Title
Happy faces facilitate inhibitory control under a narrow scope of attention

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 45(45)

Authors
Pandey, Shubham
Gupta, Rashmi

Publication Date
2023

Peer reviewed

Happy faces facilitate inhibitory control under a narrow scope of attention

Shubham Pandey (shubham.cogsci@gmail.com)
Cognitive and Behavioural Neuroscience Laboratory, Department of Humanities and Social Sciences,
Indian Institute of Technology Bombay, Mumbai, Maharashtra 400076, India

Rashmi Gupta (rash_cogsci@yahoo.com)
Cognitive and Behavioural Neuroscience Laboratory, Department of Humanities and Social Sciences,
Indian Institute of Technology Bombay, Mumbai, Maharashtra 400076, India

Abstract

Response inhibition refers to the ability to suppress a prepotent response. Studies investigating the role of emotional information in response inhibition have yielded inconsistent results; some studies have shown that positive emotion, compared to negative, facilitates inhibitory control, while other studies have shown opposite effects. We resolve this debate by hypothesizing that the scope of attention with which emotional information is processed can explain these mixed results. We combined a stop signal task with a global-local Navon task. Participants were required to detect a target presented at either a global or local perceptual level (letters H, S, and T). Occasionally, they encountered a stop signal face with irrelevant angry, happy, or neutral expressions. We found that irrelevant happy facial expression impaired inhibitory control compared to angry facial expression under global processing; however, this effect got reversed under local processing, i.e., happy faces facilitated inhibitory control compared to angry faces.

Keywords: emotion, response inhibition, attention, global, local, happy, angry

Introduction

Response inhibition involves cancelling initially planned but inappropriate responses to current goals (Logan & Cowan, 1984). There are many examples of the importance of response inhibition in our day-to-day lives, such as refraining from crossing a road when a car suddenly comes around the corner. In laboratory settings, the stop-signal task is frequently used to study response inhibition (Logan & Cowan, 1984; Pandey & Gupta, 2022a). In this task, participants respond to a go signal on most trials and refrain from responding when presented with an additional signal, a stop signal on infrequent trials. Successful inhibition depends on the availability of attentional resources (Logan & Cowan, 1984; Scalzo et al., 2016; Pandey & Gupta, 2022a). Successful inhibition implies shifting attentional resources from the go signal to the stop signal upon detection of the stop signal and activating an alternative task goal (the stop goal) or action plan. Therefore, perceptual and attentional processes are essential to inform sensorimotor integration during successful response inhibition (Chmielewski & Beste, 2016). If task-irrelevant stimuli capture attention away from the task, it would lead to poor inhibitory control (Pandey & Gupta, 2022 a, b). Therefore, the availability of attentional resources is a crucial factor that determines the outcome of recruited inhibitory control.

Response Inhibition and Emotion (happy vs angry)

Emotional information surrounds a significant part of our daily lives while performing various cognitive tasks, making decisions, and solving problems; therefore, emotional information interacts with other cognitive processes (Gupta, 2019, see for a review; Pessoa, 2009). Emotional information and response inhibition are crucial elements in goal-directed behaviour. Therefore, studying the link between these two systems is essential to understand adaptive and maladaptive behaviour (Lodha & Gupta, 2023a; b). Studies investigating the role of emotional information as stop signal in response inhibition have yielded mixed and inconsistent results. In some studies, positive and negative emotional information facilitated response inhibition compared to neutral information (Pessoa et al., 2012: Experiment 1; Battaglia et al., 2022). Other studies showed that positive emotional information facilitated response inhibition compared to negative (Pandey & Gupta, 2022a, b; Pandey & Gupta, 2023; Williams, Lenze & Waring, 2020) and neutral emotional information (Nayak, Kuo, & Tsai, 2019; Williams, Lenze & Waring, 2020; Pandey & Gupta, 2022b). In other studies, negative emotional information facilitated response inhibition compared to positive and neutral emotional information (Gupta & Singh, 2021; Pawliczek et al., 2013; Senderecka, 2016; Senderecka, 2018; Zheng et al., 2020). Therefore, the results are mixed and the underlying mechanism behind how emotional information facilitates/interferes with response inhibition remains unknown.

We break down these mixed results into three competing accounts. First, the *freezing account* posits that negative emotional information causes a momentary cognitive freeze (Lang, Bradley, & Cuthbert, 1997; Bradley et al., 2001); thus, negative emotional information helps to stop an ongoing action and facilitates inhibitory control (Senderecka, 2016). Second, the *attentional resource account* (Schimmack, 2005) posits that to process positive emotional information, fewer attentional resources are required, and to process negative emotional information, a lot of attentional resources are required (Srivastava & Srinivasan, 2010). In this case, positive emotional information would leave enough resources for the inhibition

In M. Goldwater, F. K. Anggoro, B. K. Hayes, & D. C. Ong (Eds.), *Proceedings of the 45th Annual Conference of the Cognitive Science Society.*

process, hence positive (relative to negative) emotional information would facilitate inhibitory control (Pandey & Gupta, 2022a, b; Pandey & Gupta, 2023). Third, the *sensory enhancement account* (Pessoa et al., 2012) posits that emotional information benefits stopping cue by making the sensory representation of stop signal strong in visual cortex, thus an emotional stop signal facilitates inhibitory control compared to non-emotional information. Previous studies tried to explain the role of emotional information in inhibitory control based on one or more of these accounts. However, these studies ignored the role of the levels of perception (global vs. local) of stimuli or the scope of attention (e.g., distributed vs. focused) in response inhibition that is highlighted in the next section.

Perception (global vs local), Attention (distributed vs focused), and Emotion (happy vs angry)

Processing visual information from scenes is a crucial component of our daily life. One way to attend relevant information in a scene is to look at the whole scene (global aspect), while the other way is to look at smaller parts of scene (local aspects). This perception of whole or parts is linked to differences in scope of attention such that global perceptual processing has been linked to a broader scope of attention, while local perceptual processing has been linked to a narrow scope of attention (Srinivasan & Gupta, 2011). The global perceptual processing style refers to processing information in a more general and bigger picture way, whereas the local perceptual processing style refers to attending to the specific details of a stimulus or processing information in a narrower and more detail-oriented way (Navon, 1977; Kimchi, 1992). This behaviour is usually examined in global local tasks (Navon task) where participants respond based on the information displayed via ambiguous stimuli: for example, a capital letter 'H' built up by small 'S' letters. The participant's task is to respond according to the global (letter H), or the local dimension.

Previous research has suggested that certain emotions are linked to specific action tendencies (Frijda, 1986; Lazarus, 1991; Levenson, 1994). In general, a reciprocal link has been established between global and local perceptual processing with positive and negative emotional information, respectively (Fredrickson, 2004; Srinivasan & Hanif, 2010; Srinivasan & Gupta, 2011). According to these findings, happy facial expressions were identified faster when preceded by a target presented at the global perceptual level compared to the local perceptual level. On the contrary, sad facial expressions were identified faster when preceded by a target presented at the local perceptual level compared to the global perceptual level (Srinivasan & Hanif, 2010). Similarly, happy facial expressions were recognised better than sad facial expressions when they were previously associated with global perceptual processing, while sad facial expressions were recognised better than happy faces when they were previously associated with local perceptual processing (Srinivasan & Gupta, 2011). Alternatively, processing positive emotional information broadens the scope of attention and action (Gupta, 2019; Subramaniam et al., 2013; Frederickson, 2004; Fenske & Eastwood, 2003), and leads to enhanced perceptual salience (Ode et al., 2012). In line with this view, Huntsigner (2013) argued that happy people focus broadly and sad people focus narrowly. Thus, global perceptual processing is linked with happy faces and local perceptual processing is linked with sad/angry faces.

If the processing of emotional information is enhanced/diminished by scope of attention, and response inhibition is also attentional resources dependent, then emotional information and scope of attention should interact with each other to bring the cumulative effect on response inhibition. If so, stop signals with irrelevant happy and angry faces should behave differently under global and local perceptual processing. Therefore, we contend that the mixed results observed in previous studies may have been due to the different levels of attention with which emotional information was processed on the task. Frischen et al. (2008) also argued that attention guidance is influenced by a dynamic interplay of emotional and perceptual factors. Notably, a few studies used go signal in the form of a big letter *X* or *O* (Pessoa et al., 2012; Gupta & Singh, 2021) which might have distributed the scope of attention (global perceptual processing), while other studies presented go signal in the form of a visual search task where the target letter was embedded among distractor letters (Pandey & Gupta, 2022b) which might have narrowed the scope of attention (or local perceptual processing). We contend that these variations might have prompted distinct scope of attention, which may have modulated results differently. Thus, the response inhibition may be modulated by the scope of attention with which emotional information is processed in the task. Indirectly, this leads us towards a perception-based account.

The Present Study

Studies investigating the role of emotional information in response inhibition have generally yielded mixed results. We contend that these mixed results could be due to the distinct scope of attention (global vs. local perceptual processing) with which emotional information is processed in the task. To investigate this, we combined a global-local Navon task with a stop signal task. The combined global-local-stop signal task is an excellent tool for systematically manipulating perceptual processing of emotional information in stop signal; thus, it provides an excellent opportunity to unravel the underlying mechanism behind how emotional information modulates inhibitory control. Therefore, the present study aimed to investigate the interactive effect of perceptual processing (global vs. local) and irrelevant emotional information (happy vs. angry) of stop signal on response inhibition.

Hypotheses

1. Based on ‘freezing account’, angry faces as stop signal would help to stop an ongoing action and facilitate inhibitory control compared to happy and neutral faces (Senderecka, 2016), regardless of scope of attention with which they are processed.
2. Based on ‘attentional resource account’, happy faces would facilitate response inhibition (Nayak et al., 2019; Williams, Lenze, & Waring, 2020; Pandey & Gupta, 2022a, b), regardless of the scope of attention with which they are processed.
3. Based on ‘sensory enhancement account’, emotional information (both angry and happy) should facilitate response inhibition, regardless of scope of attention with which they are processed (Pessoa et al., 2012).

The following two hypotheses are modification of hypotheses no. two and three after incorporating the levels (global and local) of perceptual processing of stimuli.

4. If global scope of attention leads to faster detention and enhanced processing of happy faces, while local scope of attention leads to faster detection and enhanced processing of angry faces, then this enhanced processing should take away attentional resources away from ongoing activities. Thus, happy faces should impair response inhibition under global processing, while angry faces should impair inhibition under local processing. We call it the ‘perception dependent attentional resource hypothesis.’
5. If the facilitated and enhanced processing of emotional faces (happy with global and angry with local) makes the sensory representation of stop signal strong, thereby facilitating response inhibition, then happy faces would facilitate inhibition under global processing while angry faces would facilitate inhibition under local processing. In other words, conflicting perceptual information at go and stop signal would impair inhibitory control. We call it the ‘perception dependent sensory representation hypothesis.’

Method

Participants

Thirty-four volunteers (10 females) aged 18-27 years (M = 19.88 years, SD = 2.04 years) with normal or corrected to normal vision. All volunteers were recruited through flyer advertisements. We estimated (using repeated measure F-test in G-Power, Cohen, 2013) a necessary sample size of 28 to detect a medium-size effect of 0.25 and obtain a power level of 0.80. All subjects were in good health, free of medications, and had no psychiatric or neurological disease history.

Apparatus and Stimuli

The study was designed in an open-source JAVA-based platform, PsyToolkit (www.psytoolkit.org; Stoet, 2010, 2017). It was administered offline in a dimly lit room at a distance of ~57 cm in front of a 24-inch LCD flat-screen B360 Gaming HD monitor, Intel(R) Core(TM) i7 CPU @3.20 GHz system of resolution 1920 × 1080, scan rate 60 Hz running Microsoft Windows 10 Pro. It was composed of a brief survey asking participants biographic details followed by a global/local disposition bias task and the main experiment. Participants were seated in a nearly dark room. For the stop-signal task, 12 faces (4 identities, three emotions: angry, happy, neutral) were selected from the NimStim face database (Tottenham et al., 2009). The faces were carefully hand-picked from the NimStim face database, which has been validated previously for emotion perception across various emotion types. These faces were cropped such that only the face portion was visible without hair, neck, and ears. The cropped faces were then converted into grayscale images with the help of GIMP software, and oval masked with a black background to avoid to impact of brightness, color, and other facial effects. The size of the faces was 9.23° × 13.07°. For go signal, transparent blue compound hierarchical letter stimuli were used where small letters (at local level) made up a big letter (global level). There were three possible letters: *H*, *S*, and *T*. T was irrelevant and always present at either local level or global level. The target letter, H or S, was present at the remaining other level. This manipulation resulted in four unique global-local stimuli (Figure 1a). All letters within the local level were always identical. Each local letter in the hierarchical stimuli subtended 0.73° × 1.06°. The size of global letter was 5.79° × 9.02°.

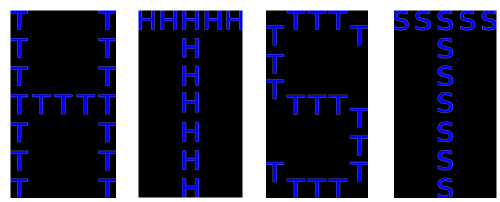

Figure 1a: Compound hierarchical go stimuli

Experiment Procedure

In this study, a combined global-local-stop-signal task was used. The background color of the screen was black. Each trial began with a centrally presented fixation point for 500 ms followed by go signal in the form of a compound letter (Figure 1b). Participants were instructed to press the left arrow key for letter *H* and the right arrow key for letter *S*. These two letters could come as either as big letter made of another irrelevant distractor letter *T* prompting global processing of go signal, or as small letters making a bit letter *T*, prompting local processing. The go-signal stayed there for 1000 ms, irrespective of the participant’s response (Pandey & Gupta, 2022a, b). A blank screen followed this for an inter-trial interval of 1000 ms, and then the next trial started.

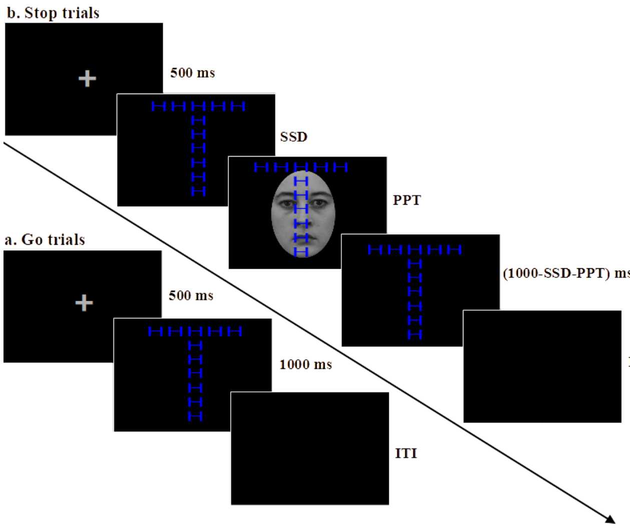

Figure 1b: Stop signal reaction time (Experiment 1)

Stop-signals were presented in 30% of total trials. In these trials, after fixation and go signal, a face appeared in the background of the compound letter stimuli (Figure 1b). This instructed participants not to press any button. The delay between go signal onset and stop-signal onset is called stop-signal delay (SSD). The initial value of the SSD was set to 250 ms. The SSD was adjusted dynamically throughout the experiment such that if participants successfully inhibited their response on a stop trial, the SSD was increased by 50 ms on a subsequent stop trial. If they failed to inhibit their response, the SSD was reduced by 50 ms on the next stop trial. The SSD could reach a minimum of 250 ms and a maximum of 750 ms. Since three emotional expressions served as stop signals, this staircase adjustment was made separately for three stop-signal conditions to ensure successful inhibition on approximately 50% of the stop trials. Two go signals (global, local) with three stop signals (angry, happy, neutral) yielded a total of six conditions.

On go trials, if participants did not press any button within a window of 1000 ms from the onset of go signal, an omission error (OE) occurred, and participants were shown visual feedback “should have pressed a button”. If participants pressed the wrong button, a discrimination error (DE) occurred, and they were shown “wrong key”. In stop trials, participants did not need to press a button. If they still pressed, a commission error (CE) occurred and they were shown “should NOT have pressed a button”. To prevent participants from developing a strategy of waiting, we used two strategies; first, the maximum allowed response time was set to 1000 ms. Second, as per Verbruggen et al’s. (2019) recommendations, participants were shown feedback of their performance on the inter-block window at the end of each block, including errors on go trials and on stop trials. Participants were instructed to respond as quickly and accurately as possible as per the recommendations made by Verbruggen et al. (2019). They were also told that sometimes it might not be possible to inhibit their response successfully and that, in such cases, they should continue performing the task. Overall, the importance of the go and stop response was stressed equally. A fixed compensation of ₹100 was provided to all participants after the successful completion of the task.

There was a total of twenty blocks. Each block had 40 trials, 70% go trials (28 trials, 14 trials of global and local each), and 30% stop trials (12 trials, four trials of angry, happy, and neutral faces each; two stop trials of each of the six conditions). Each participant was provided with an initial practice session to familiarize them with the task and estimate their error on go and nogo trials. Two different neutral uncropped grayscale faces from the KDEF database (Lundqvist, Flykt, & Öhman, 1998) were used as stop-signal for practice. Participants did practice till they made six consecutive go trials and six consecutive stop-trials correct or exhausted the maximum allowed trials (200 go trials, 100 stop trials).

Research design and data analysis

The experiment includes two independent variables: 3 (emotion: angry, happy, neutral) x 2 (levels of processing of go signal: global, local). We also used the global-local dispositional bias score as a covariate in the preliminary analysis to check for the role of predisposition towards local or global perceptual dimension. Results are reported with covariate, whereas this score improved the model. In the stop signal task, the main variable of interest is the stop signal reaction time (SSRT), which is used as a metric of successful inhibition. It cannot be directly observed as there is no behavioural marker of successful inhibition. Its calculation involves finding the point at which the internal response to the stop signal occurs (in the participant's mind). Mathematically, it is estimated by integrating the go RT distribution and finding the point at which the integral (area under RT curve) equals p(respond | stop signal) (Verbruggen et al., 2019). In practise, the mean stop signal delay (SSD) is subtracted from the nth RT of go RT distribution. The mean SSD is the average of SSDs from all stop trials, correct and incorrect ones. The n value is obtained by multiplying the number of trials in the rank-ordered go RT distribution by the probability of responding correctly (successful inhibition rate) in a stop signal condition (Verbruggen et al., 2019). For this purpose, we considered the full go RT distribution after replacing the go omissions with the maximum possible RT, 1000 ms (Verbruggen et al., 2019). This was done separately for all six conditions. A lower SSRT value means that the participant takes less time to internally respond to stop signals, and hence a lower SSRT reflects better inhibitory control (Logan & Cowan, 1984; Verbruggen et al., 2019). Other variables of interest were go reaction time, successful inhibition rate (the percentage of correct stop trials), and reaction time on error stop trials (non-cancelled RT). The correct go reaction time was calculated after removing trial RTs 3 SD away from the mean. Data from two participants were removed due to a high difference in the inhibition rate between two conditions, suggesting that the participants did not pay attention to the task. All pairwise comparisons in stop trials were performed after Bonferroni correction such that the threshold for the p-value was adjusted to 0.016 (=0.05/3).

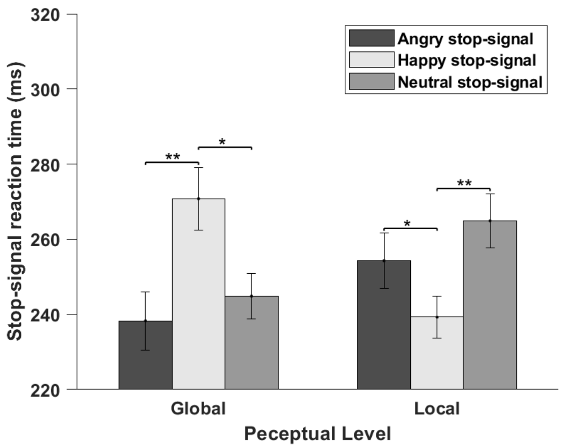

Figure 2: Stop signal reaction time (Experiment 1)

Result

Stop trials:

Stop signal reaction time (SSRT) The main effect of perceptual processing was not significant, $F(1, 29) = 0.07$, $p = 0.78$, $\eta_p^2 = 0.003$. The main effect of emotion was not significant, $F(2, 58) = 1.75$, $p = 0.18$, $\eta_p^2 = 0.05$. However, we found a highly significant interaction effect of perceptual processing and emotion, $F(2, 58) = 11.35$, $p < 0.001$, $\eta_p^2 = 0.28$. Pairwise comparisons showed that, under global processing, SSRTs were significantly higher for stop signal with irrelevant happy facial expression compared to angry, $t(29) = 3.70$, $p < 0.001$, $d = 0.67$, and neutral, $t(29) = 2.58$, $p = 0.015$, $d = 0.47$, facial expressions (Figure 2). There was no significant difference in stop signals with irrelevant angry and neutral facial expressions, $t(29) = 0.82$, $p = 0.41$, $d = 0.15$. Thus, stop signal with irrelevant happy facial expressions significantly impaired the inhibitory control under global perceptual processing of go signal. Under local perceptual processing, SSRTs were significantly lower for stop signal with happy facial expressions compared to stop signal with angry, $t(29) = -2.51$, $p = 0.018$, $d = 0.45$, and neutral, $t(26) = -3.67$, $p < 0.001$, $d = 0.67$, facial expressions (see Table 2, for values). There was no significant difference between angry and neutral stop signal, $t(26) = 1.33$, $p = 0.19$, $d = 0.24$. Across emotion conditions, the pairwise comparison results were: angry global vs. angry local, $t(29) = -1.85$, $p = .07$, $d = -0.33$; happy global vs. happy local, $t(29) = 3.81$, $p < .001$, $d = 0.69$; neutral global vs. neutral local, $t(29) = -2.12$, $p = .04$, $d = -0.38$. Thus, stop signal with irrelevant happy facial expressions significantly facilitated inhibitory control under local perceptual processing of go signal.

Go trials:

The discrimination error for the go signal presented at the local perceptual level was marginally significant compared to the go signal presented at the global perceptual level, $F(1, 29) = 3.67$, $p = .065$, $\eta_p^2 = 0.112$ (see Table 1 for values). There was no significant main effect of the perceptual level of the go signal on other measures: omission error, $F(1, 29) = 1.48$, $p = .48$, $\eta_p^2 = 0.016$; correct go RT, $F(1, 29) = 0.198$, $p = .66$, $\eta_p^2 = 0.007$. However, when controlled for global-local disposition bias in the model, the interaction effect of the perceptual level of the go signal and the global-local bias on correct go RT was marginally significant, $F(1, 26) = 4.07$, $p = .053$, $\eta_p^2 = 0.13$. The correct go RT for global perceptual processing (M = 750.66 ms, SD = 71.24 ms) was faster compared to local perceptual processing (M = 754.97 ms, SD = 70.57 ms). Thus, there is a weak effect suggesting global processing of go signal-sped response execution (go response) than local processing.

Discussion

The primary aim of this study was to investigate the interactive role of perceptual processing and irrelevant emotional information in response inhibition. Our results show that stop-signal with irrelevant happy facial expressions modulate response inhibition differently under global and local perceptual processing. For example, we found that stop-signal with irrelevant happy facial expressions (relative to angry and neutral) impaired and facilitated inhibitory control under global and local perceptual processing, respectively. Thus, these results support the "perception dependent attentional resources hypothesis." To reiterate, a globally processed go signal broadens and distributes the focus of attention, which facilitates channelizing attentional resources for detecting and processing happy faces. This facilitated processing of happy faces consumes most of the available attentional resources leaving fewer resources available for primary task demand such as the inhibition process. The scarcity of attentional/cognitive resources for the inhibition process impairs inhibitory control. Thus, enhanced processing of happy faces under the global perceptual level of attention takes attentional resources away from the inhibition process, impairing inhibition. Similarly, enhanced processing of angry faces under the local perceptual level of attention takes attentional resources away from the inhibition process, impairing inhibition.

The freezing behavior based hypothesis

The "freezing" behaviour of negative emotions hypothesis predicts that negative emotions should cause a momentary cognitive freeze (Lang, Bradley, & Cuthbert, 1997; Bradley et al., 2001; Öhman, Flykt, & Esteves, 2001). This freeze should help in stopping behaviour, thus, negative emotion should facilitate response inhibition. However, we found that angry faces facilitate response inhibition than happy faces under global perceptual processing but impair response inhibition than happy faces under local perceptual processing. Had there been a freezing effect, we should have found facilitated inhibitory control by angry faces both global and local conditions. Thus, our results do not support the freezing behaviour of negative emotion hypothesis. Notice that a freezing account effect would make more sense with evolutionarily significant threatening stimuli (images of spiders, snakes, or electric shock) as stop signals. Though conveying a potential threat, negative facial expressions like anger may not be as threatening as other evolutionarily significant threatening stimuli that carry an immediate danger in the environment and pose a risk to survival (spiders, snakes) (Sagliano et al., 2014). Most importantly, the stop signal task has two processes, the go process triggered by go signal and stop process triggered by stop signal (Logan & Cowan, 1984). A threatening stimulus prior to the onset of both processes (i.e., before go signal onset) would freeze the go process, i.e., slow down response execution which would facilitate inhibition. Thus, threatening stimuli may still produce freezing behaviour and facilitate response inhibition when present as a distractor in the background or before go signal. Future work should test this possibility.

The sensory enhancement of stop signal by emotional information hypothesis

Pessoa et al. (2012) investigated the role of happy, fearful, and neutral faces as stop signals in response inhibition. They found that happy and fearful faces facilitated response inhibition (decreased stop signal reaction time) compared to neutral faces. They argued that the emotional information contained in stop signal enhanced sensory representation of stop signal in visual cortex. This enhanced representation made stop signal more potent and robust leading to better detection of stop signal and better inhibitory control. We find this explanation elusive due to several reasons. First, both happy and fearful faces activate approach-related behaviour (Hammer & Marsh, 2015) and may produce similar motivational tendencies (Marsh et al., 2010; Fischer-Shofty et al., 2010). So an absence of difference in SSRT between happy and fearful faces stop signal should be treated with caution. Traditionally, several studies have shown that emotional information generally proves detrimental to the other task as emotional stimuli capture attentional resources away from the task (Schimmack, 2005; Schupp et al., 2006; Nummenmaa et al., 2006; Belopolsky et al., 2011), particularly negative emotional stimuli (Burra et al., 2017). Thus, to process emotional information, attentional resources are needed. Thus, irrelevant emotional information affects other cognitive processes based on how much attentional resources it captures away from the main task. This suggests an attentional resources-based mechanism.

The attentional resources based hypotheses

Pessoa (2009) proposed a "dual competition framework", which posits that executive control sub-components interact with each other, such that resources utilised by one component will not be available to the other components. Hence, according to this framework, if irrelevant emotional information captures attentional resources away from task, this would leave fewer attentional resources available for main task requirements such as response inhibition. Thus, irrelevant emotional information would impair response inhibition. Since the processing of positive emotional information involves fewer attentional resources, positive emotional stimuli would facilitate response inhibition compared to negative emotional stimuli (Pandey & Gupta, 2022a; b; Pandey & Gupta, 2023). However, our results do not show a general inhibition facilitation by stop signal with positive emotional information. Instead, happy faces as stop signal facilitated response inhibition only under local perceptual processing. In contrast, angry faces as stop signal facilitated response inhibition under global perceptual processing. Nonetheless, the results are consistent with attentional resources-based hypotheses. Notably, under global perceptual processing, happy faces were processed in an enhanced manner which may have consumed more attentional resources than angry faces. However, under local perceptual processing, angry faces were processed in an enhanced manner which may have consumed more attentional resources than happy faces. Thus, attention capture by emotional stimuli is not general; instead, the perceptual level also influences the amount of attentional resources captured by happy and angry faces. Together, these results support the dependent attentional resources-based hypothesis.

Conclusion: In summary, we show that irrelevant emotional information interacts with the scope of attention and affects response inhibition. In the case of a distributed scope of attention (global perpetual level), a stop signal with irrelevant happy faces compared to angry faces impair inhibitory control. However, in the case of a narrow scope of attention, a stop signal with irrelevant happy faces compared to angry faces facilitate inhibitory control. We contend that the processing of happy faces is enhanced under global scope of attention and the processing of angry faces is enhanced under local scope of attention. This enhanced processing takes away most of the available attentional resources leaving fewer resources for inhibition process, thereby impairing inhibitory control. Overall, our results may help to understand why there are mixed results in the literature while investigating the role of irrelevant emotional information in response inhibition.

Data availability statement: The script used to design the experiment, the datasets generated and/or analysed during the current study, the data analysis files are available at https://osf.io/vtr8e/?view_only=d23a812490434e15ac23507d66f461ec

References

Belopolsky, A. V., Devue, C., & Theeuwes, J. (2011). Angry faces hold the eyes. *Visual Cognition*, *19*(1), 27-36.

Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001). Emotion and motivation I: defensive and appetitive reactions in picture processing. *Emotion*, *1*(3), 276.

Burra, N., Coll, S. Y., Barras, C., & Kerzel, D. (2017). Electrophysiological evidence for attentional capture by irrelevant angry facial expressions: Naturalistic faces. *Neuroscience letters*, *637*, 44-49.

Chmielewski, W. X., & Beste, C. (2016). Perceptual conflict during sensorimotor integration processes-a neurophysiological study in response inhibition. *Scientific Reports*, *6*(1), 26289.

Chen, Z., Veling, H., Dijksterhuis, A., & Holland, R. W. (2016). How does not responding to appetitive stimuli cause devaluation: Evaluative conditioning or response inhibition?. *Journal of Experimental Psychology: General*, *145*(12), 1687.

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Routledge.

Dale, G., & Arnell, K. M. (2013). Investigating the stability of and relationships among global/local processing measures. *Attention, Perception, & Psychophysics*, *75*(3), 394–406.

De Houwer, J., & Tibboel, H. (2010). Stop what you are not doing! Emotional pictures interfere with the task not to respond. *Psychonomic bulletin & review*, *17*, 699-703.

Fischer-Shofty M., Shamay-Tsoory S. G., Harari H., & Levkovitz Y. (2010). The effect of intranasal administration of oxytocin on fear recognition. *Neuropsychologia, 48*, 179–184

Frijda, N. H. (1986). *The emotions*. Cambridge University Press.

Fredrickson, B. L. (2004). The broaden–and–build theory of positive emotions. *Philosophical transactions of the royal society of London. Series B: Biological Sciences*, *359*(1449), 1367-1377.

Frischen, A., Eastwood, J. D., & Smilek, D. (2008). Visual search for faces with emotional expressions. *Psychological bulletin*, *134*(5), 662.

Gupta, R. (2019). Positive emotions have a unique capacity to capture attention. *Progress in Brain Research*, *247*, 23-46.

Gupta, R., & Singh, J. P. (2021). Only irrelevant angry, but not happy, expressions facilitate the response inhibition. *Attention, Perception, & Psychophysics*, *83*(1), 114-121.

Hammer, J. L., & Marsh, A. A. (2015). Why do fearful facial expressions elicit behavioral approach? Evidence from a combined approach avoidance implicit association test. *Emotion, 15(2)*, 223–231.

JASP Team (2021). JASP (Version)[Computer software].

Kerusauskaite, S. G., Simione, L., Raffone, A., & Srinivasan, N. (2020). Global–local processing and dispositional bias interact with emotion processing in the psychological refractory period paradigm. *Experimental Brain Research*, *238*(2), 345–354.

Kimchi, R. (1992). Primacy of wholistic processing and global/local paradigm: a critical review. *Psychological bulletin*, *112*(1), 24.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. *Attention and orienting: Sensory and motivational processes*, *97*, 135.

Lazarus, R. S. (1991). Cognition and motivation in emotion. *American psychologist*, *46*(4), 352.

Levenson, R. W. (1999). The intrapersonal functions of emotion. *Cognition & Emotion*, *13*(5), 481-504.

Lodha, S., & Gupta, R. (2023a). Irrelevant angry, but not happy, faces facilitate response inhibition in mindfulness meditators. *Current Psychology*, 1-16.

Lodha, S., & Gupta, R. (2023b). Are You Distracted by Pleasure? Practice Mindfulness Meditation. *Journal of Cognitive Enhancement*, 1-20.

Logan, G. D., & Cowan, W. B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological review*, *91*(3), 295.

Marsh, A.A., Yu, H.H., Pine, D.S., & Blair, R.J. (2010). Oxytocin improves specific recognition of positive facial expressions. *Psychopharmacology, 209(3)*, 225–232

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive psychology*, *9*(3), 353-383.

Navon, D. (2003). What does a compound letter tell the psychologist's mind?. *Acta psychologica*, *114*(3), 273-309.

Nayak, S., Kuo, C., & Tsai, A. C. H. (2019). Mid-frontal theta modulates response inhibition and decision making processes in emotional contexts. *Brain Sciences*, *9*(10), 271.

Nummenmaa, L., Hyönä, J., & Calvo, M. G. (2006). Eye movement assessment of selective attentional capture by emotional pictures. *Emotion*, *6*(2), 257.

Ode, S., Winters, P. L., & Robinson, M. D. (2012). Approach motivation as incentive salience: Perceptual sources of evidence in relation to positive word primes. *Emotion*, *12*(1), 91–101.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of experimental psychology: general*, *130*(3), 466.

Pandey, S., & Gupta, R. (2022a). Irrelevant positive emotional information facilitates response inhibition only under a high perceptual load. *Scientific Reports*, *12*(1).

Pandey, S., & Gupta, R. (2022b). Irrelevant angry faces impair response inhibition, and the go and stop processes share attentional resources. *Scientific Reports*, *12*(1).

Pandey, S., & Gupta, R. (2023). Implicit angry faces interfere with response inhibition and response adjustment. *Cognition and Emotion*, 1-17.

Pawliczek, C. M., Derntl, B., Kellermann, T., Kohn, N., Gur, R. C., & Habel, U. (2013). Inhibitory control and trait aggression: neural and behavioral insights using the emotional stop signal task. *Neuroimage*, *79*, 264-274.

Pessoa, L. (2009). How do emotion and motivation direct executive control?. *Trends in cognitive sciences*, *13*(4), 160-166.

Pessoa, L., Padmala, S., Kenzer, A., & Bauer, A. (2012). Interactions between cognition and emotion during response inhibition. *Emotion*, *12*(1), 192.

Sagliano, L., Cappuccio, A., Trojano, L., & Conson, M. (2014). Approaching threats elicit a freeze-like response in humans. *Neuroscience letters*, *561*, 35-40.

Scalzo, F., O'Connor, D. A., Orr, C., Murphy, K., & Hester, R. (2016). Attention diversion improves response inhibition of immediate reward, but only when it is beneficial: An fMRI study. *Frontiers in Human Neuroscience*, *10*, 429.

Schimmack, U., (2005). Attentional interference effects of emotional pictures: threat, negativity, or arousal?. *Emotion*, *5*(1), 55.

Schupp, H. T., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006). Emotion and attention: event-related brain potential studies. *Progress in brain research*, *156*, 31-51.

Senderecka, M. (2016). Threatening visual stimuli influence response inhibition and error monitoring: An event-related potential study. *Biological Psychology*, *113*, 24-36.

Senderecka, M. (2018). Emotional enhancement of error detection—The role of perceptual processing and inhibition monitoring in failed auditory stop trials. *Cognitive, Affective, & Behavioral Neuroscience*, *18*, 1-20.

Stoet, G. (2010). PsyToolkit - A software package for programming psychological experiments using Linux. *Behavior Research Methods, 42(4)*, 1096-1104.

Stoet, G. (2017). PsyToolkit: A novel web-based method for running online questionnaires and reaction-time experiments. *Teaching of Psychology, 44(1)*, 24-31.

Srivastava, P., & Srinivasan, N. (2010). Time course of visual attention with emotional faces. *Attention, Perception, & Psychophysics*, *72*(2), 369-377.

Srinivasan, N., & Gupta, R. (2011). Rapid communication: Global–local processing affects recognition of distractor emotional faces. *Quarterly Journal of Experimental Psychology*, *64*(3), 425-433.

Srinivasan, N., & Hanif, A. (2010). Global-happy and local-sad: Perceptual processing affects emotion identification. *Cognition and Emotion*, *24*(6), 1062-1069.

Subramaniam, K., Beeman, M., Faust, M., & Mashal, N. (2013). Positively valenced stimuli facilitate creative novel metaphoric processes by enhancing medial prefrontal cortical activation. *Frontiers in Psychology*, *4*, 211.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., ...& Nelson, C. (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry Research*, *168(3),* 242-249.

Verbruggen, F., Aron, A. R., Band, G. P., Beste, C., Bissett, P. G., Brockett, A. T., ... & Boehler, C. N. (2019). A consensus guide to capturing the ability to inhibit actions and impulsive behaviors in the stop-signal task. *elife*, *8*, e46323.

Williams, S. E., Lenze, E. J., & Waring, J. D. (2020). Positive information facilitates response inhibition in older adults only when emotion is task-relevant. *Cognition and Emotion*, *34*(8), 1632-1645.

Zheng, Q., Yang, T. X., & Ye, Z. (2020). Emotional stop cues facilitate inhibitory control in schizophrenia. *Journal of the International Neuropsychological Society*, *26*(3), 286-293.