, 40 neutral-distractor trials and 40 emotional-distractor trials (20 mutilation and 20 erotic images). However, no reliable habituation emerged across the three mini-blocks, ruling out this possibility and indicating in general that the inhibition of emotional distractors occurred rapidly and did not develop over time [Mini-block (3 levels) x valence (neutral, emotional), F (2, 46) =1.148, p=.326, η^2_p = .048].

Another possibility is that the attenuation of the emotional distraction might reflect a preparatory inhibitory mechanism that is engaged in order to protect the target processing from the expected occurrence of emotional distractors. Specifically, there is a form of preparatory inhibitory control of attention which is referred to as “expectation suppression” (Noonan, Crittenden, Jensen & Stokes, 2017). Similar to the Comparator model of Sokolov, predictive coding models suggest that the cognitive system generates and updates prediction about incoming input by extracting stimulus regularities from the surrounding environment. In this way, the world is simplified, and the attentional allocation is regulated in such a way that it is suppressed for expected items because they provide little new information; it is not necessary to process them further. Thus, predictable stimuli tend to be less behaviorally significant than new, surprising events. In accordance with this hypothesis, Kennedy and coworkers (Kennedy, Newman & Most, 2017) have recently demonstrated that the predictability of emotional distractors is a determinant for preventing their attentional capture; specifically, observers voluntarily shielded themselves from emotional interference when they were explicitly forewarned trial-by-trial about the occurrence of emotional distractors, and distractor inhibition was effective when the participants were alerted as to the type of distractor to expect, compared to when a general alert about the occurrence of a distractor was given.

In Experiment 1a, no prior information regarding the specific occurrence of emotional stimuli was given to participants, and they were not explicitly aware of the high frequency of distracting events, as responses from a final questionnaire suggest. However, the emotional stimuli occurred more frequently (40%), making the temporal distance between the occurrence of two consecutive emotional stimuli much shorter (M = 2.03sec) in the 80% block compared to the 20% block (10%; M= 20.60sec). It is possible that emotional stimuli were therefore implicitly expected in the high frequency block, leading observers to engage preparatory inhibitory mechanisms in order to prevent emotional distraction.

Taking the above considerations into account, Experiment 2 was conducted to clarify the observed reduction of emotional interference in the high distractor frequency context. Specifically, the aim was to disentangle whether this reduction was due to:

a) the short time interval between emotional distractors and hence the predictability of the occurrence of emotional distractors;
b) the mere high occurrence of distractors independently of their content (overall frequency of distractor occurrence).

To this aim, we reproduced the same paradigm used in Experiment 1 by presenting two blocks that differed in the overall frequency of distractor occurrence (20% versus 80%) with the critical difference that emotional pictures were rare (10%) in both of them and, therefore, only the frequency of occurrence of neutral distractors was varied between the two blocks. Crucially, the temporal distance between the occurrence of one emotional stimulus and the next did not differ between the blocks (approximately 20sec).

(i) At a behavioral level, if observers inhibit emotional distractors when their occurrence is expected – and therefore what matters is the lapse between their occurrence, that is, the frequency of emotional distractors - then we should not find a frequency effect. By contrast, if the critical factor is the mere high occurrence of distractors independently of their content (overall frequency of distractor occurrence), then even the high occurrence of neutral distractors should matter, and we should find a reduction in the emotional interference in the 80% block compared to in the 20% block, regardless of the rareness of emotional stimuli.

(ii) At a cortical level, if the affective modulation of the LPP is not affected by contextual factors such as the time interval between emotional distractors or the overall frequency distractor occurrence, as suggested by Experiment 1a, we should observe no difference between the two blocks. Alternatively, the marginal reduction of the emotional modulation of the LPP in the high frequency block could indicate that evaluation processes, and the engagement of motivational systems, are sensitive to the frequency of occurrence of emotional distractors. However, considering that emotional stimuli occurred only in 40% of trials, we failed to find a significant reduction. In this case, if the only critical factor is the emotional frequency, we should not expect to find any tendency toward reduction.

Experiment 1b

Method

The same method described in Experiment 1a was used, with the variations described in the Design and Procedure section.

Participants

A total of 20 healthy students (11 females; mean age: 21.6 years) of the University of Bologna (Italy) participated in the experiment as volunteers, and signed an informed consent form prior to beginning the experiment. The study was approved by the Ethical Committee of the Department of Psychology at the University of Bologna. All participants had normal or corrected-to-normal visual acuity and none were color blind. All of them were naïve as to the aim of the experiment. Participants were randomly assigned to the run-down (n= 10) or run-up (n= 10) condition order.

Materials

Picture stimuli were identical to those used in Experiment 1. Additionally, 180 new neutral images (pictures depicting objects, urban places and building interior) were selected on the Internet to be presented during the 80% block. The equipment used to present stimuli was the same as in Experiment 1a.

Design and procedure

Similar to Experiment 1a, Experiment 1b consisted of a practice phase (100 trials), which was followed by two experimental blocks, each consisting of 300 trials: the 20% block and the 80% block, whose order of presentation was balanced across participants. As shown in Fig. 3.1, the design of Experiment 1b was identical to that used in Experiment 1 with the important exception that emotional distracting pictures were presented only rarely (10% of the trials) in both blocks. In the 20% block, pictures were present in 20% of the trials (half emotional and half neutral content). In the 80% block, rare emotional distractors (10%) and frequent neutral distractors (70%) occurred in 80% of the trials. The time lapse between the occurrence of emotional stimuli was also kept similar between the two blocks; in the 20% block, the mean was 20.11 seconds (ranging from a minimum of 2.02s to a maximum of 42.52s) and in the 80% block it was 20.53 seconds (ranging from 4.05s to 68.85s).

As in Experiment 1a, pictures were never repeated within or across blocks. Observers were instructed to focus on the task and ignore task-irrelevant images, and they were not explicitly informed about the uneven distribution of distracting pictures between the two blocks.

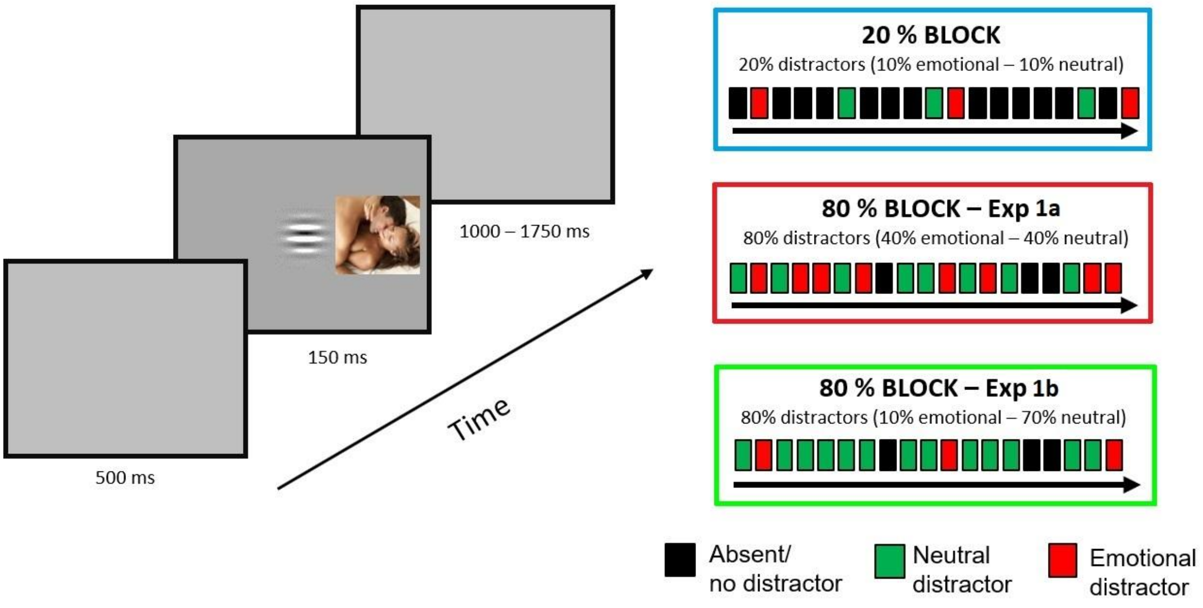

Figure 3.1. Experimental design of Experiment 1b. Comparison between the 80% block used in Experiment 1a and Experiment 1b

Data Analyses

As in Experiment 1a, incorrect trials and outlier trials with RTs above or below 3SDs above the individual means in each block for each trial type were excluded from further analyses, with this outlier trimming resulting in a removal of 3.7% of the total RT data. The statistical design was identical to that described in Experiment 1a.

An ANOVA on RTs and LPP with factors Block (2 levels) and Valence (3 levels) was performed considering only the 10% of neutral-distractor trials containing human beings, instead of all the neutral categories (human and non-human) as done in the following analyses. By excluding the neutral distractors without human beings that were added in the 80% block, in these analyses the 20% and 80% blocks were equal regarding number, frequency, and semantic content of neutral distractors, also that for the frequency of emotional pictures. Results and figures are reported in

Appendix B. By analyzing only human-neutral, results did not differ from findings that included all the neutral contents (human and non-human categories).

Results

Behavioral measures

Response times (RTs). As shown in Fig. 3.2, the current behavioral results strictly resemble those of the previous experiment. As expected, the abrupt appearance of pictures distracted participants even though such images were completely irrelevant for the task at hand, and the greatest interference was yielded when pictures conveyed an emotional content. Importantly, observers were less distracted by novel rare emotional pictures when the frequency of occurrence of the overall task-irrelevant images increased. Statistically, analyses of RTs yielded a significant effect of Trial Type, F (2, 38) =47.067, $p < .001$, $\eta^2_p = .712$, with slower RTs in distractor-present trials (emotional and neutral) compared to distractor-absent trials, F_s (1,19) > 53.637, $p_s < .001$, $\eta^2_{ps} > .738$ and, especially, in emotional-distractor trials compared to neutral-distractor trials, F (1, 19) = 31.419, $p < .001$, $\eta^2_p = .623$. No significant effect of Block was observed, F (1,19) = .996, p = .331, $\eta^2_p = .050$. Finally, a significant interaction Block x Trial Type was found, F (2, 38) =12.330, $p < .001$, $\eta^2_p = .394$. Following up on this interaction, the Block effect was tested for each Trial Type: emotional stimuli slowed down response times more when they appeared in the 20% block than in the 80% block, F (1, 19) =7.737, p = .012, $\eta^2_p = .289$, while no difference was found for neutral distractors between the two blocks, F (1, 19) =.346, p = .563, $\eta^2_p = .018$. Conversely, as in Experiment 1, participants were faster to respond to the task in the 20% block than in the 80% block during trials in which no distractor was presented, F (1, 19) = 5.693, p = .028, $\eta^2_p = .231$. More importantly for our aim, the emotional interference effect (the difference between emotional and neutral) was affected by the frequency of distractor occurrence, as confirmed by a significant Block X Valence interaction, F (1, 19) =6.302, p = .021, η^2_p = .249. Following up on this interaction, we found that a Valence effect was still present in the 80% block (M= 29.03 ms), F(1, 19) =26.771, p < .001, η^2_p = .585, but it was severely attenuated compared to the 20% block (M= 56.67 ms), F(1, 19) = 21.993, p < .001, η^2_p = .537.

On the other hand, this modulation of the behavioral interference between the two blocks was not affected, even in part, by the order with which the two blocks were performed (Fig. 3.3). Statistically, not only did the Condition Order x Block x Trial Type interaction, F (2, 36) = .992, p = .390, η^2_p = .049 fail to reach significance, but also the Condition Order x Block x Valence interaction was non-significant, F (1, 18)= .013, p = .912, η^2_p = .001, indicating that in the run-down there were no crossover effects from the 80% block in which attentional capture by rare emotional stimuli was attenuated in the subsequent 20% block.

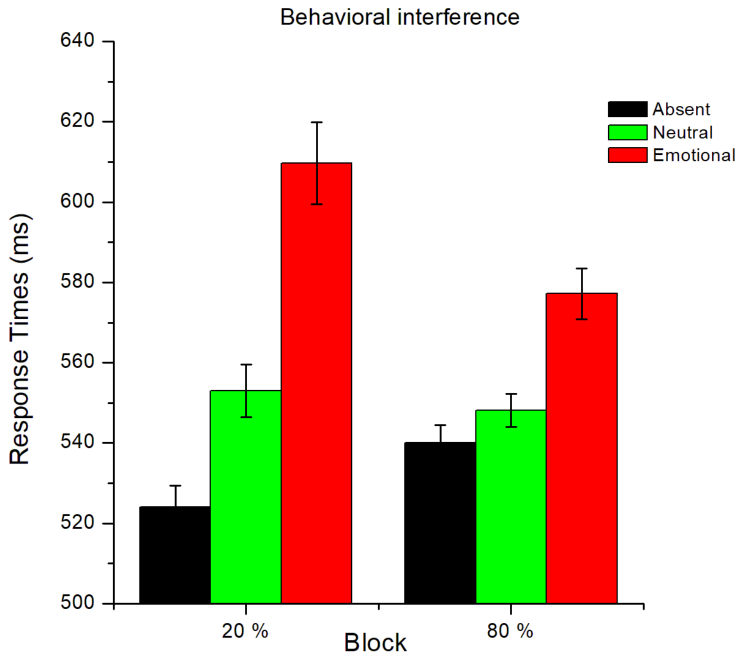

Figure 3.2. Effect of the frequency of picture occurrence on reaction times in Experiment 1b. Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014).

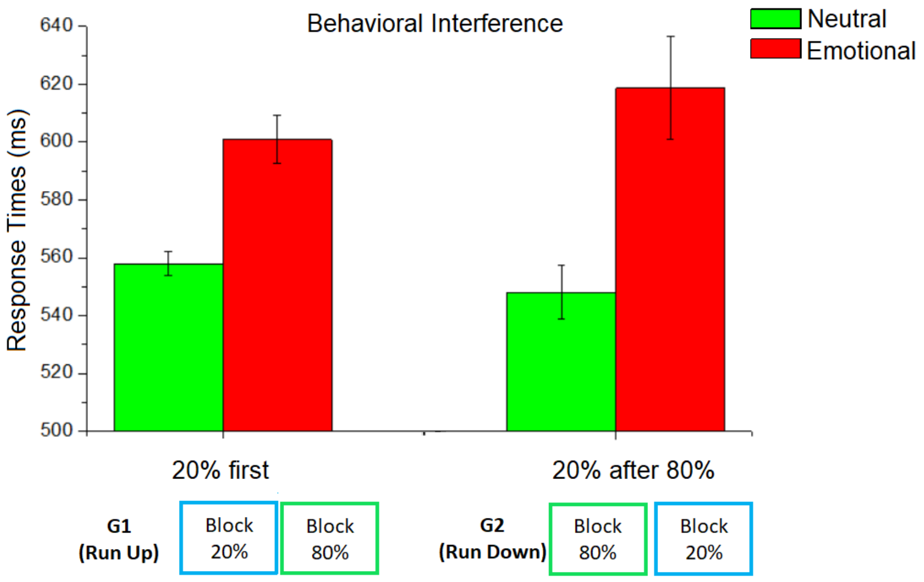

Figure 3.3. Effect of condition order on the emotional interference effect in Experiment 1b Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014).

Accuracy. An ANOVA, with the same factors as before, was also conducted on accuracy (see Table 1 in the Appendix A), but no significant main effects or interaction emerged, thus excluding the possibility of the observed RT-pattern being due to a speed-accuracy trade-off [Block, F (1,19) = 1.806, p = .195, η^2_p = .087; Trial Type, F (2,38) = 3.053, p = .082, η^2_p = .138; Block X Trial Type interaction, F (2,38) =.235, p = .792, η^2_p = .012].

Late positive potential

As illustrated in Fig. 3.4, emotional stimuli elicited a larger positivity over parieto-occipital sensor sites in the 450-900 ms time interval, and emotional modulation of the LPP was enhanced when rare emotional distractors were embedded among frequent neutral distractors.

As expected, the late positive potential was modulated by Trial Type, F (2, 38) = 36.978, p < .001, η^2_p = .661, with emotional stimuli eliciting a more pronounced LPP compared to neutral ones, F (1, 19) = 45.664, p < .001, η^2_p = .706. No significant main effect of Block was observed, F (1, 19) = .153 p =

.700, η^2_p = .008. A significant Block X Trial Type interaction, F (2, 38) = 3.251, p =.050, η^2_p = .146 was followed by simple main effect tests. LPP amplitude was more positive when viewing a rare emotional image in the 80% block than in the 20% block, F (1, 19) = 4.283, p =.052, η^2_p = .184, while there was no variation between the two blocks when viewing neutral images, F (1,19) = 2.233, p =.152, η^2_p = .105. In the same way, there was no difference in distractor-absent trials between the two blocks, F (1,19) =.212, p =.650, η^2_p = .011. Overall, the emotional modulation of the LPP differed between the two blocks, F (1, 19) = 5.487, p = .030, η^2_p = .224, and further investigation as to the effect of Valence in each block confirmed that emotional stimuli prompted a larger LPP compared to neutral stimuli in both the 20% block (M= 0.93 µV), F(1, 19) = 19.940, p < .001, η^2_p = .512 and the 80% block (M= 1.69 µV), F(1, 19) = 33.666, p < .001, η^2_p = .639 showing, critically, that the emotional modulation tended to increase, rather than reduce, in the 80% block.

The Order of Presentation did not interact with any of the within factors or interactions; Order X Block X Trial Type, F= (2, 36) = .905, p = .414, η^2_p = .048, and Order X Block X Valence, F (1, 18) = 1.307, p = .268, η^2_p = .068.

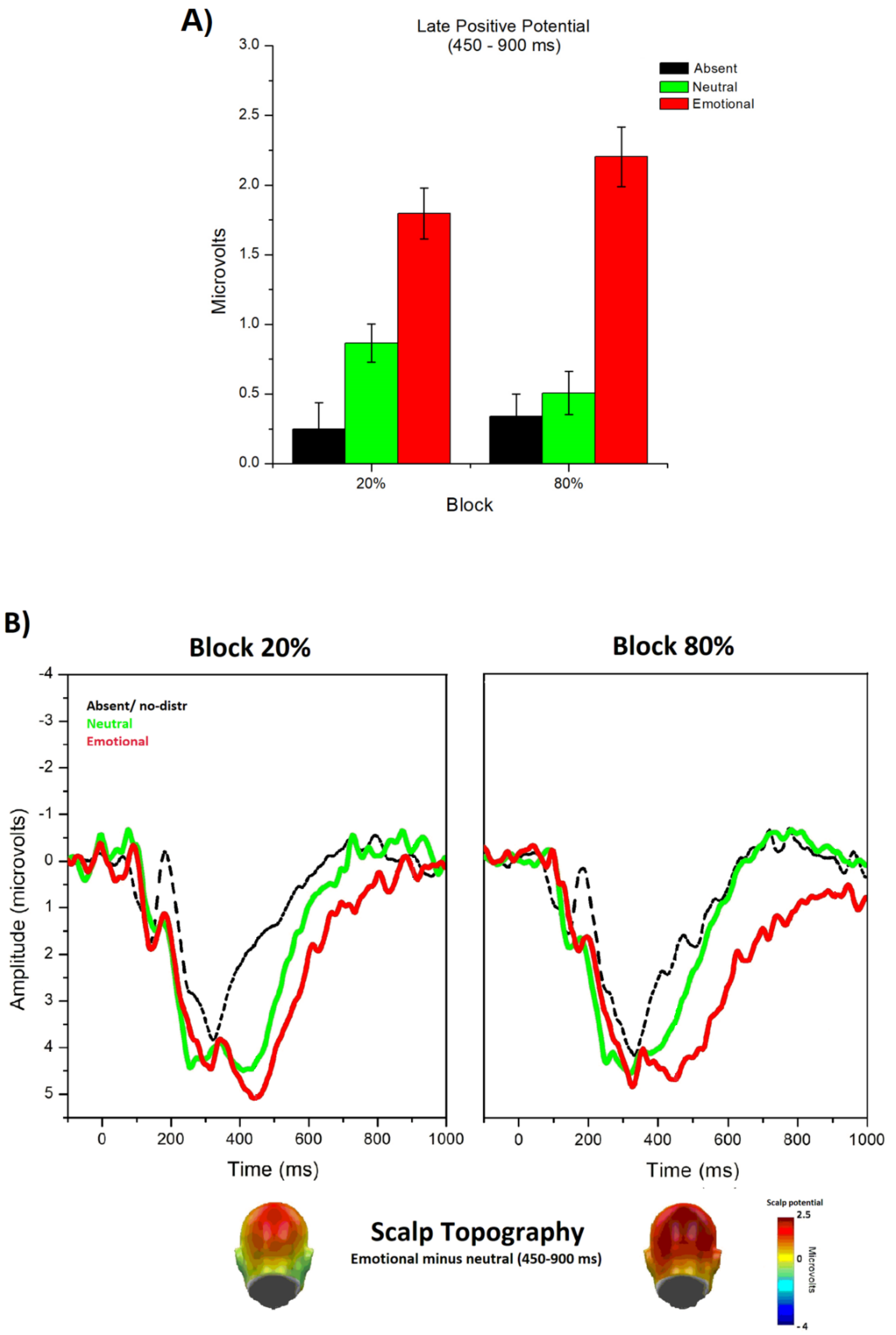

Figure 3.4. Effect of the frequency of picture occurrence on the (A) LPP amplitude in Experiment 1b. Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014). (B): Grand-averaged ERP waveforms averaged over parieto-occipital sensors used for the analysis of the LPP for neutral and emotional pictures in the 20% block and in the 80% block. Insets below each graph are the back views of the scalp topography (450–900 ms) of the difference between emotional and neutral picture processing.

Awareness of distractor frequency

As in Experiment 1a, we examined whether the modulation of the emotional interference between the two blocks depended on participants having “recognized” the high frequency of distractor occurrence in the 80% block. By analyzing the participants’ responses to the general (post-experimental) query about whether the two blocks differed from each other, we found that 13 of the 20 participants (65%), more than half of the sample, answered “no” and, even after a brief interview with the experimenter, they reported not having noticed any changes in the frequency with which distractors had occurred between the two blocks. For these participants who were aware of the difference, we analyzed the following answer in which we asked to them to approximately report the distractor frequency within each block; 5 of the 7 correctly indicated which of the two blocks was the one in which distractors occurred frequently, while 2 participants were completely wrong.

We analyzed the behavioral results separately for those who were aware (n=5) and those who were unaware (n=15) about the frequency manipulation as a between-subjects variable. Since there were no interactions with the other variables, Group (aware, unaware) x Block (20%, 80%) x Valence (emotional, neutral), F (1, 18) =.318, p=.580, η^2_p = .017, it is possible that some awareness about the high frequency of distractor occurrence is not determinant for the attenuation of the emotional distraction.

Comparison between experiments

We performed a direct comparison between the two experiments to assess whether both the overall distractor frequency and the specific frequency of emotional stimuli played a critical role in the modulation of the behavioral interference (Fig. 3.5). Interestingly, an ANOVA on RTs, with Block and Valence as within-subject factors and Experiment as between-subject factor did not find a significant interaction, F (1, 42) = .045, p = .832, η^2_p = .001, suggesting that the effect of frequency on the behavioral interference was not, even in part, due to the temporal distance and/or the specific frequency of emotional distractors.

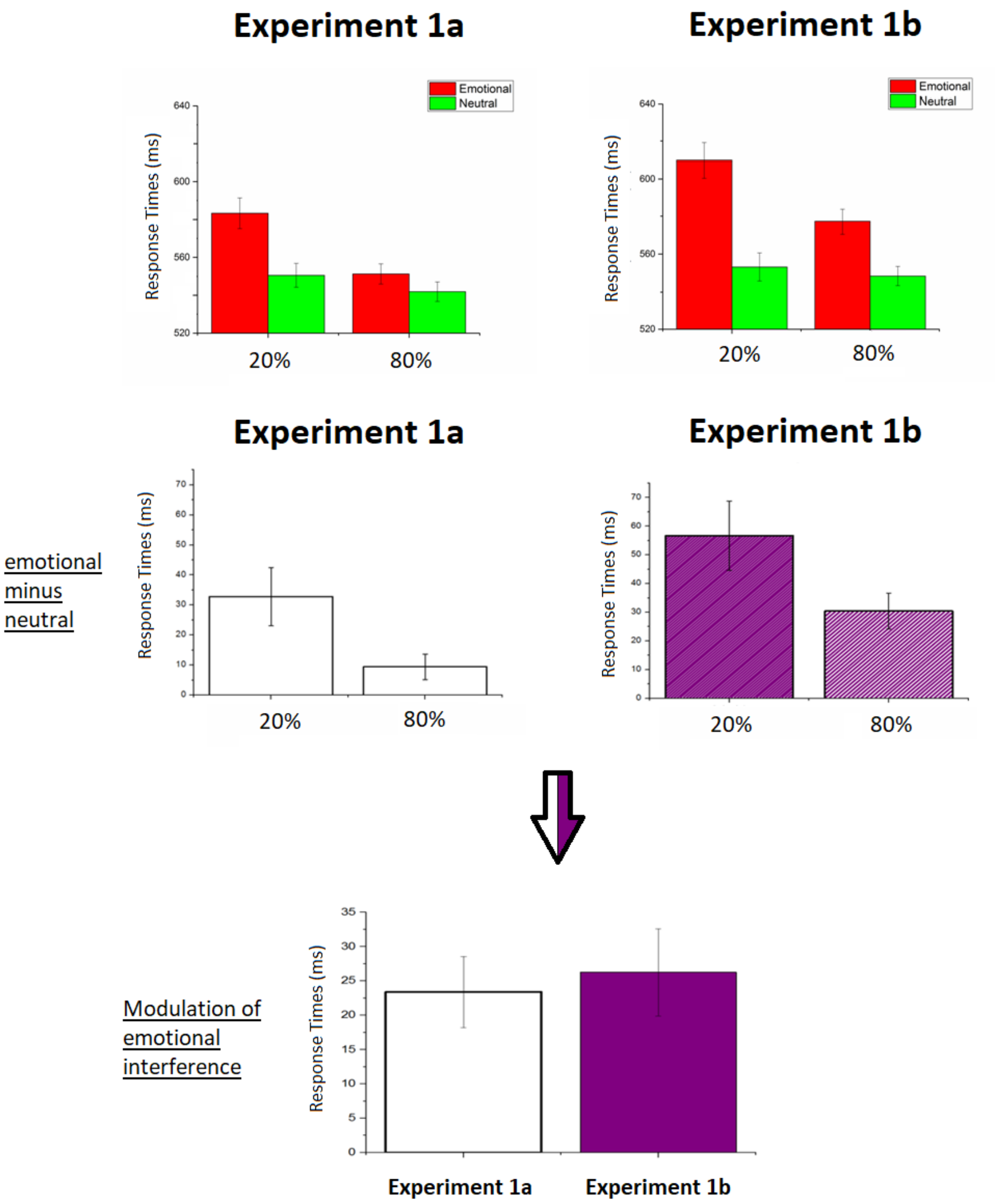

Figure 3.5. Comparison between Experiment1a and 1b. Top: the graphics show response times for emotional and neutral trials in both blocks for Experiment 1a (on the left) and Experiment 1b (on the right). Middle: the difference score (emotional minus neutral) in the two blocks. Bottom: the difference between the difference scores in the 20% block and in the 80% block in the two experiments.

At a cortical level (Fig. 3.6), an Experiment x Block x Valence interaction was present, F (1,41) = 9.773, p = .003, η^2_p = .192, indicating that the affective modulation of the LPP varied between the two experiments. Specifically, the 20% blocks of the two experiments showed a similar modulation of the LPP, which is not surprising, considering that the 20% block of Experiment 1a was identical to the 20% block of Experiment 1b; F (1,41) = .123, p = .727, η^2_p = .003. Crucially, the Valence effect differed between the two 80% blocks, F (1,41) = 11.093, p = .002, η^2_p = .213, and, interestingly, suggesting that the LPP was not sensitive to the overall distractor frequency but rather to some factors related to the specific occurrence of emotional stimuli per se, such as their frequency or the temporal distance between their appearance.

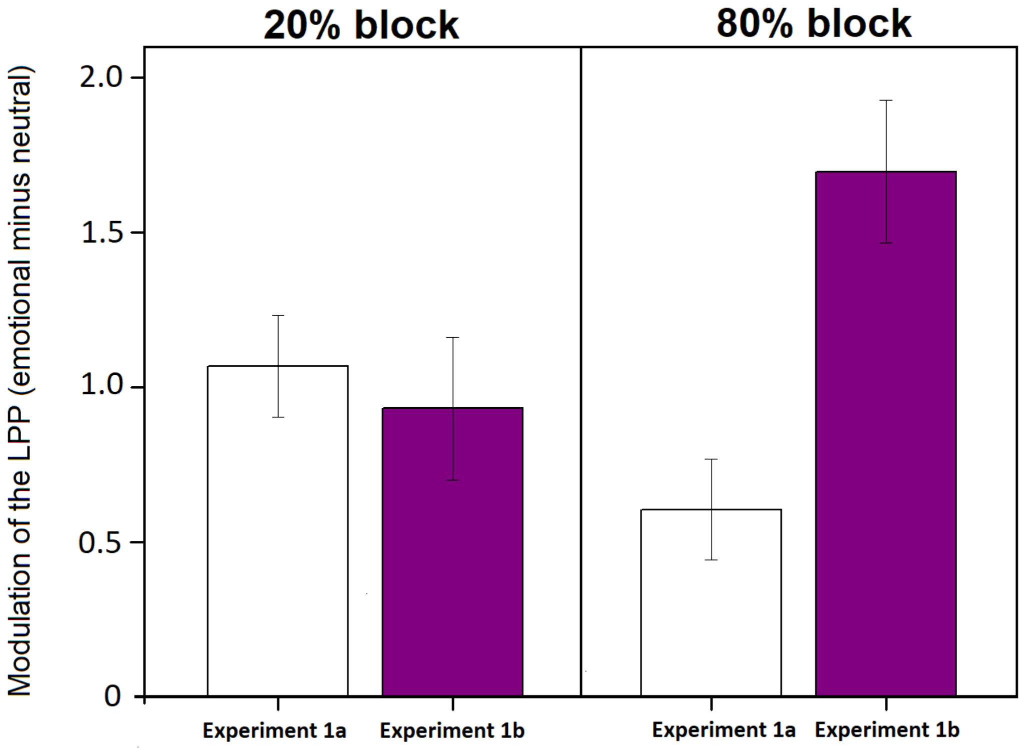

Figure 3.6. Comparison of the modulation of the LPP between Experiment 1a and 1b in the 20% block (on the left) and in the 80% block (on the right)

Discussion

Experiment 1 suggests that the susceptibility to distraction by emotional stimuli changed as a function of the frequency of distractor occurrence, despite emotional stimuli being rare, and, thus, their occurrence being impossible to predict. Specifically, emotional interference was reduced in contexts in which distractors occurred too frequently (i.e., in the majority of trials), independently of whether emotional stimuli were frequent (Experiment 1a), or only rarely presented in the midst of frequent neutral distractors (Experiment 1b). In contrast, the affective modulation of the LPP was only marginally affected by the frequency of emotional distractors (Experiment 1a), and was not reduced by high distractor frequency when emotional distractors were rare (Experiment 1b), indicating that behavioral and electrophysiological indexes of distraction reflect different stages of emotional processing. Altogether, these findings suggest that evaluation of emotional stimuli, and activation of motivational systems, occur mandatorily; however, some further and probably later mechanisms control emotional attentional capture in order to reduce their distracting effect.

This conclusion is in line with a recent study (Grimshaw, Kranz, Carmel, Moody & Devue, 2017), which has demonstrated the effect of distractor frequency on emotional interference by using a low load perceptual task similar to that used in the current study. However, the two paradigms have critical methodological differences which it is worth dwelling on. Specifically, in Grimshaw and collaborators' study (2017) a target letter and five small "o"s appeared in the center of the screen for 100 ms and observers were required to discriminate the identity of the target (N or X), while ignoring a peripheral distracting image that was presented at the same time below or above the letter display. The frequency of distractor occurrence was manipulated in a between-subjects design: a group of observers was exposed to the high distractor frequency condition in which distractors occurred in the majority of trials (75%), while the other group was submitted to the low distractor frequency condition in which distractors appeared rarely (25%). Each condition consisted in 8 blocks of 48 trials each and, critically, the valence of the distractors was blocked so that in each block neutral and emotional images were never presented together. The findings clearly showed that emotional distractors interfered in the low frequency blocks, but that this emotional interference completely disappeared in the high frequency blocks. The authors hypothesize that top-down inhibitory mechanisms of attentional control were differently engaged based on contextual factors: when emotional stimuli were rare they were attended to and evaluated because they could carry important information, and only afterwards was attention reoriented toward the primary task (reactive attentional control). Conversely, when emotional stimuli were frequent, and did not entail any consequences, their informational value was limited thus making it convenient to prevent attention from being allocated to them by preemptively engaging inhibitory mechanisms (proactive attentional control). Although the authors' interpretation is appealing, several mechanisms could explain this effect, and the lack of an emotional attentional capture in the high frequency condition could be due to several factors, such as the predictability of the occurrence of emotional stimuli or a reduced motivational engagement. Moreover, although the observation that the emotional interference disappeared with frequent distractor occurrence suggests that the emotional content no longer impacted picture processing, supporting a scenario in which emotional distractors were effectively inhibited, the inhibition of such stimuli may occur at different stages of processing. Therefore, as far as the nature of this reduction is concerned, the study by Grimshaw and coworkers (2017) leaves several critical questions open that we have attempted to address.

Regarding the **predictability of emotional distractors**, in the study by Grimshaw et al. (2017), emotional and neutral images were presented separately in distinct blocks, and therefore there was no uncertainty as to the nature of the distractor that would appear in each block. Thus, in the high frequency context in which distractors appeared in almost every trial, the occurrence of distractors was not only expected, but observers also knew whether those distractors would have an emotional content (Kennedy et al., 2017; Zhao and Most, 2018). It was therefore possible that the emotional valence of task-irrelevant images needed to be fully predictable in order for observers to proactively inhibit the distractors. Is it possible to ignore emotional distractors when we do not know whether or not the appearing distracting images will be emotional? To answer this question, in the current paradigm, emotional (pleasant and unpleasant) stimuli were intermixed with neutral stimuli within each block, leading to uncertainty regarding the upcoming distractor in each trial. In this circumstance, a reduction in the emotional interference was still found, ruling out the possibility that the emotional distraction was strategically attenuated only due to the predictability of the emotional nature of the stimulus. Moreover, emotional interference declined even when emotional distractors were presented rarely among neutral stimuli with a variable interval between their appearance, and therefore in a condition in which there was a scarce possibility of knowing, preemptively, when the images would have an emotional content (Experiment 1b). This last finding is important in that it shows that the reason that allocation of attention is prioritized to rare emotional stimuli is not because such stimuli may carry important information, as Grimshaw and collaborators suggest. Conversely, the degree to which rare emotional stimuli interfere with performance is merely modulated by the high occurrence of distractors, independently of their content (overall frequency of distractor occurrence). Our results therefore suggest that observers learn to ignore emotional distractors, rare or not, when they have enough experience with task-irrelevant stimuli, even if these are neutral distractors.

Another possible explanation for the lack of emotional interference in the high frequency context that Grimshaw and collaborators found is an overall decline in **motivational engagement**. This explanation entails that observers did not learn to inhibit emotional distractors but, rather, emotional images became less significant over time, independently of their status of distractors, and hence captured less attention. In order to explore this issue, in the current experiments, we decided to manipulate the frequency of distracting images in a within-subject design by presenting a low frequency and a high frequency block to each participant, and randomizing the order of presentation of the two blocks between two groups of observers. It was found that the emotional interference in the low frequency context was not reduced for those participants who had previously been exposed to a high distracting context, ruling out the hypothesis that observers become less motivationally engaged through several exposures to emotional images. Since the emotional interference was greatly reduced in the high frequency context and there were no crossover effects in the subsequent low frequency context, it was confirmed that the overall frequency of distractor occurrence was the critical factor determining the degree to which emotional stimuli captured attention and distracted observers in a given context. It is therefore possible that the frequent exposure to distractors triggered a top-down filtering mechanism which was rapidly disengaged when task-irrelevant images appeared only rarely.

Concerning the stage at which the emotional processing impacted the high frequency context, here ERPs were used to track picture processing prior to overt responses, focusing on the LPP, which has been suggested to reflect the evaluative processing of the emotional stimulus and the activation of the motivational systems. Interestingly, it was found that the content of the distractors was still processed by the brain, as indicated by the persistence of the affective modulation of the LPP, despite the behavioural interference being strongly attenuated. Specifically, it was found that the evaluative processing of emotional stimuli, and the engagement of motivational systems, was not affected by emotional distractor frequency (Experiment 1a). This persistence of the LPP suggests that it is crucial to evaluate the emotional content of emotional distractors independently of how frequently these stimuli occur. Moreover, the emotional modulation of the LPP increased when rare emotional distractors were interspersed among frequent neutral distractors (Experiment 1b), compared to a low frequency context in which distractors appeared rarely, possibly suggesting an enhanced motivational engagement due to an enhanced categorical distinctiveness of the emotional stimuli. In fact, it is possible that the frequent occurrence of neutral images generated a homogeneous, uniform neutral context from which emotional images emerged because they represent a distinct, unique category, and this uniqueness makes them more significant.

Importantly, the comparison between different measures of emotional processing is critical in highlighting that the processing of emotional stimuli is not completely prevented in the high frequency context as hypothesized in previous work (Grimshaw et al., 2017), suggesting that the decline of emotional interference is due to an inhibitory mechanism that selectively impacts attentional capture (using behavioral interference as a classical or “gold standard” measure in cognitive psychology) after the semantic processing of emotional distractors and engagement of motivational systems has occurred.

In the light of all these observations, one of our main question regarded the nature of the attentional control that subtended the decrease in emotional interference, and specifically if this control was learned over time or occurred immediately. If this reduction was the result of practicing to overcome distraction, then emotional interference should be expected to decrease gradually over time. Critically, in Experiment 1a (see the Discussion session) we split the high frequency block in three mini-blocks of 100 trials each and we found that performance was just aided from the first 100 trials through the end of the block, indicating that participant’s ability to control distraction was evident from the beginning. To confirm this result, we conducted the same analysis in Experiment 1b. Again, no reliable habituation emerged across the mini-blocks [Mini-block (3 levels) x Valence (neutral, emotional), F (2, 38) =.310, p=.735, η^2_p = .016]. Thus, this control mechanism does not stem from a gradual learning process, but it is quickly engaged as soon as the occurrence of distractors become likely.

A possible explanation for the rapid attenuation of the emotional interference is that observers become effective in focus their attention on the task, or on its location (i.e., a **facilitation of the task processing**). Several studies have demonstrated that when attention is explicitly cued to the location in which the target will appear, an abrupt onset that appears in a different location fails to capture attention (Yantis and Jonides, 1990). In this case, the task was constantly presented at the center of the display, making it possible that observers learned to focus on that position at the start of each trial and indirectly ignore all the irrelevant stimuli appearing elsewhere. However, in two experiments, we found that the response times slowed down in the distractor-absent trials of the high frequency context, compared to the low frequency condition, whereas we should expect faster responses if the processing of the task were enhanced.

Alternatively, it is possible that the attenuation of emotional distraction could be mediated by a **spatially-specific inhibition** of any sensory stimulus appearing in the distractor locations (Awh, Matsukura & Serences, 2003; Serences, Yantis, Culberson & Awh, 2004; Kelley and Yantis, 2009). In fact, although the irrelevant images could appear either to the left or to the right of the central task, these two positions were unchanged throughout the entire experiment, and so the distractor positions were both predictable and completely irrelevant for the primary task. Yet, a piece of evidence against this possibility is that the LPP was still enhanced in the high frequency block, indicating that participants continued to elaborate the emotional content of the images. If observers had become effective at filtering distractor information based on location, then the emotional content should have had no impact in the 80% block. Moreover, we found a rapid reduction of the emotional interference just in the first trials of the block, while a spatial suppression would likely require time to be established, as there would be initial uncertainty regarding the location, the content and the task relevance of the distracting pictures. In line with this hypothesis, Kelley and Yantis (2009) found that a spatially suppression of the distractor locations developed slowly as demonstrated by the fact that the interference of distracting images was attenuated gradually during the during the experiment. Critically, the authors provided evidence that the reduction of distractor interference was only in part attributable to a spatial inhibition, and concomitant processes were possibly implicated.

Overall, the emotional interference effect found in the current study seems to reflect a specific inhibition of emotional distractor events rather than some indirect inhibitory processes such as their spatial positions or an enhancement of task processing, and such inhibition seems to be mediated by a context-specific mechanism.

Experiment 2: Generalization of the learned rejection of distractors

In the first study, it was demonstrated that attentional capture by novel and rare emotional stimuli was attenuated with frequent exposure to distractors, indicating that the brain can reject emotional distractor through experience. However, this attenuation was short-lasting and did not impact the emotional attentional capture when the frequency of distractor occurrence was low. Experiment 2 was conducted in order to examine whether extensive practice with distractors promotes long-lasting effects on emotional attentional capture. A previous study (Codispoti et al. 2016) has evaluated the effect of practice by demonstrating that observers quickly learn to ignore a set of emotional distracting images when repeatedly exposed to them, but are once again distracted as soon as novel images were presented, suggesting that the subtended learning process is stimulus-specific and does not generalize to novel (i.e., never seen before) emotional events. For this reason:

1) The main purpose of Experiment 2 is to investigate whether observers are able to attenuate attentional capture by novel and rare emotional stimuli after a practice session with variable task-irrelevant stimuli. Literature on perceptual salience indicates that novel (never seen) distractors fail to capture attention when presented after practice with variable distracting stimuli, while they still capture attention after a practice phase with the same repeated set of stimuli, suggesting that observers learn to reject task-irrelevant stimuli, rather than a specific stimulus, when dealing with completely different and unpredictable distracting events. Thus, observers learn to attenuate distraction and generalize this rejection to novel stimuli beyond the practice regime (Vatterott et al., 2018; Won and Geng, 2018; Kelley and Yantis, 2009). Two possible outcomes could result from this practice with variable distracting stimuli; on the one hand (a) we expect to attenuate the emotional interference effect after practice with highly heterogeneous neutral distractors if extensive exposure with variable

distractors is also effective in preventing attentional capture by emotional significant stimuli. Alternatively, it is possible that (b) practice with highly heterogeneous neutral distractors is not sufficient to prevent capture by significant emotional stimuli, meaning that rejection does not generalize to stimuli with a different semantic meaning, and hence emotional stimuli may cause interference despite practice.

2) A further aim is to examine which stage of the emotional processing is affected by variable practice by comparing the emotional interference effect with the affective modulation of the LPP. At a cortical level, the affective modulation of the LPP seems to be unaffected by distractor experience, in terms of repeated exposure to the same distractors and frequent exposure to heterogeneous distractors. Thus, unlike what we expect for the behavioral interference (RT slowing), we should expect the LPP modulation to remain unmodulated by extensive practice with variable neutral stimuli, and a rejection of emotional stimuli occurs only after the emotional stimulus has been evaluated and has engaged the motivational systems.

Experiment 2a – Practice with variable neutral distractors

Method

Participants

A total of 21 healthy students (11 females; ranging from 19 to 30 years of age) of the University of Parma (Italy) participated in the experiment as volunteers. All participants had normal or corrected-to-normal visual acuity. The study was approved by the Ethical Committee of the Department of Psychology at the University of Parma, and prior to participating, all subjects signed an informed consent.

Materials and design

A total of 600 pictures were selected as distractor stimuli from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008), and from public domain pictures available on the Internet. The pictures comprised 30 pleasant (heterosexual erotic couples), 30 unpleasant (mutilated bodies), and 540 neutral (depicting human beings [n=60] and without human beings [n=480]; specifically, objects, animals, urban streets, building interiors, means of transport) images. The emotional pictures and "human" neutral pictures were those used in Experiment 1 (see Materials of Experiment 1 for subjective rating of valence and arousal, LPP modulation, and skin conductance changes in response to the viewing of these images).

Images were displayed on a gray background of a 19 CRT monitor (60 refresh rate). Each scene subtended 14.3° horizontal by 10.8° vertical degrees of visual angle and were positioned either to the left or to the right of a central Gabor patch. The distance between the inner edge of the distractor image and the center of the Gabor patch was 4° of visual angle. The Gabor patch (sinusoidal gratings with a Gaussian envelope), used for the orientation discrimination task, subtended 5.3° x 5.3° of visual angle and it could be horizontally or vertically oriented. Gabor patches were generated using custom MATLAB software by overlapping two distinct Gabor filters with the same orientation but different frequencies (0.94 and 9.4 frequency x visual angle, respectively).

All stimuli were equated in brightness and contrast to control for potential confounds resulting from low-level visual properties of the images. Stimulus presentation and data collection were performed using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002).

For each participant, all 600 images (60 emotional and 540 neutral) were presented during an experimental session. The session consisted of three phases: an initial Pre-Test phase, a Practice Phase and a final Post-Test phase.

The experimental design is illustrated in Fig. 4.1. The Pre-Test and Post-Test phase were identical and consisted of 300 trials each in which distractors appeared randomly in 50% of the trials. The 50% of trials in which distractors were present were subdivided into 10% emotional (half pleasant and half unpleasant) distractor trials and 40% neutral distractor trials; within the neutral category 10% were "human", and the remaining 30% of images belonged to non-human categories (trained neutral). The practice phase consisted of two blocks of 300 trials each, in which distractors appeared in 50 % of the trials, and were exclusively neutral non-human categories (trained neutral). Before the beginning of the experiment, participants performed a set of 150 practice trials, in which no distractors appeared, to familiarize themselves with the task.

Across participants, emotional and human neutral pictures were randomly assigned to the Pre-Test or to the Post-Test, and the trained neutral images were randomly presented in the Pre-Test, Post-

Test, or Practice. Nevertheless, within each participant, no picture was ever repeated across the experiment (i.e., novel). The Pre-Test was introduced to effectively compare susceptibility to emotional distraction before and after practice, and, therefore, to evaluate the efficacy of the practice provided.

In the Pre-Test and Post-Test, the order of trial type (trials without distractor, emotional distractor trials, and neutral distractor trials were pseudo-randomized with the restrictions that (i) the emotional pictures could occur no more than twice consecutively, (ii) emotional pictures of the same valence were never presented one after the other, (iii) pictures never appeared more than three times on the same side. E-prime software synchronized the presentation of the stimuli and triggered EEG recording in each trial.

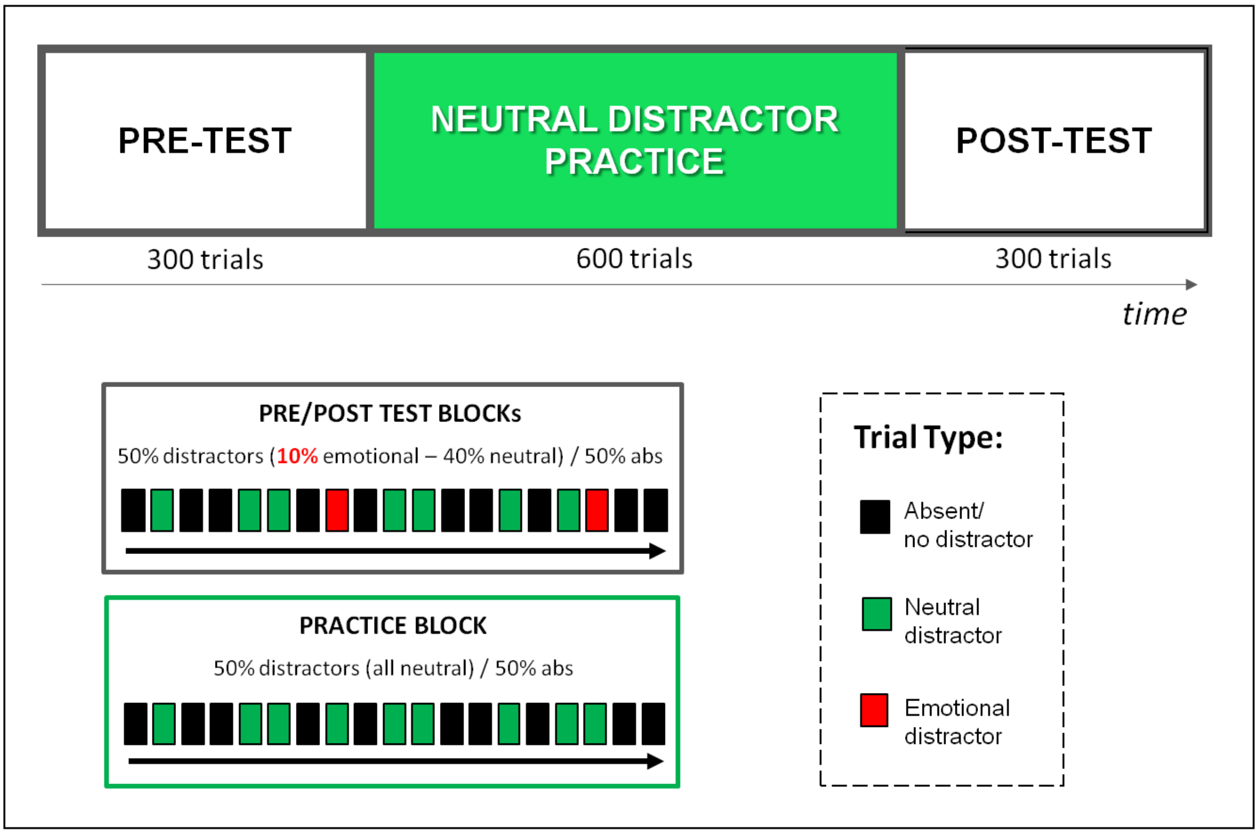

Figure 4.1. Experimental design in Experiment 2a

Procedure

Upon arrival at the laboratory, participants signed an informed consent form. They were then seated in a recliner in a small, sound-attenuated, dimly lit room, and the EEG sensor net was attached. Participants sat in front of the computer monitor with their head supported by a chinrest. The distance between their eyes and the monitor was 51 cm for all subjects.

The experimental paradigm was the same as that used in Experiment 1 (Figure 4.2). Each trial started with the presentation of a uniform gray background displayed for 500 ms. This was followed by the appearance of a Gabor patch in the center of the screen for 150 ms. The participant's task was to determine, as quickly and as accurately as possible, whether the Gabor patch was vertical or horizontal by pressing one of two buttons on the keyboard ("v" or "b") with the index of their dominant hand. In distractor-present trials, a distractor image was presented simultaneously with the Gabor, appearing equally often in the left or right visual fields. During the Pre-Test and the Post-Test, the image could be either emotional or neutral, while during the Practice phase all distractors were neutral. Participants were explicitly informed that there would be a distractor in some trials and were instructed to maintain fixation on the center of the screen, focusing their attention exclusively on the Gabor patch while ignoring distractor images. Consecutive trials were separated by a gray screen for a variable amount of time ranging from 1400 to 2000 ms (intertrial interval, ITI). During this period, behavioral responses to the orientation task were collected.

Before the beginning of the experiment, participants performed a block of 150 trials in which distractors were never presented. During the experiment, they started with the Pre-Test phase, following by the Practice phase and the final Post-Test phase. Between each block a 5-min break was given. The experiment lasted approximately 52 minutes.

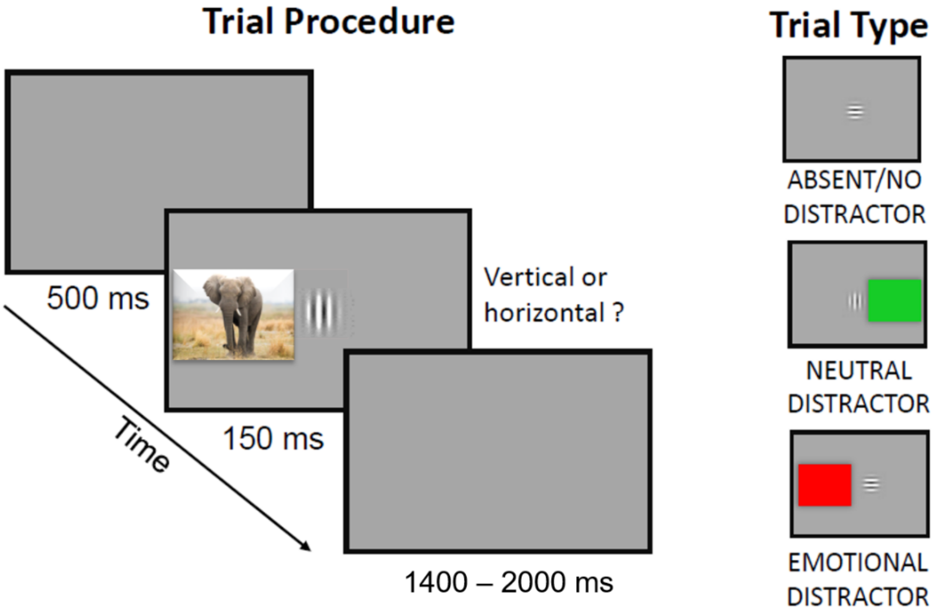

Figure 4.2. Sequence of events and trial type in Experiment 2

EEG recording and processing

Electroencephalogram (EEG) was recorded at a sampling rate of 1000 Hz using the San Diego System with a 60 dense sensor array. All data were re-referenced to the average of all scalp electrodes. Additionally, a sensor was attached below the left eye. For each trial, EEGs were corrected for blinks and eye movements using a regression technique based on the electrodes above and below the left eye, and to the left and right side of the eyes (Schlögl et al., 2007). Off-line analysis was performed using Emegs (Peyk, De Cesarei, & Junghöfer, 2011). First, data were initially filtered (30 Hz low-pass and 0.1 Hz high-pass). Then, trials and sensors containing artifacts were detected through a statistical procedure specifically developed for dense-array EEG (Junghöfer, Elbert, Tucker, & Rockstroh, 2000). Trials containing a high number of neighboring bad sensors were discarded; for the rest of the trials, sensors containing artifactual data were replaced by interpolating the nearest good sensors. Finally, data were re-referenced to the average of all sensors, and a baseline correction based on the 200 ms prior to stimulus onset was performed.

Averaged ERP waveforms were calculated according to factors Block and Trial Type. The region and time interval of interest were selected based on an initial examination of the ERP waveforms and topography. The LPP was scored as the average of the ERP waveform in the 450 and 900 ms after stimulus onset at the parieto-occipital sensor group (11 sensors: 33, 34, 35, 41, 42, 43, 44, 45, 51, 52, 53) where the LPP amplitude was largest (Picton etal., 2000).

Data collection and analysis

Reaction times (RTs) and ERP analyses were performed only on accurate trials. The initial 150 trials served to acquaint participants with the task and were not included in the analyses. Trials with RTs shorter than 250 ms or longer than 1350 ms were treated as inaccurate. In each participant, for each valence of each condition, response times above or below three standard deviations from the mean were discarded as outliers.

The primary purpose of the experiment was to determine whether rejection of neutral distractors generalizes to highly significant emotional stimuli, and at what stage of processing the novel stimuli are rejected. Hence, data were submitted to a repeated measures analysis of variance (ANOVA) for within-subject factors Phase (two levels: Pre-Test, Post-Test) and Valence (two levels: human neutral, emotional). We compared emotional stimuli with human neutral stimuli, since they were balanced in terms of frequency of occurrence, and since neither of these categories were presented during the Practice phase. To deal with violations of sphericity, a Huynh-Feldt correction was applied to the degrees of freedom. For each ANOVA test, the partial eta squared statistic (η^2_p), that indicates the proportion of variance that is explained by experimental conditions over the total variance, is reported.

Results

Behavioral measures

Response Times (RTs). Figure 4.3 illustrates reaction times to the Gabor orientation task. As expected, slower RTs were observed for rare emotional, compared to neutral, distracting pictures during the Pre-Test block. However, this emotional interference was attenuated in the Post-Test block, but still largely enhanced, suggesting that practice with variable neutral distractors was not sufficient to prevent attentional capture by significant emotional distractors.

Statistically, analysis of RTs yielded a significant effect of Valence, F (1, 20) = 13.642, p = .001, η^2_p = .405, indicating that participants were slower at responding to the task when an image with an emotional, compared to a neutral content appeared, F(1,20) = 13.642, p = .001 , η^2_p = .405. A significant effect of Phase was also observed, F(1,20) = 10.764, p = .004 , η^2_p = .350, simply confirming that, the overall RT performance improved as a function of practice, with faster RTs in the Post-Test phase compared to the Pre-Test phase. More importantly, we found a significant Block x Trial Type interaction, F(1, 20) = 5.739, p = .026, η^2_p = .223. Following up on this interaction, we tested the Phase effect for each picture Valence: emotional distractors as well as neutral distractors interfered more (slower RT) in the Pre-Test than in the Post-Test [emotional: F(1, 20) = 11.519, p = .003, η^2_p = .365, neutral: F(1, 20) = 7.860, p = .011, η^2_p = .282]. Yet, when testing the Valence effect in each Phase, we found that RTs were slower for emotional compared to neutral distractors in both the Pre-Test (55,68), F(1, 20) = 14.852, p = .001, η^2_p = .426 and, although attenuated, in the Post-Test block (M= 31.48), F(1, 20) = 8.210, p = .010, η^2_p = .291**,** indicating that the interference reduction after practice was larger for emotional compared to neutral pictures.

Considering that behavioral interference of emotional stimuli was only attenuated with variable practice, it was possible that attention was still allocated to these stimuli due to their categorical distinctiveness. To test this hypothesis, we analyzed whether neutral categories that were presented only during Test phases (human neutral categories) differed from the categories viewed during the practice phase (trained neutral categories). However, the interaction Phase x Neutral Type (human, trained) was not significant, $F(1, 20) = 3.078$, $p = .095$, $\eta^2_p = .133$, ruling out the possibility that categories of distractors never seen during the practice captured attention due to their distinctiveness.

Accuracy. Overall accuracy was high (mean: 96.4%; see Table 2 in the Appendix C). Analysis of accuracy failed to show any significant main effect of Valence and Phase, or a Phase x Valence interaction, $F_s < .09$, $p_s > .05$

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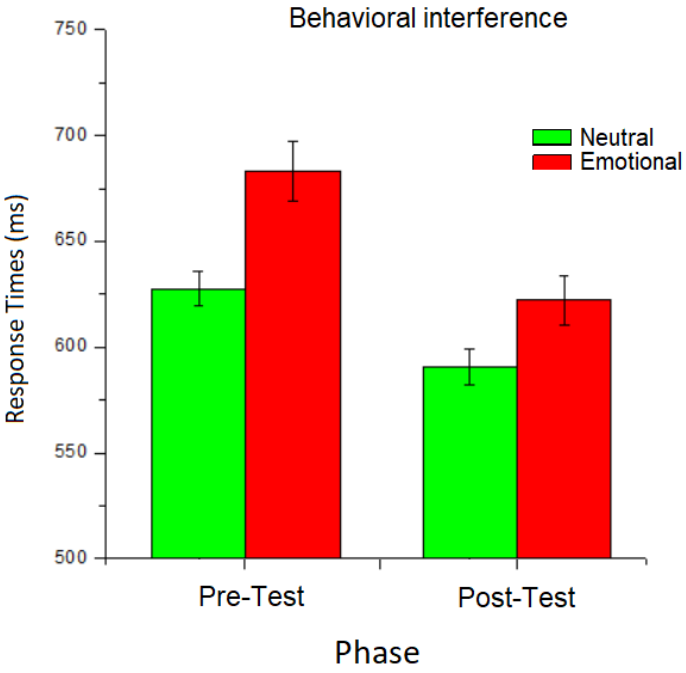


Figure 4.3. Effect of practice with variable neutral distractors on reaction times in Experiment 2a. Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014).

Late Positive Potential

As shown in Fig. 4.4, emotional images elicited a larger positivity over parietal sensors in the 450-900 ms time interval, and practice in rejecting heterogeneous neutral distractors had no effect on this emotional modulation of the LPP.

During the Pre-Test, the LPP was clearly modulated by stimulus Valence, F(1, 21) = 26.276, $p < .001$, $\eta^2_p = .556$, with pictures with an emotional content eliciting a pronounced LPP compared to those with neutral contents. A significant effect of Phase was observed, F(1, 21) = 2.134, p = .159, $\eta^2_p = .092$, showing that the overall amplitude of the LPP reduced after practice. Critically, the interaction Phase x Valence, F(1, 21) = 1.215, p = .283, $\eta^2_p = .055$, failed to reach significance, indicating that affective modulation of the LPP did not vary between the two phases. Consistently, the LPP amplitude continued to be enhanced during viewing of task-irrelevant emotional, compared to neutral pictures, regardless of the practice [Pre-Test (M= 1.56 μV), F (1, 21) = 34.300, $p < .001$, $\eta^2_p = .620$, Post-Test (M=1.22 μV) = F(1, 21) = 12.067, p = .002, $\eta^2_p = .365$].

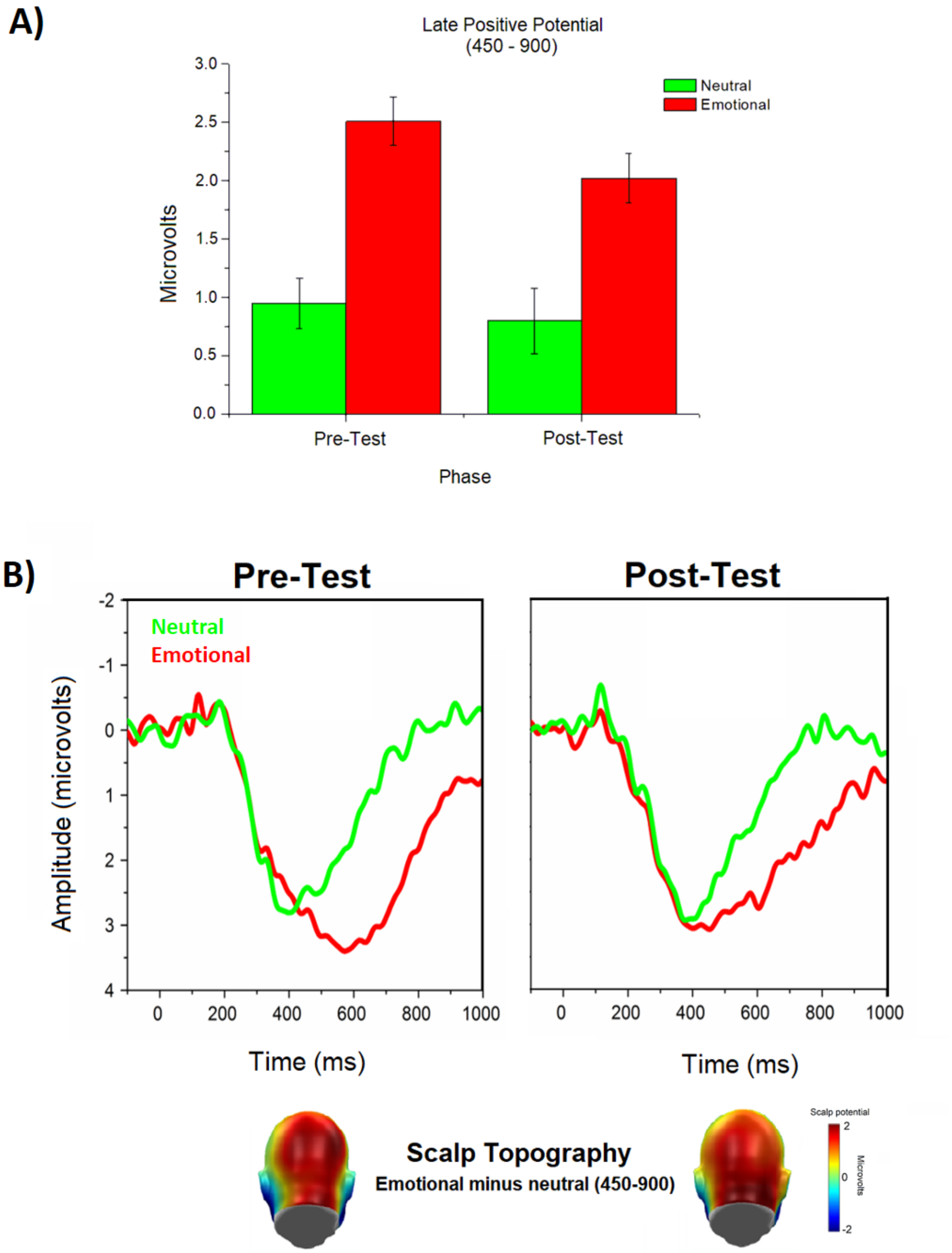


Figure 4.4. Effect of practice with variable neutral distractors on the (A) LPP amplitude in Experiment 2a. Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014). (B): Grand-averaged ERP waveforms averaged over parieto-occipital sensors used for the analysis of the LPP for neutral and emotional pictures in the Pre-Test and in the Post-Test. Insets below each graph are the back views of the scalp topography (450–900 ms) of the difference between emotional and neutral picture processing.

Discussion

The findings of Experiment 1 suggest that when observers were trained to inhibit all variable and perceptually-complex neutral distractors, they were able to generalize this inhibition to emotional stimuli, despite the emotional interference and notwithstanding the fact that the affective modulation of the LPP still persisted.

The role of practice in attentional capture is a topic that has been investigated only recently. The literature indicates that prolonged exposure (practice) to distracting items induces distractor suppression and tunes attentional filters to the stimuli to be ignored. When the trained distractors are variable, the attentional filter encodes multiple features and encompasses broad representations, with the advantage of generalizing suppression more easily beyond the specific trained exemplars to other potential stimuli belonging to the same category (Dixon et al., 2009). Thus, "heterogeneous" practice is the prerequisite for the generalization of distractor suppression, whereas "homogeneous" practice with the same repeated stimulus prompts efficient suppression of the specific learned distractors only (Kelley and Yantis, 2009; 2010; Vatterott et al., 2012; 2018). So far, to our knowledge, this "practice effect" has been mostly demonstrated using perceptually simple neutral distractors (Vatterott et al., 2018; Geng et al., 2018), figure-ground compositions (i.e., objects without a background), or meaningless objects (Kelley and Yantis, 2009). The current experiment extends these prior results by demonstrating that practice with a high variety of neutral natural scenes, depicting meaningful and perceptually-complex situations, fosters a generalizing suppression of images with novel contents, including emotionally relevant stimuli. In fact, the interaction found in this study was highly informative in the sense that it showed an even stronger attenuation of behavioral interference for emotional, compared to neutral, distractors, further supporting the effectiveness of heterogeneous practice in distractor suppression.

On the other hand, it is also important to mention that the interference of emotional distractors did not disappear after practice, indicating that these stimuli were still effective in prompting an orienting response and thus behavioral interference. Moreover, the emotional modulation of the LPP was completely unaffected by practice with neutral distractors, maintaining an enhanced positivity for emotional distractors across the whole experiment, which may reflect the obligatory engagement of motivational systems regardless of practice with distractors.

Considering these findings, a question arises: Do observers need specific practice (experience) with emotional distractors in order to effectively inhibit their processing? The decline of the emotional interference seems to be due to a general inhibition of task-irrelevant stimuli, which is learned during practice with highly variable neutral distractors. A more direct and sustained experience with emotional distractors might be necessary to tune a specific filter which is highly effective in preventing the processing of task-irrelevant emotional categories. The impact of this type of practice may be even more evident at the level of engagement of motivational systems, reflected in the LPP affective modulation, which did not show even a hint of practice effect in Experiment 2a. To examine these hypotheses, a second experiment was conducted by maintaining the conditions of Experiment 2a unchanged, with the critical exception that observers performed a practice phase with only emotional (pleasant and unpleasant) distracting images, rather than neutral images.

Experiment 2b - Practice with variable emotional distractors

Method

The same method as that described in Experiment 2a was used, with the variation described below in the Design and Procedure section.

Participants

A total of 22 healthy students (16 females; ranging from 18 to 30 years of age) of the University of Parma (Italy) participated in the experiment as volunteers, and signed an informed consent form prior to beginning the experiment. The study was approved by the Ethical Committee of the Department of Psychology at the University of Parma. All participants had normal or corrected-to-normal visual acuity and none of them were color blind. All participants were naïve as to the aim of the experiment. Due to technical problems 7 of the 22 participants were removed from EEG analyses.

Design and procedure

In Experiment 2b, we used the same design and procedure as that used in Experiment 2a with the exception that during the practice phase only emotional pictures were presented (Fig. 5.1). During the Pre-Test and the Post-Test, we used the same emotional and neutral images as those in Experiment 2a. A total of 300 new emotional pictures were selected from public domain pictures available on the Internet to be presented during the practice phase: half were pleasant (heterosexual couples) and half unpleasant (mutilated bodies) scenes.

Across participants, emotional and neutral pictures were randomly assigned to the Pre-Test or to the Post-Test. Nevertheless, within each participant, no picture was ever repeated across the experiment (i.e., novel). Before the beginning of the experiment, participants performed a set of 150 practice trials, in which no distractors appeared, to familiarize themselves with the task. In the Pre-Test, Post-Test, and Practice phases, the order of trial type (distractor-absent trials, emotional distractor trials and neutral distractor trials) was pseudo-randomized with the restrictions that (i) the emotional pictures could occur no more than twice consecutively, (ii) emotional pictures of the same valence were never presented one after the other, (iii) pictures never appeared more than three times on the same side. The same restrictions were used for emotional stimuli during the practice phase. E-prime software synchronized the presentation of the stimuli and triggered EEG recording in each trial.

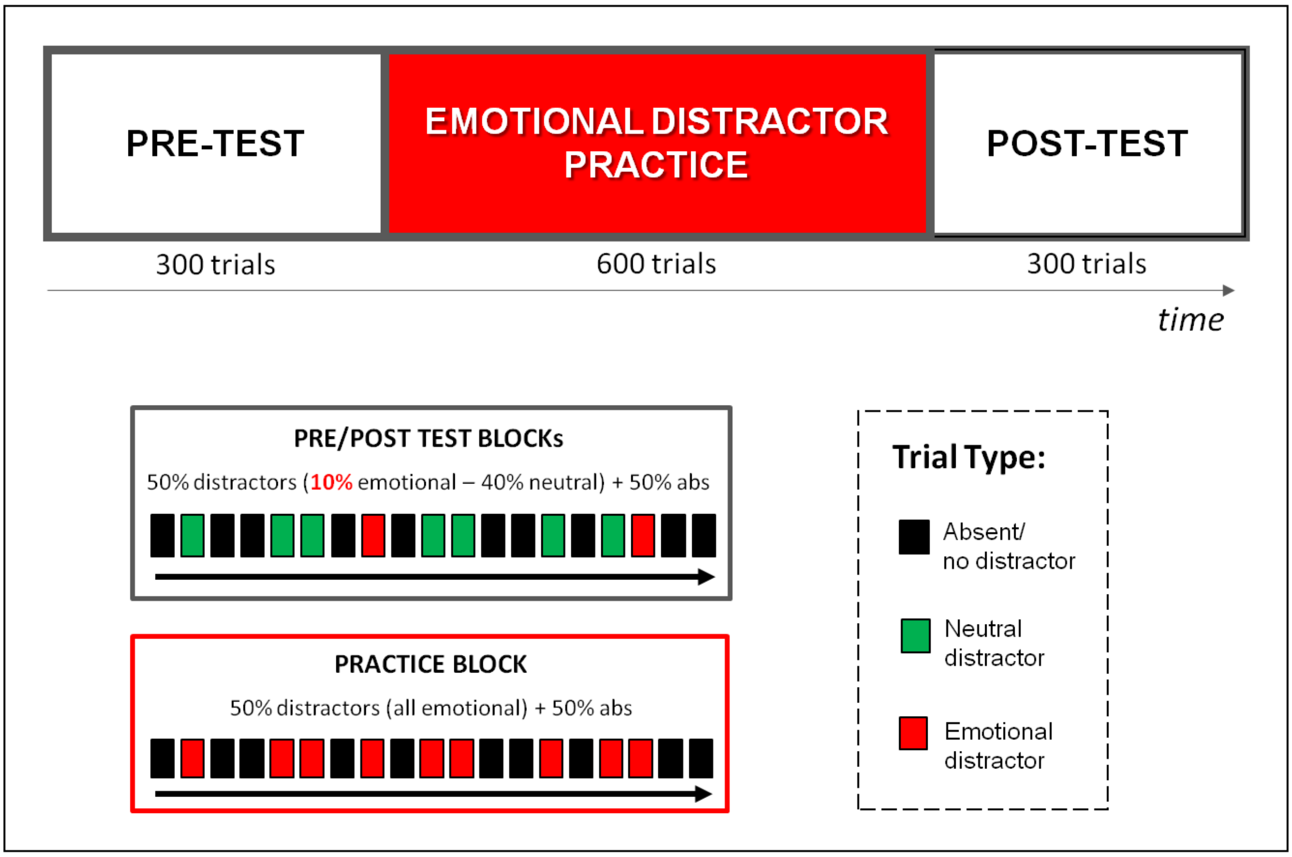


Figure 5.1. Experimental design of Experiment 2b

Data collection and analysis

As in Experiment 2a, reaction times (RTs) and ERP analyses were performed only on accurate trials. The initial block of 150 trials served to acquaint participants with the task and these trials were not included in the analyses. Trials with RTs shorter than 250 ms or longer than 1350 ms were treated as inaccurate. In each participant, for each valence of each condition, response times above or below three standard deviations from the mean were discarded as outliers. The statistical design was identical to that described in Experiment 2a.

Results

Behavioral measures

Response times. As illustrated in Figure 5.2, slower RTs were observed for emotional compared to neutral distractors during the Pre-Test block. Critically, the emotional interference effect disappeared in the Post-Test block, suggesting that practice with variable emotional distractors exerts a long-lasting effect on emotional attentional capture leading to the inhibition of novel rare emotional images.

The analyses revealed pronounced main effects of both factors. As expected, participants were clearly slower to respond to the task when a distracting image had an emotional (pleasant, unpleasant) rather than a neutral content [Valence, F (1, 21) = 7.198, p = .014, η^2_p = .255]. Moreover, responses were faster in the Post-Test compared to the Pre-Test, indicating thqt participants became faster over time in responding to the task [Phase, F (1, 21) = 15.075, p = .001, η^2_p = .418]. More importantly, the Phase x Valence interaction, F(1, 21)=6.623, p=.018, η^2_p=.240, was significant. Following up on this interaction we found slower responses for both emotional and neutral distracting trials during the Pre-Test than in the Post-Test [emotional trial: F(1, 21)= 15.451, p=.001, η^2_p=.424; neutral trial F(1, 21)= 11.014, p=.003, η^2_p=.344]. Critically, when testing the Valence effect in each Phase a significant emotional interference (difference between emotional and neutral stimuli) was found only in the Pre-Test (M= 38.50), F(1, 21)=10.568, p=.004, η^2_p=.335, and disappeared in the Post-Test (M= 11.67), F(1, 21)= 1.533, p=.229, η^2_p=.068.

Accuracy. Overall accuracy was high (M=95.6%; see Table 2 in the Appendix C); however, we found a significant main effect of Valence, indicating that participants were less accurate in responding to the task when viewing an emotional rather than a neutral image, F(1, 21)=6.396, p=.020, η^2_p=.233. No significant effect of Phase was showed, F(1, 21)= .030, p=.863, η^2_p=.0013. A significant Block x Trial Type interaction was observed, F(1, 21)= 4.905, p=.038, η^2_p=.189, and following up on this interaction, an emotional interference effect was found during the Pre-Test, F(1, 21)= 10.315, p=.004, η^2_p=.329, but not during the Post-Test, (p>.05), thus ruling out a speed-accuracy trade-off as an explanation of RT performance.

Figure 5.2. Effect of practice with variable emotional distractors on reaction times in Experiment 2b. Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014).

Late Positive Potential

As expected, the LPP showed a clear affect modulation in the Pre-Test and, surprisingly, a reduction in the Post-Test, indicating that the extent to which rare emotional distractors are processed changes with extensive practice with variable task-irrelevant emotional stimuli.

The Late positive potential was modulated by Block, F(1,14)=14.150, p=.002, η^2_p=.503 and the Valence of the distractor, F(1,14)=11.249, p=.005, η^2_p=.446. Critically, the interaction Phase x Valence was significant, F(1,14)=12.667, p=.003, η^2_p=.475; specifically, in the Post-Test emotional contents elicited a more pronounced late positive potential compared to neutral contents, (M= 0.49 μV), F(1,14)=4.928, p=.043, η^2_p=.260, but this affective modulation (difference between emotional and neutral) was attenuated compared to the Pre-Test, (M= 1.57 μV), F=(1,14)=13.253, p=.003, η^2_p=.486.

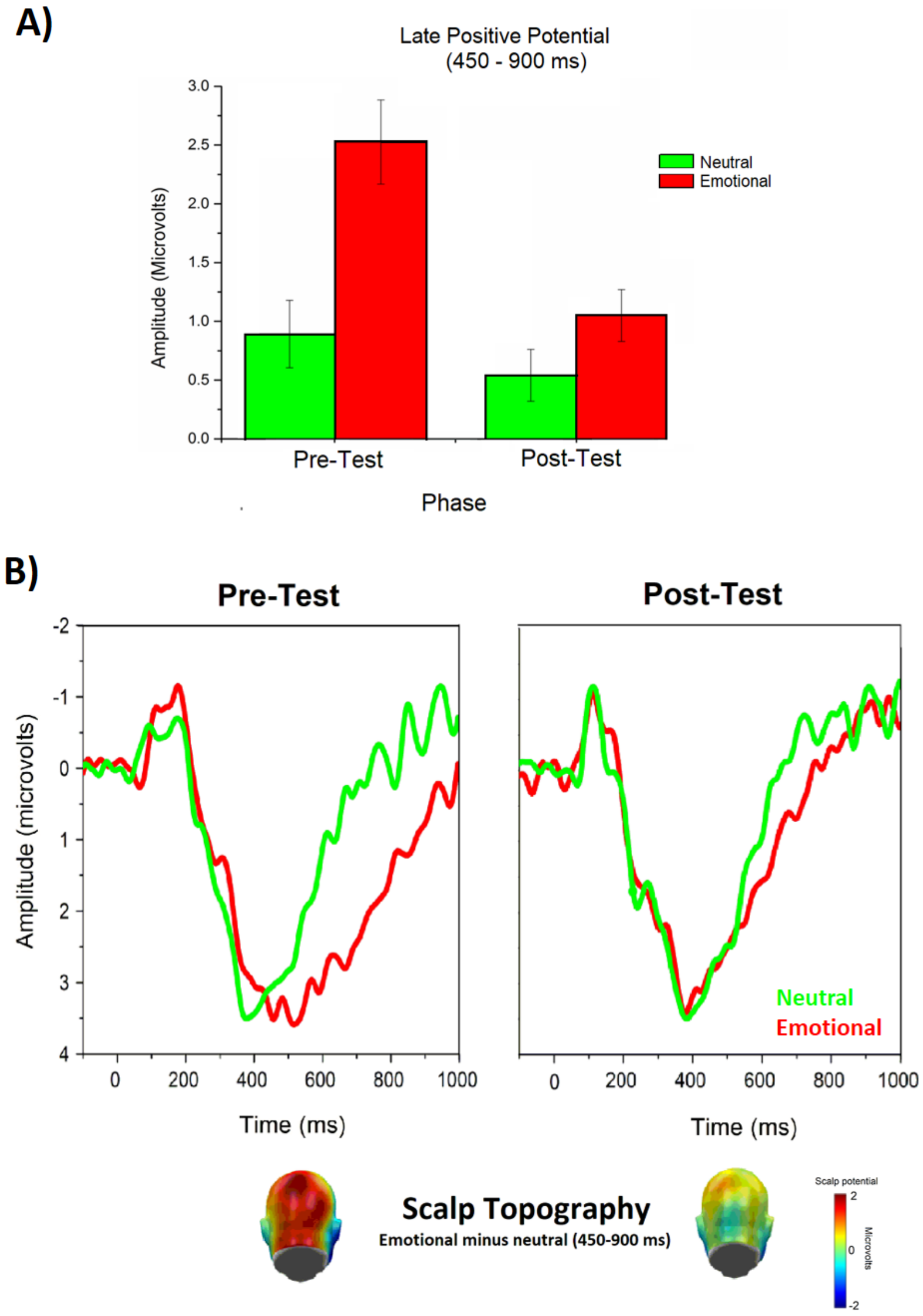


Figure 5.3. Effect of practice with variable emotional distractors on the (A) LPP amplitude in Experiment 2b. Error bars show ±1 SEM calculated within participants using the method of O'Brien and Cousineau (2014). (B): Grand-averaged ERP waveforms averaged over parieto-occipital sensors used for the analysis of the LPP for neutral and emotional pictures in the Pre-Test and in the Post-Test. Insets below each graph are the back views of the scalp topography (450–900 ms) of the difference between emotional and neutral picture processing.

Discussion

Consistent with Experiment 1, the occurrence of task-irrelevant emotional stimuli diverted attentional resources, slowing down the response times in the concurrent task, and activated the motivational systems, as indicated by the enhanced late positive potential. In addition, Experiment 2 suggests that the processing of task-irrelevant emotional stimuli changed as a function of the practice phase with variable distractors, despite these stimuli being rare, and, hence, even more significant. Accordingly, emotional interference was reduced after a practice session in which participants were required to ignore variable neutral distractors (Experiment 2a) and was eliminated after practice with variable emotional distractors (Experiment 2b). Moreover, the degree to which emotional stimuli were evaluated, and engaged the motivational systems, decreased after extensive exposure to task-irrelevant and inconsequential emotional stimuli (Experiment 2b), as shown by the attenuation of the affective modulation of the LPP. However, even after practice, emotional distractors persisted in engaging the motivational systems. Altogether, these findings suggest that emotional attentional capture is not an obligatory process, but one that is highly shaped by experience and learning mechanisms.

A recent study by Kelley and Yantis (2009) examined a similar issue, namely how practice affects the deployment of selective attention in order to filter distracting neutral stimuli. In their study, observers were asked to ignore all variable, peripheral, neutral images while performing a central discrimination task. Observers became faster at responding to the task with practice and, more importantly, new distracting images failed to capture attention when presented in novel (not trained) positions after the practice phase, indicating generalization of the inhibitory process. From their findings, the authors suggested that heterogeneous practice with numerous to-be-ignored features induces several inhibitory connections among numerous cortical areas, generating such a broad filtering system that novel distracting images are inhibited despite appearing in locations that are different from those in the practice block. The findings of Kelley and Yantis mirrored the current results, which examined improved inhibition not only for neutral but also for emotional distracting images. The idea that the attentional allocation system learns to suppress emotional distracting stimuli through practice is appealing; however, the current findings are open to numerous alternative explanations.

On one hand, it is quite evident that attentional capture by emotional stimuli, and its interference in the overt response (reaction times) is quite a flexible process, that can also be attenuated with general practice with any kind of distractor, not necessarily only with emotional contents; on the other hand, it remains unclear whether the lack of emotional RT modulation in the post-test that followed the emotional practice session (Experiment 2b) reflects active filtering of any kind of emotional stimulus, or some other habituation process. Extensive practice with emotional distractors only may provide a high familiarization with certain stimulus categories, making them easier to recognize, and thus faster to ignore. In this case, the mechanism responsible for the attenuation of emotional capture after practice is not due to direct experience with emotional stimuli as distractors, but a more general exposure to emotional pictures. Future investigations may disentangle this issue by comparing the effect of a practice phase in which emotional stimuli are task-irrelevant (as in Experiment 2b) with a practice phase in which the emotional content of the stimulus is task-relevant (e.g., to discriminate whether a picture is pleasant or unpleasant). If participants learn specifically to reject emotional stimuli in virtue of the fact that they are task-irrelevant (i.e., distractors), attending to them throughout a practice session in which they are task-relevant should interrupt any suppression in the Post-Test when, once again, they become distractors to be ignored.

Another possible explanation of the absence of emotional interference after emotional practice takes into account basic habituation mechanisms (Gati & Ben-Shakar, 1990): although emotional stimuli used in the practice phase are all novel, never repeated, pictures, they belong to only a few categories that share several features among picture exemplars, especially within each valence (i.e., mutilations and erotica). Thus, an orienting response to these pictures may habituate as a consequence of the redundancy of features across different distractors (blood, naked bodies, etc.). This account implies that the habituation of OR to distractors should apply only to emotional images that share the same features during practice, and not to the completely novel emotional category. Considering that highly arousing emotional stimuli, like those depicting mutilation and erotica, are equally effective in capturing attention, future studies may consider using only one category (e.g., erotic couples) during practice and a different category (e.g., mutilation) in the pre- and post-tests, ruling out the possibility that the decrease of attentional capture in the Post-Test may be due to habituation to simple features of the emotional category.

The findings of Experiment 2 give some indication that the emotional distraction changed as a function of practice and of the type of practice. In fact, exposure to neutral distractors only was not sufficient to prevent emotional interference, and a specific practice phase with variable emotional distractors seemed to aid the filtering. Although the two types of practice seemed to induce different effects on emotional interference when analyzed separately, a direct statistical comparison between the two studies showed a similar pattern (p = *n.s*). It should be noted that the low statistical power (because of the low sample size of the two experiments) could explain the lack of statistical significance; however, future studies are necessary in order to clarify whether, and to what extent, practice with emotional stimuli induces more effective filtering of emotional distractors. For example, the difference between the two types of practice, if any difference exists, should clearly emerge through a more extensive practice phase (similar to practice used in studies on perceptual learning) In fact, protracted exposure to distracting stimuli through several sessions per day should induce profound and enduring plastic changes in the mechanisms subserving attentional orienting, and different changes should be induced based on the type of distractor exposure.

Chapter 3

General discussion

The current thesis aims to examine the role of experience and learning in the allocation of attention to novel (never repeated) emotional distractors, as reflected in behavioral interference (response times) and cortical correlates of affective processing (ERPs; Late positive potential), both in terms of distractor frequency and practice. In this chapter, I will discuss the main findings by highlighting their importance regarding the initial aims of this research.

The primary aim of the current thesis was to examine to what extent experience with task-irrelevant stimuli modulates the interference of emotional distractors. Experiment 1 clearly shows that frequent exposure to task-irrelevant stimuli was effective in attenuating the interference caused by emotional distractors in the primary ongoing task. Interestingly, emotional distraction was attenuated also in contexts in which rare emotional distractors were interspersed among frequent neutral distractors, and therefore when these stimuli were even more distinct and unexpected. These findings answer our main question, suggesting that attentional capture by emotional stimuli is not impenetrable by top-down control, but the attentional allocation system adapts by ignoring irrelevant emotional stimuli throughout contextual experience. Importantly, susceptibility to being distracted by task-irrelevant emotional stimuli changes rapidly as a function of the context. In fact, emotional interference was reduced exclusively in contexts in which task-irrelevant stimuli appeared too frequently (i.e., in the majority of trials) and did not persist in subsequent contexts in which the occurrence of distracting stimuli was rare, suggesting that the subtended inhibitory control was rapidly disengaged as soon as the context changed.

In Experiment 2, it was found that distractor experience could induce a long-lasting effect on emotional attentional capture. Specifically, observers became less susceptible to being distracted by the appearance of task-irrelevant emotional stimuli after extensive exposure (practice) to heterogeneous neutral distractors, suggesting that observers learn to inhibit them for the successfully completion of the task. Interestingly, emotional interference almost vanishes through extensive exposure to variable emotional distractors, indicating that although emotional stimuli are significant they do not capture attention in a mandatory fashion.

It is important to emphasize that these findings have implications for our understanding of attentional allocation in the affective processing domain. Our results show that it is possible to ignore emotional stimuli that are entirely novel, that is, stimuli that have never been encountered before, a term that within an experiment implies that a stimulus is not repeated. We demonstrated that experience with variable task-irrelevant stimuli (namely: distractor frequency and extensive practice) is effective in attenuating the interference of novel emotional images, and these results are important considering that in real-life situations we are often exposed to distractors with a variable and unpredictable appearance.

Importantly, the observation that emotional interference decreased, and in some circumstances, disappeared, suggests that the emotional content of the image no longer impacted picture processing, and emotional distractors were effectively inhibited. However, the inhibition of task-irrelevant emotional stimuli may occur at a different stage of processing, and it has recently been demonstrated that the semantic processing of emotional stimuli can occur even when their behavioral interference in the main task disappears (Codispoti et al., 2016). In order to clarify which stage of emotional processing was affected by distractor frequency and by practice with distracting stimuli, we recorded ERPs to track picture processing before the behavioral response, and we analyzed the affective modulation of the LPP, which is considered to index the evaluative processing of the emotional cues and the engagement of cortico-limbic motivational systems. Interestingly, it was found that the affective modulation of the LPP was only slightly affected by distractor frequency (Experiment 1) as well as by practice with distractors (Experiment 2a). Even an extensive practice phase with a high number of emotional distractors did not drastically reduce the LPP affective modulation (Experiment 2b). Therefore, these findings, taken together, indicate that emotional distractors are evaluated, and engage motivational systems, even when their behavioral interference in the primary task is inhibited, and, consequently, when they do not cause distraction.

The dissociation reported in the current study between the affective modulation of the LPP and the emotional interference adds evidence to the emerging consensus that electrophysiological and behavioral measures of distraction, even if often observed together, do not correlate. In deviance distraction literature, for example, it has recently been found that behavioral distraction produced by the presentation of a rare, different sound disappeared when the sound became uninformative, meaning that it did not predict the occurrence of the subsequent target, but still elicited a P3a response. This dissociation was interpreted by the authors as the fact that rare salient sounds always undergo some involuntary evaluation processes, but translate into behavioral distraction only when informative (Parmentier 2014), suggesting that distractor interference is controlled by further, and presumably later, mechanisms. Considering that the behavioral interference caused by distractors is the standard measure used in cognitive psychology to investigate attentional capture, findings that the behavioral interference is attenuated in the absence of a similar attenuation of the emotional modulation of the LPP, possibly indicates that the distractor experience selectively modulates the attentional processes, after the emotional stimulus has been evaluated. Interestingly, a dissociation between the affective modulation of the LPP and emotional interference has been previously reported in response to stimulus repetition (Codispoti, 2016). The authors showed that, while the affective modulation of the LPP persisted even after massive repetition of emotional images, the behavioral interference disappeared rapidly. From their findings, they proposed that while evaluative processes are mandatory, and continue to engage the motivational system, attentional processes are not necessary after several repetitions of the same stimulus, suggesting that these two processes may occur independently in order to prevent limited attentional resources from being allocated to clearly irrelevant emotional stimuli.

It should be noted that, in the current studies, observers were exposed to emotional distracting images that were never repeated, and although emotional interference was strongly attenuated in all the experiments, it disappeared only when exposure to emotional distractors was prolonged over time. Moreover, in both studies, experience affected the emotional interference selectively rather than prompting a general interference of task-irrelevant stimuli; in fact, frequent exposure to task-irrelevant stimuli attenuated only the interference of pictures with an emotional content and no effect was found on neutral distracting images. Moreover, after the practice session the interference of emotional stimuli was attenuated to a greater extent compared to that of neutral stimuli. One interpretation of these findings is that novel emotional stimuli are evaluated and capture attentional resources every time that they appear, therefore, in a fairly mandatory fashion. However, attentional dwell-time on emotional distracting images reduced when observers acquire experience with distracting images, suggesting that in these situations the categorization of emotional stimuli as irrelevant and innocuous occurs faster. The evaluative system may orient the organism toward the stimulus (what is it?), and when the stimulus is categorized as novel (not previously encountered), it triggers an attentional allocation to it in order to enhance its processing and prepare the organism for action. Through experience, observers learn which stimuli are relevant and which are irrelevant, and attentional resources are rapidly disengaged from the emotional content of the image in order to be re-oriented to the concurrent primary task. Considering that pictures depicting both pleasant and unpleasant content engage more attentional resources compared to neutral stimuli, the hypothesis that experience affects the attentional dwell-time, or rapidity of disengagement, could better explain the reason why we found a selective attenuation of emotional interference.

In accord with our hypothesis, a recent study failed to find an effect of distractor frequency on the emotion-induced blindness (EIB) effect (Zhao & Most, 2018). To notice, the EIB effect is investigated by using RSVP paradigms in which the emotional content of a picture is not spatially decoupled from the task, and hence no orientation of attention is needed. In that sense, it is possible that distractor experience specifically affects processes relating to subcomponents of spatial capture of attention, such as the attentional shift towards the emotional distracting image, or the subsequent attentional engagement with the image or the disengagement from the image.

By far, in literature on perceptual distraction, it has been suggested that frequent or extensive exposure to distracting stimuli trigger a proactive control, which anticipates the occurrence of a distractor and suppress related attentional processing of the stimulus. Although the attenuation of emotional interference that we found in response to distractor experience could be similarly attributed to a proactive control of emotional distraction, is it really necessary to refer to such mechanism or can we explain our results as a reactive control? With the disengagement hypothesis, we suggest that attention to emotional distractors is reactively inhibited (i.e., terminated) so that the task-oriented behavior may resume.

Future studies are required to disentangle whether the decline of behavioral interference reflects a reduced allocation of attentional resources or a faster disengagement of attention. In this regard, it could be useful to test the effect of distractor exposure (both in terms of frequency and of practice) on specific spatial attention tasks such as the dot probe paradigms in which it is possible to disambiguate which attentional processes between attentional engagement and attentional disengagement is affected. Moreover, it should be interesting to explore the role of these types of distractor experience on clinical populations, as in people with anxiety disorder, who are known to have difficulty in disengaging attention from emotional stimuli, especially the threat-related pictures.

Appendix A

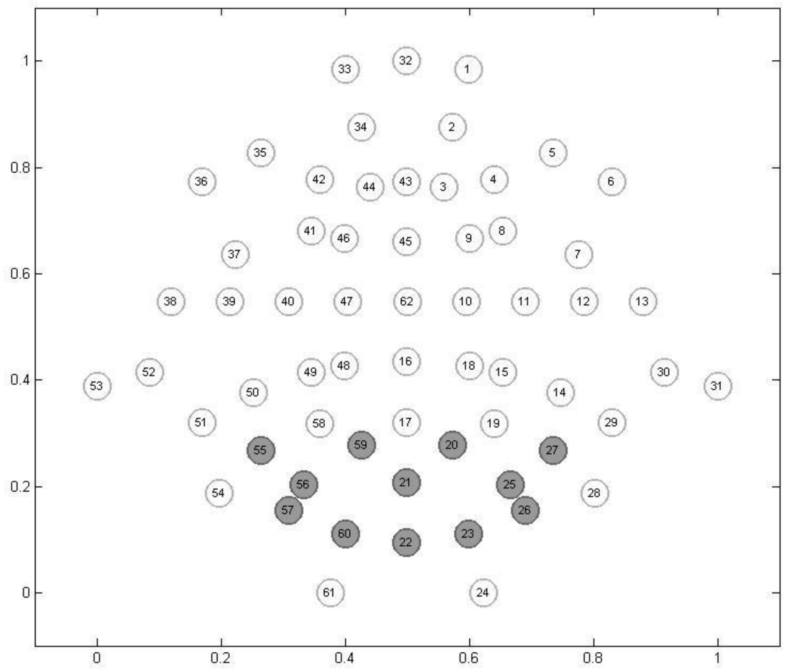
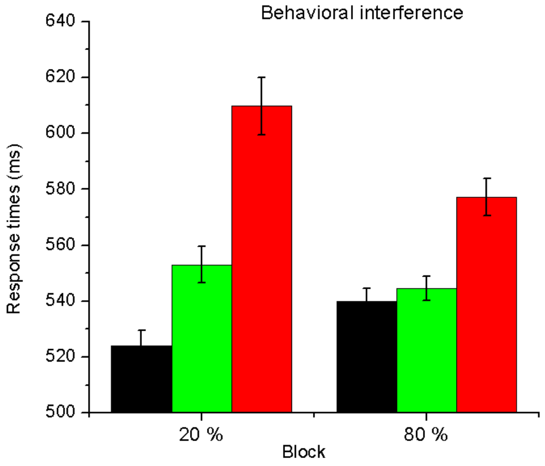
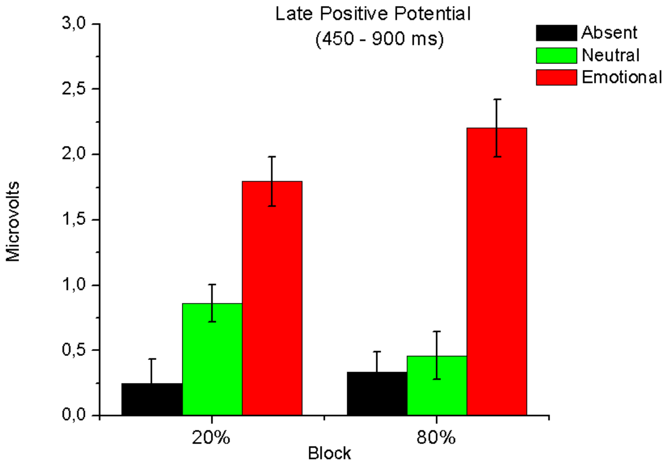


Table 1. Mean percentage of accurate response (SE in parentheses) for each trial type, block, and experiment

		Block 20%	Block 80%
Experiment 1a	Absent	97.7 (0.3)	97.8 (0.4)
	Neutral	98.3 (0.7)	97.7 (0.4)
	Emotional	94.2 (1.1)	96.6 (0.5)
Experiment 1b	Absent	97.2 (0.4)	97.7 (0.5)
	Neutral	96.5 (0.6)	97.3 (0.3)
	Emotional	95.3 (1.0)	96.5 (0.6)

Appendix B





As shown by the figure on the left, analyses of RTs yielded a significant effect of Trial Type, F (2, 38) =44.856, $p < .001$, η^2_p = .702. No significant effect of Block was observed, F (1,19) = 1.428, p = .247, η^2_p = .070. Finally, a significant interaction Block x Trial Type was found, F (2, 38) =12.039, $p < .001$, η^2_p = .388. Following up on this interaction, the Block effect was tested for each Trial Type: emotional stimuli slowed down response times more when they appeared in the 20% block than in the 80% block, F (1, 19) =7.737, p = .012, η^2_p = .289, while no difference was found for neutral distractors between the two blocks, F (1, 19) =1.142, p = .299, η^2_p = .057. Conversely, participants were faster to respond to the task in the 20% block than in the 80% block during trials in which distractors were absent, F (1, 19) = 5.693, p = .028, η^2_p = .231. More importantly, the emotional interference effect was affected by the frequency of distractor occurrence, as confirmed by a significant Block X Valence interaction, F (1, 19) =4.464, p = .048, η^2_p = .190. Following up on this interaction, we found that a Valence effect was still present in the 80% block (M= 32.60 ms), F(1, 19) =23.886, $p < .001$, η^2_p = .557, but it was severely attenuated compared to the 20% block (M= 56.67 ms), F(1, 19) = 21.993, $p < .001$, η^2_p = .537.

As shown by the figure on the right, the late positive potential was modulated by Trial Type, F (2, 38) = 36.716, $p < .001$, η^2_p = .659. No significant main effect of Block was observed, F (1, 19) = .062, p = .805, η^2_p = .003. A significant Block X Trial Type interaction, F (2, 38) = 3.290, p =.048, η^2_p = .148 was followed by simple main effect tests. LPP amplitude was more positive when viewing a rare emotional image in the 80% block than in the 20% block, F (1, 19) = 4.283, p =.052, η^2_p = .184, while there was no variation between the two blocks when viewing neutral images, F (1,19) = 2.208, p =.154, η^2_p = .104. In the same way, there was no difference in distractor-absent trials between the two blocks, F (1,19) =.212, p =.650, η^2_p = .011. Overall, the emotional modulation of the LPP differed between the two blocks, F (1, 19) = 5.201, p = .034, η^2_p = .215, and further investigation as to the effect of Valence in each block confirmed that emotional stimuli prompted a larger LPP compared to neutral stimuli in both the 20% block (M= 0.93 µV), F(1, 19) = 19.940, $p < .001$, η^2_p = .512 and the 80% block (M= 1.74 µV), F(1, 19) = 28.615, $p < .001$, η^2_p = .601 showing, critically, that the emotional modulation tended to increase, rather than reduce, in the 80% block.

Appendix C

Table 2. Mean percentage of accurate response (SE in parentheses) for each trial type, phase, and experiment

		Pre-Test	Post-Test
Experiment 2a	Neutral	96.8 (0.9)	96.2 (0.7)
	Emotional	96.8 (0.8)	96.2 (0.8)
Experiment 2b	Neutral	97.2 (0.6)	95.2 (0.8)
	Emotional	94.8 (0.8)	95.8 (0.8)

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