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Interference of Emotional Information in Briefly Presented Scene Arrays

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Research has shown that the presentation of emotional information interferes with the processing of neutral information. The present study examined whether one can suppress this interference when being asked to ignore an emotional scene before attention is engaged with a target or if emotional information always engages attention, resulting in attentional capture. We examined participants' ability to actively inhibit emotional scenes of different valence and arousal when identifying neutral scenes. In three experiments, a 4-scene array was presented for 250 ms while one emotional scene was present in the display. The scene was either to be ignored or freely available in the array. The results show that the interference from emotional scenes is a pervasive phenomenon, suggesting an involuntary attentional capture by emotional scenes. Moreover, despite the vast literature on the evolutionary advantage of preferential processing of negative information, we show a potent attentional bias toward positive information.

Key words: attentional bias, directed inhibition, emotional interference, Sperling paradigm, visual attention

Introduction

There is a preponderance of evidence supporting the notion that emotional information is selected automatically without the need for attention (Anderson, Christoff, Panitz, Rosa, & Gabrieli, 2003; Bradley, Keil, & Lang, 2012; Oca, Villa, Cervantes, & Welbourne, 2012; Pessoa, Padmala, & Morland, 2005; Schupp, Junghöfer, Weike, & Hamm, 2003) and that attention is preferentially allocated to emotional events even when those stimuli are not consciously perceived (Anticevic, Barch, & Repovs, 2010; Calvo, Nummenmaa, & Hyönä, 2008; Dolcos & McCarthy, 2006; Kalanthroff, Cohen, & Henik, 2013; Padmala, Bauer, & Pessoa, 2011). For example, an emotional event is more likely to permeate consciousness as documented through paradigms such as inattentional blindness (Mack & Rock, 1998; New & German, 2014; Wiemer, Gerdes, & Pauli, 2013), attentional blink (Choisdealbha, Piech, Fuller, & Zald, 2017; Most, Chun, Widders, & Zald, 2005; Oca et al., 2012), or continuous flash suppression (Yang, Zald, & Blake, 2007), demonstrating a privileged status of emotional information in visual attention.

The facilitation and preferential processing of emotional information at the expense of neutral information is well documented through interference of emotional information when processing other neutral information (Keil & Ihssen, 2004; New & German, 2015; Yiend et al., 2008; Yiend, 2010). In other words, attention is effectively captured by a distracting, task-irrel-

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evant emotional event, and causes attentional disengagement from the originally attended task (Gupta, Hur, & Lavie, 2016; Nummenmaa, Hyönä, & Calvo, 2006). An emotional event presented prior to, simultaneously with, or even after a neutral event disrupts processing of other neutral events, which has been attributed to an instinctive and involuntary attentional shift toward those emotional events (Becker, 2012; Choisdealbha et al., 2017; Fernández-Martín & Calvo, 2016; Krug & Carter, 2012; Öhman, Flykt, & Esteves, 2001; Oca et al., 2012; Sakaki, Gorlick, & Mather, 2011). Likewise, eye movement studies illustrate that initial fixations are more likely to land on emotional information (Adolphs, Tranel, & Buchanan, 2015; Calvo & Lang, 2005), and that semantic details of emotional information can be picked up even in peripheral vision (Bocanegra & Zeelenberg, 2009; Calvo et al., 2008).

However, not all emotional information presents interference of equal magnitude. Exposure to a transient negative stimulus (regardless of its arousal level) generally impairs performance to a greater extent in attentional and working memory tasks compared to a positively valenced event (Bolte, Goshke, & Kuhl, 2003; Calvo et al., 2008; Kuhbandner, Spitzer, & Pekrun, 2011; Sakaki et al., 2011), even though positive information is rated as equally arousing as negative events (Garcí-a-Pacios, Río, Villalobos, Ruiz-Vargas, & Maestú, 2015). Choisdealbha and colleagues (2017) utilized the attentional blink paradigm and presented neutral landscape images both prior to and after the emotional distractor, where erotic and gory stimuli elicited the greatest blink effect. Supplementing this, when compared with low- and high-arousal positive images, high-arousal negative stimuli tend to narrow one's useful field of view, resulting in poorer performance on the main letter identification task (Masuda, 2015; Nobata, Hakoda, & Ninose, 2010; Sekuler, Bennett, & Mamelak, 2000). Negative high arousal objects also decay slower from iconic memory in comparison to all others emotional stimuli (Kuhbandner et al., 2011).

The emotional interference effect is so powerful that it persists even when explicitly tasked with maintaining visual fixation on a neutral stimulus while emotional stimuli appear in peripheral vision (Calvo et al., 2008), or when given monetary reward for resisting the processing of those stimuli (Most, Smith, Cooter, Levy, & Zald, 2007; Piech, Pastorino, & Zald, 2010). Here, we add to the body of existing literature by examining the interference of emotional information in briefly presented scenes using a novel, pre-cue paradigm. Adopted from the directed forgetting paradigm (Bjork, LaBerge, & LeGrand, 1968), where the participant is typically given items or word lists to either actively remember or forget, we devised a directed ignoring paradigm in which participants were asked to actively ignore one scene from a four scene array. This to-be-ignored scene could be either emotional or neutral, and participants were told to ignore the scene as it will never be reported on it. We hypothesized that emotional stimuli would lead to attentional capture despite the conscious attempt to inhibit the interference of this information. Based on previous studies, we believed that negative high arousal stimuli would be particularly potent in disrupting processing of other information. (Calvo et al., 2008; Choisdealbha et al., 2017; Kuhbandner et al., 2011; Sakaki et al., 2011; Sekuler et al., 2000). In a series of experiments, we examined whether a concurrent presentation of an emotional distractor in an array of otherwise neutral scenes would disrupt a memory representation for those scenes. If the prioritization of emotional visual scenes is automatic one will not be able to suppress this emotional scene even when volitionally attempting to avoid its processing. Second, we were interested in the possible discrepancy in interference that may result from negative and positive scenes. Lastly, we were inter-

ested in elucidating the fate of non-emotional visual scenes that are neighboring an emotional visual scene of various valence and arousal.

General Materials and Methods

Participants

32, 35, and 31 college students participated in the experiments 1, 2, and 3, respectively, for course credit. All participants reported that they had normal or corrected-to-normal vision. No participant took part in more than one experiment to avoid any potential practice effects.

Stimuli and Conditions

Stimuli for the experiment were neutral and emotional scenes were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999), which has been shown to be internally consistent with cross-cultural validity. Each scene was selected based on its rating of arousal (the level of "arousability" or physiological reactivity ranging from low arousal to high arousal) and its valence (an index of its pleasantness or its hedonistic value varying from negative through neutral to positive) as indicated in the IAPS Manual. We decided to select stimuli for the experiment from IAPS as it provides ratings for valence and arousal on a scale from 1-9. The stimuli in all of the experiments were the same as we needed to control for variables such as the presence or absence of agents in the scene, scene complexity, or chromatic parameters of each scene.

All four experiments had the following within-subject conditions:

In all experiments, *the emotional condition* consisted of only one emotional scene in an array of otherwise neutral scenes, while *the neutral condition* comprised an array of solely neutral scenes. The to-be-cued and the to-be-reported on scenes were matched for presence of agents. There were 20 training trials, and a total of 24 experimental trials (12 in the emotional condition and 12 in the neutral condition). The 12 experimental trials had 3 scenes from the following emotional conditions: negative high arousal, negative low arousal, positive high arousal, and positive low arousal. The number of trials was low because we were committed to selecting scenes with specific arousal and valence parameters so they could be clearly classified as neutral or emotional. We compensated for this through a larger sample size for the within-subject design we used.

At the end of each trial, participants were prompted to write their response identifying the gist of the post-cued scene. More specifically, they were asked to describe the scene in much detail. To measure gist identification, the participant's response was given one of three scores: A score of 0 means they incorrectly identified the scene, a score of 1 implies they did not fully identify the gist of the scene (i.e., if the scene was a snake and they reported "animal" or if the scene was a child crying and they reported "person"), while a score of 2 was given if they properly identified the scene. Ultimately, their cumulative score is what is reported in the subsequent figures and results as the gist identification score. Participants completed one version of the experiment (see the conditions below). The individual emotional scene conditions were as follows [2 (arousal) x 2 (valence)], with the stimuli within each condition being randomized to account for order effects:

Positive valence and high arousal (PHA). The arousal ratings of images presented in this condition ranged from 5.41 to 7.35, while valence ratings varied between 6.82 and 8.34. Examples of images included in this conditions were naked bodies, adventurous sports (a person skiing or skydiving), and images depicting victory (a person winning a competition).

Positive valence and low arousal (PLA). The arousal ratings of images presented in this condition ranged from 2.51 to 3.94, while valence ratings varied between 6.54 and 8.05. Examples in this condition could be affection-evoking images (a smiling girl) or positive nature images (a meadow full of flowers).

Negative valence and high arousal (NHA). The arousal ratings of images presented in this condition ranged from 5.17 to 6.99, while valence ratings varied between 1.67 and 3.95. Some examples are scenes containing injured bodies (a man with blood on his face), scenes containing threatening animals (a biting dog, a snake, a spider) or accident scenes (airplane crash, fire scenes).

Negative valence and low arousal (NLA). The arousal ratings of images presented in this condition ranged from 3.52 to 4.96, while valence ratings varied between 1.95 and 3.92. Scenes selected for this category were for instance images of sad persons (a child hiding in a corner) or funeral or cemetery scene.

Experiment 1

Rationale

Because of the well-documented pervasive nature of emotional interference, we aimed to examine whether one can suppress the interference from emotional scenes when asked to disregard the scene as it would not be reported on. In order to accomplish this, we devised a precueing paradigm (similar to the directed forgetting paradigm), in which we instructed the participants to ignore one of the scenes by presenting a pre-cue at the location of that to-be-ignored scene.

Procedure

At the beginning of the experiment, each participant read and signed an informed consent form. A research assistant explained the nature of the task, that is, to identify the scene gist as accurately and in as much detail as possible of the cued scene, while ignoring a scene that was pre-cued at the beginning of each trial. Subsequently, the participant started a training session comprising 20 trials. None of the scenes presented during the training session were presented in the actual experimental session. The training session was procedurally identical to the experimental part and its objective was to familiarize participants with the experiment and their task.

Partial Report Paradigm

Each trial started with the presentation of a fixation cross at the center of the screen for 1500 ms, followed by a 4-scene array template. This template was presented for 2000ms and included a pre-cue (crossed out location of one of the scenes in the array) that determined which scene is to be ignored. There was an ISI of 2000ms before the presentation of the actual 4-scene array, which was presented for 250ms. Immediately upon the disappearance of the scene array, a post-cue (a red line placed beneath the location of one of the lower two scenes or above the location of one of the upper two scenes) indicating which scene to report was presented (100 ms). The cue was followed by a text box in which participants were required to report the gist of the cued scene. For schematic illustration, see Figure 1.

Each individual scene subtended 6 x 5 degrees of visual angle at a viewing distance of 56 cm. The scene array consisted of 4 scenes centered around the fixation cross. The center of each scene was ~ 5.3 visual degrees away from fixation, while the nearest corner of the scene was ~1.4 degrees from fixation.

Depending on the experimental condition, the 4-scene arrays either contained or did not contain an emotionally charged scene, which al-

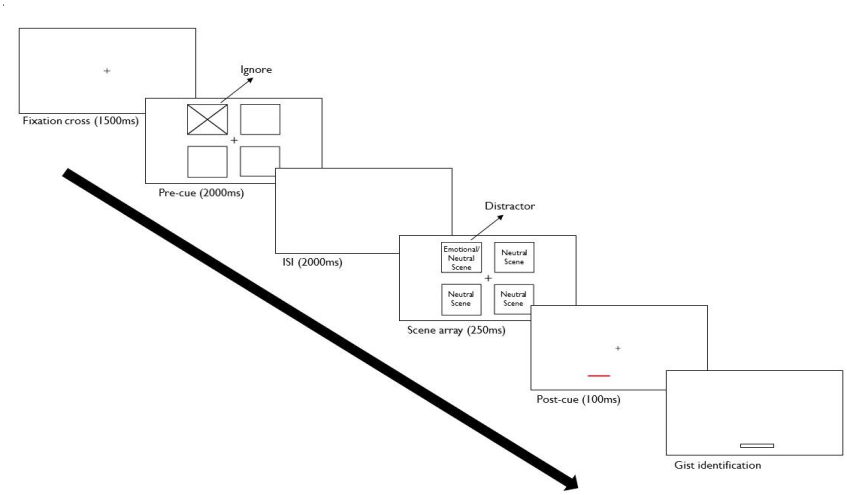

Figure 1 Schematic illustration of the experimental design in Experiment 1.

Figure 2 Gist identification of neutral scenes in emotional or neutral interference conditions in Experiment 1.

ways presented the interference. The experiment included 24 trials (12 in the emotional and 12 in the neutral condition) presented in a fully random order.

Experiment 1: Results

We computed a dependent *t*-test in order to examine the differences in reporting the gist of neutral scenes in the emotional versus neutral interference condition. We found that participants identified fewer neutral scene gists in the emotional interference ($M = 4.36$, $SD = 1.98$) condition in comparison with the neutral interference condition ($M = 5.89$, $SD = 2.11$), $t(31) = 5.10$, $p < .001$ ($p = .0001$), 95% confidence interval [CI]:-2.144 to -0.919. The results (displayed in Figure 2) indicate that despite

the instruction to suppress the emotional distractor, participants' performance was heavily affected by it.

Discussion

In Experiment 1, the pre-cue presented for 2000ms before the onset of a 4-scene matrix designated which scene was to be ignored as it would never be reported on. The to-be-inhibited scene was either emotional or neutral and participants were supposed to report on another neutral scene in the array. As hypothesized, it was found that fewer scenes were identified in the emotional distractor condition than the neutral distractor condition, suggesting interference from emotional scenes. This is most likely due to both conscious and unconscious attentional capture by emotional scenes (Anderson et al., 2003; Anticevic et al., 2010; Bradley et al., 2012; Calvo et al., 2008; Dolcos & McCarthy, 2006; Kalanthroff et al., 2013; Oca et al., 2012; Padmala et al., 2011) and the inability to filter and control emotional stimulus despite being told to ignore it (Bjork et al., 1968; McKenna & Sharma, 1995; Most et al., 2005; Vuilleumier, Armony, Driver, & Dolan, 2001; Williams, Moss, Bradshaw, & Mattingley, 2005). Positive high-arousal stimuli resulted in the greatest "emotion-induced blindness", which has been observed even when monetary incentives for inhibiting such stimuli are involved (Most et al., 2005; Most et al., 2007). Interestingly, negative high-arousal scenes did not interfere much differently from the neutral scenes. The results of the individual valence-arousal combination scenes are displayed in Figure 5 and Table 1. This data suggests that these negative high arousal stimuli may be more easily processed causing a smaller interference effect (Anderson, 2005; Calvo & Marrero, 2009; Gupta et al., 2016; Mathewson, Arnell, & Mansfield, 2008; Most et al., 2007; Schimmack, 2005).

Experiment 2

Rationale

We aimed to compare the directed inhibition of emotional scenes in Experiment 1 with a pre-cueing paradigm, where the emotional scene is never pre-cued (to be ignored), but instead another neutral scene is pre-cued (to be ignored) while the emotional scene is in the scene array. This was a control condition in order to compare the full "potency" of emotional scenes and see the potential automatic attentional capture from emotional scenes when participants are not asked to ignore them.

Procedure

The procedure was identical to Experiment 1, with the only difference being that the participants were never instructed to ignore the emotional scene. In the emotional condition, participants were instead instructed to ignore another neutral scene in the array.

Experiment 2: Results

We computed a dependent t-test in order to examine the differences in reporting the gist of neutral scenes in the emotional versus neutral interference condition. We found that participants identified fewer neutral scene gists in the emotional interference ($M = 4.47$, $SD = 1.66$) in comparison with the neutral interference condition ($M = 5.70$, $SD = 1.55$), $t(34) = 4.21$, $p < .001$ ($p = .0002$), 95% confidence interval [CI]: -1.821 to -0.636. The results are displayed in Figure 3.

Additionally, we compared individual interference conditions for results in both Experiment 1 and Experiment 2. This was done to examine participants' ability to inhibit interference from emotional scenes (Experiment 1) in comparison to emotional scene being freely avail-

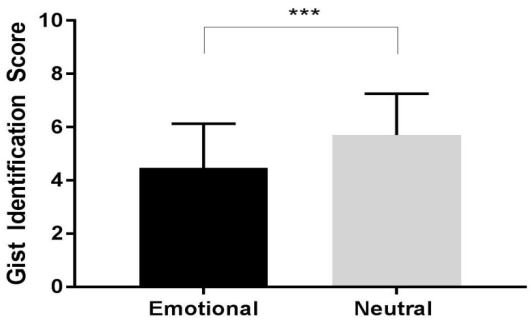

Figure 3 Gist identification of neutral scenes in the emotional or neutral interference conditions in Experiment 2.

able in the scene array (Experiment 2). An unpaired *t*-test showed that participants did not perform differently in those two conditions, $p = 0.80$. Therefore, one can conclude that emotional scenes cause an emotional capture and cannot be easily inhibited as documented by no differences in the identification of neutral scenes in the emotional interference condition between Experiment 1 and Experiment 2.

Discussion

In Experiment 2, which presented a control condition, the pre-cue was used to indicate the ignoring of a scene that would always be neutral, while either one scene in the vicinity was emotional and the other two neutral or all other scenes were neutral. Once again, fewer scene gists were identified in the emotional interference condition than in the neutral interference condition. Similarly, as documented in the previous experiment, the particularly positive scenes (of both arousal levels) interfered to a greater extent than neutral images, however this was not true for negative high arousal scenes (Table 1 and Figure 5). Furthermore, the findings indicate that, similar to Experiment 1 and previous literature, emotional scenes lead to attentional capture and disrupt subsequent processing of neutral information. This was particularly true for positive high arousal scenes (Keil & Ihssen, 2004; Fernández-Martín & Calvo, 2016; New & German, 2015; Oca et al., 2012; Yiend, 2010). Additionally, both Experiments 1 and 2 exemplified the automatic capture by emotional information and the inability to volitionally suppress their interference (Bjork et al., 1968; Kalanthroff et al., 2013; McKenna & Sharma, 1995; Most et al., 2005; Vuilleumier et al., 2001; Williams et al., 2005).

Experiment 3

Rationale

In Experiment 3, we employed the traditional partial report paradigm (Clarke & Mack, 2014; Sperling, 1960[1]) as a supplemental control experiment (in addition to Experiment 2). We aimed

[1] Developed by George Sperling, the partial report paradigm measures iconic memory capacity by having participants recall a random subset of items from a visual display using cued recall. Here, we used it to understand an individual's ability to maintain simultaneously several scenes while reporting on only one of the scenes from the scene array. This was performed in order to understand the interference of one of the scenes with processing of the scene that was cued. The partial report paradigm using scene arrays was designed by Clarke and Mack in 2014.

to examine the potential interference from emotional stimuli while not including any pre-cue indicating inhibition or ignoring of any scene.

Procedure

The procedure was identical to Experiments 1 and 2, with the only exception being the absence of a pre-cue indicating any particular scene to be ignored. In both emotional and neutral conditions, participants were asked to report on a gist of a neutral scene while there could be an emotional scene distractor in the scene array (emotional interference condition) or no emotional scene distractor (neutral interference condition). The performance was more difficult as now participants had to encode and maintain all 4 scenes from the array as no scene was to be ignored as in the Experiments 1 and 2, where only 3 scenes had to be encoded and maintained. The reasoning for this experiment was to ensure that the participants were actively using the pre-cue in both experiments 1 and 2 (but particularly Experiment 1, as it examined the ability to actively inhibit the emotional stimulus). We used the same design (2 x 2 scene matrix) without the presentation of a pre-cue that indicated which scene should be ignored. If participants were properly inhibiting a scene using the pre-cue, we should see that the performance in Experiment 1 should be superior to the performance in Experiment 3. The response set was different because participants had to select one of 4 scenes (instead of 3 in Experiment 1). Therefore, we transformed the mean gist identification scores in both Experiments 1 and 3 so they would be comparable (this transformation is described in the Results section).

Experiment 3: Results

Paired *t*-test revealed that in reporting gist of neutral scenes, participants identified fewer neutral scene gists in the emotional interference ($M = 3.13$, $SD = 1.74$) in comparison with the neutral interference condition ($M = 4.82$, $SD = 1.77$), $t(30) = 6.03$, $p < .001$ ($p = .0001$), 95% Confidence Interval [CI]: -2.267 to -1.120. The results are displayed in Figure 4.

In terms of individual emotional scenes categories, once again PHA, PLA, and NLA scenes interfered significantly more than neutral im-

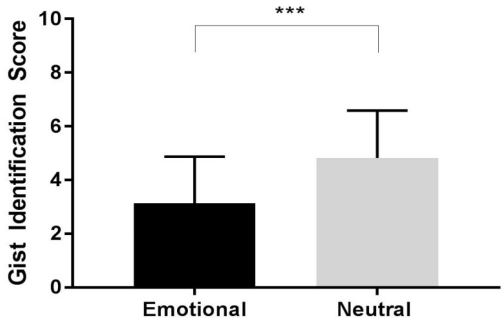

Figure 4 Gist identification of neutral scenes in emotional or neutral interference conditions in Experiment 3.

ages, and performance on neutral scene gist identification was not significantly different in the NHA emotional interference condition than the neutral scene interference condition.

Examining the Effectiveness of the Pre-Cue

As mentioned previously, we tested whether the pre-cue was truly effectively used by participants and we did this by comparing the results of Experiment 1 (where pre-cue was used) with the results of Experiment 3, where no pre-cue was used to ignore a scene.

In Experiment 1, the response set was ultimately 3 scenes, since participants only had to maintain 3 scenes in their iconic memory before reporting on one of them. However, in Experiment 3, the response set was 4 scenes. To compare those results, we needed to transform those scores by finding a common denominator. We did so by computing the score as if reporting for one singular scene. Therefore, performance in Experiment 1 was divided by 3 and performance in Experiment 3 was divided by 4, in order to achieve this level of comparability.

We subsequently computed independent *t*-tests for both the emotional interference and all neutral conditions in Experiments 1 and 3. As such, participants reported on more scenes in the emotional pre-cue condition (Experiment 1) ($M = 1.45$, $SD = .66$) than in the emotional no pre-cue condition (Experiment 3) ($M = .81$, $SD = .44$), $t(61) = 4.51$, $p < .0001$ ($p = .000014$). Additionally, in the neutral condition, participants once again identified more scenes in the pre-cue condition (Experiment 1) ($M = 1.96$, $SD = .70$) compared to the no pre-cue condition (Experiment 3) ($M = 1.21$, $SD = .44$), $t(61) = 5.08$, $p < .0001$ ($p = .00001$). This demonstrates that participants were, indeed, using the pre-cue effectively in Experiment 1 as their normalized performance was better than their performance in Experiment 3 with no-cue.

Discussion

In Experiment 3, a typical partial-report paradigm was used. In the emotional condition, an emotional scene was in the vicinity of the to-be-reported neutral scene, which was compared to all neutral scenes in the array. Fewer neutral scene gists were identified when there was interference from an emotional scene than a neutral scene. Again, as displayed in Table 1 and Figure 5 positive images interfered most, while negative high-arousal once again resulted in the smallest interference with a magnitude that of neutral scenes. Even with more images to be maintained in the visual sensory memory, emotional images interfered with the neutral scene processing (Clarke & Mack, 2014; Dick, 1974; Kuhbandner et al., 2011).

Additional Analyses: The Interference of Individual Emotional Categories

As an additional goal of the study was to examine the interference from individual emotional categories (PHA, PLA, NHA, NLA), we compared performance on target neutral scene gist identification for those emotional categories compared to neutral scene distractors. Since there were 12 emotional scenes in total (3 for each emotional category), we had to divide the performance for all neutral scene gist performance by 4 to be able to achieve such a comparison.

We consistently found that NHA scenes interfered to the same extent as neutral scenes, as indicated in Figure 5 and Table 1 (p values for NHA and neutral scenes, $p > .05$). However, all other emotional scene categories interfered significantly more than neutral scenes. Namely, PHA inferred to the greatest extent in all experiments ($p < .001$), followed by PLA ($p < .001$), and then NLA scenes ($p < .01$, $p < .01$, and $p < .001$ for Experiments 1, 2, and 3, respectively).

Table 1 *Comparison of gist identification scores between neutral distractor and individual emotional categories distractors in individual experiments*

Experiment/ Emotional Category	Experiment 1 (Ignore Emotional)	Experiment 2 (Ignore neutral only)	Experiment 3 (No inhibition)
NHA	1.719(ns)	1.629(ns)	1.081(ns)
PHA	0.641(***)	0.800(***)	0.758(***)
NLA	0.969(**)	1.000(**)	0.677(***)
PLA	0.938(***)	1.043(***)	0.613(***)
NEUTRAL	1.473	1.425	1.206

Note. The table shows means for the number of neutral scene identifications due to interference from individual emotional scenes (NHA = negative high arousal, PHA = positive high arousal, NLA = negative low arousal, PLA = positive low arousal) or neutral scenes which were the control condition. The performance on all neutral scene conditions was divided by 4, as there were 4 different emotional categories which made up 12 scenes, and 12 neutral scenes in total. In order to be able to compare the individual emotional categories of the presented scenes, we divided the performance on neutral scene condition by 4.
*p < .05. **p < .01, ***p < .001.

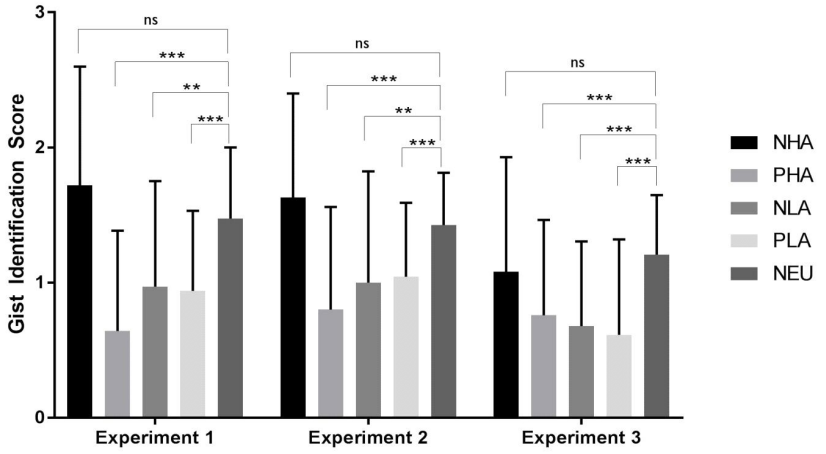

Figure 5 Gist identification of neutral scenes based on individual emotional categories or neutral interference conditions throughout all the experiments.

General Discussion

The current study examined one's ability to inhibit and filter emotional scenes in briefly presented scene arrays. We were also interested in one' ability to identify non-emotional visual scenes that were adjacent to an emotional scene in the array. Previous studies have shown that emotionally arousing scenes modulate visual attention, causing attentional capture and subsequent slower attentional disengagement (Anticevic et al., 2010; Bradley et al., 2012; Brockmole & Boot, 2009; Buodo, Sarlo, & Palomba, 2002; Dennis et al., 2008; Fernández-Martín & Calvo, 2016; Garcí-a-Pacios et al., 2015; Gupta et al., 2016; Jefferies, Smilek, Eich, & Enns, 2008; Lang, Bradley, & Cuthbert, 1997; Mathewson et al., 2008; Oca et al., 2012; Pessoa et al., 2005; Vuilleumier et al., 2001; Yiend et al., 2008; and see Yiend, 2010 for a review). We hypothesized that if an emotional visual scene receives preferential processing, one will not be able to suppress the processing of those emotional scenes even when tasked with directly inhibiting them.

In Experiment 1, the pre-cue was presented before the onset of the stimulus array, which designated which scene was to be ignored as it would never be reported on. Subsequently, participants were directed to report on a neutral scene in the array, while the to-be-inhibited scene was either emotional or neutral. Experiment 2 presented a control condition, where the pre-cue was used to indicate inhibition of a neutral scene, while all other scenes were either neutral (completely neutral condition) or one emotional (emotional interference condition). Finally, in Experiment 3, the typical partial-report paradigm was used; in the emotional condition, an emotional scene was in the vicinity of the to-be-reported neutral scene, which was compared to a neutral condition, where all neutral scenes were presented in the array.

We found an interference effect from emotional scenes regardless of instruction. Even when the participants were instructed to inhibit emotional scenes, these scenes interfered with the processing of neutral scenes. Results of Experiment 1 demonstrated that individuals cannot disengage from an emotional scene even when told to ignore it as it is irrelevant, and its processing is subsequently detrimental to the performance in the primary task. In Experiment 2, we have shown that emotional scenes also cause attentional capture – if an emotional scene is freely present in the scene array, it negatively affects the performance on identifying non-emotional scenes. Regardless of instruction, emotional scenes seem to cause attentional capture and reduce the ability to identify neutral scenes. This attentional capture by emotional scenes seems to be automatic and pervasive regardless of whether the emotional scene was to be ignored or freely available in the scene array. Our study corroborates accounts supporting automatic attentional capture by emotion, specifically by non-threatening, evolutionarily relevant stimuli such as food (Lang et al., 1997; Piech et al., 2010), threatening stimuli (Brailsford, Catherwood, Tyson, & Edgar, 2014; Dennis et al., 2008; Koster, Crombez, Verschuere, & Houwer, 2004; New & German, 2015; Öhman et al., 2001; Wiemer, Gerdes, & Pauli, 2012; Williams et al., 2005; Yang et al., 2007), and erotic images or words (Arnell, Killman, & Fijavz, 2007; Gupta et al., 2016; Most et al., 2007; Schimmack, 2015; Sennwald et al., 2015). Here we exemplify that simultaneous presentation of competing visual scenes results in preferential processing of emotional information. This favored orientation of visual attention towards high-priority stimuli through top-down and bottom-up processes is posited by the arousal-biased competition model (for a review, see Mather & Sutherland, 2011; Wang, Kennedy, & Most, 2012; Zeelenberg, Wagenmakers, & Rotteveel, 2006).

Despite the illustrated attentional capture and interference from emotional scenes, we show that negatively valenced, high arousal (NHA) scenes do not seem to interfere with the processing of neutral scenes to the same extent as other emotional scenes (specifically negatively valenced, low-arousal and positively valenced, low and high-arousal scenes). In fact, negative high arousal scenes exhibited the same level of interference as neutral scenes when identifying the cued neutral scene. The fact that this finding is in direct opposition with studies demonstrating that emotionally negative stimuli create a greater interference in many gist and scene identification tasks (Biederman, 1982; Jefferies et al., 2008; Kuhbandner et al., 2011; Sakaki et al., 2011; Schimmack, 2005) might be explained by several mechanisms. First, NHA scenes might be more easily inhibited and therefore their interference effect is smaller or equivalent to other non-emotional scenes. However, if this were the case, we would find greater interference in Experiment 2 in which the participants were never cued to inhibit emotional scenes, when in fact performance was akin to that of Experiment 1. Therefore, it is more likely that those scenes might be more easily processed, using fewer attentional resources and reflecting automatic, capacity-free bottom-up processing (Carretie, Hinojosa, Martin-Loeches, Mercado, & Tapia, 2004). A few studies have shown that gory distractors lead to a smaller disruption in identifying targets in math solving and RSVP tasks (attentional blink) when compared to erotic images (Anderson, 2005; Mathewson et al., 2008; Most et al., 2007; Schimmack, 2005), and additionally, that negatively valenced scenes and faces are more poorly detected than happy faces in a visual and letter search task (Calvo & Marrero, 2009; Gupta et al., 2016). Those studies similarly show smaller attentional bias toward threatening scenes (NHA), and it seems that there is a smaller interference from negative images when the task's perceptual load is high. Indeed, amygdala activation in response to the presence of irrelevant negatively valenced distractors is eliminated under high perceptual load (Pessoa et al., 2005). Research by Gupta et al. (2016) consistently showed that interference from negative scenes is load-contingent while interference from positive information is not, and positive information interference is pervasive regardless of the task load. This differential interference effect for positive and negative information was shown across different semantic categories (such as erotic and happy for positive scenes, and gory and angry for negative scenes). Furthermore, happy faces are more likely to capture attention in an inattentional blindness task than sad faces (Mack & Rock, 1998), and positive scenes, particularly erotica, were found to impair target detection in an attentional blink paradigm to much greater extent than both disgusting and fear-containing scenes (Ciesielski, Armstrong, Zald, & Olatunji, 2010). However, due to the complex nature of attentional bias, this can also be contingent on other variables, such as personality traits, mental illness, or one's emotional state (Duque & Vázquez, 2015; Sears, Newman, Ference, & Thomas, 2011).

In relation to the current study, one could argue that the pre-cue used to instruct participants to ignore the scene actually drew the participants' attention towards the scene. However, we found that this was not the case. To ensure that participants were actually using the pre-cue effectively and thus ignored the pre-cued scenes, we ran a control experiment (Experiment 3) without a pre-cue which included a 2 x 2 scene array but otherwise emulated the design of Experiment 1. We observed that the pre-cue was in fact used effectively, as participants performed significantly better when the pre-cue was presented when compared to the no pre-cue performance (this was observed for both emotional a neutral conditions).

The difficulty of the task is also important to consider: the perceptual load has been shown to modulate attentional capture of negative, task-irrelevant stimuli and amygdala response (Gupta et al., 2016; Pessoa et al., 2005), suggesting that the allocation of attention and the difficulty or level of engagement in the task also greatly affect the amount of interference that may occur. Our task was attentionally demanding, as participants had to maintain several scenes in their working memory before the cue appeared, and therefore we can conclude that threatening scenes do not captivate attention (evident through the lack of their interference). Going forward, it is important to take into account these variables in future experimental designs and further examine the potential load-contingency of emotional information of different valence and arousal levels. Currently, we are exploring the power of recall by including a post-cue instead of inhibition.

Taken together, the results of the current study suggest a powerful interference effect by emotional scenes, but not negative high arousal stimuli. It makes sense that an individual's attention would be motivated to shift towards the biological desire to reproduce, as seen in the PHA condition. This effect could also be enhanced in part because of societal taboos surrounding sexual scenes (Arnell et al., 2007; Mathewson et al., 2008; Sennwald et al., 2015). However, similar interference effects observed when non-sexual, low arousal positive scenes (PLA) and even non-threatening, low arousal negative scenes (NLA) were presented, which raises some questions. It is still unclear why the negative high-arousal as well as the low-arousal condition would not consistently elicit an effect similar to that seen from the positive high- and low-arousal conditions. Previous literature has suggested that, although the transient, emotion-induced blindness effects between positive and negative high-arousal stimuli are similar, they may not be processed identically and therefore subsequently produce differential effects (Arnell et al., 2007; Bocanegra & Zeelenberg, 2011; Gupta et al., 2016; Most et al., 2007). Perhaps the negative stimuli were simply not biologically threatening enough or were presented too briefly to warrant disengagement from the task, which would result in less interference.

Our study thus corroborates the potent attentional capture by positively valenced scenes, and extends the current understanding of this advantage for briefly presented scenes that are in competition with each other.

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