Threat-induced Impulsivity in Go/Nogo Tasks: Relationships to Task-relevance of Emotional Stimuli and Virtual Proximity

Thomas E. Gladwin[a*]

Martin Möbius[b]

Matthijs Vink[cd]

[a] Department of Psychology and Counseling, University of Chichester, Chichester, United Kingdom.

[b] Behavioral Science Institute, Radboud University Nijmegen, Nijmegen, The Netherlands.

[c] Department of Psychiatry, Brain Center Rudolf Magnus, Utrecht University Medical Center, Utrecht, The Netherlands.

[d] Departments of Developmental and Experimental Psychology, Utrecht University, Utrecht, The Netherlands

* Corresponding author: Thomas E. Gladwin, Address: Department of Psychology and Counselling, University of Chichester, College Lane, Chichester, PO19 6PE, United Kingdom. Tel.: +447895625183. Email: thomas.gladwin@gmail.com.

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Abstract

Threatening stimuli are thought to induce impulsive responses, but Emotional Go/Nogo task results are not in line with this. We extend previous research by comparing effects of task-relevance of emotional stimuli and virtual proximity. Four studies were performed to test this in healthy college students. When emotional stimuli were task-relevant, threat both increased commission errors and decreased RT, but this was not found when emotional stimuli were task-irrelevant. This was found in both between-subject and within-subject designs. These effects were found using a task version with equal go and nogo rates, but not with 90%-10% go-nogo rates. Proximity was found to increase threat-induced speeding, with task-relevant stimuli only, although effects on accuracy were less clear. Threat stimuli can thus induce impulsive responding, but effects depend on features of the task design. The results may be of use in understanding theoretically unexpected results involving threat and impulsivity and designing future studies.

Keywords

Emotional Go-Nogo; Task-relevance; Faces; Impulsivity; Proximity

1. Introduction

Threat-related stimuli induce tendencies to respond impulsively, in the sense of executing responses when they should be withheld (Hartikainen, Siiskonen, & Ogawa, 2012; Nieuwenhuys, Savelsbergh, & Oudejans, 2012; Schutter, Hofman, & Van Honk, 2008; van Peer, Gladwin, & Nieuwenhuys, 2018; Verbruggen & De Houwer, 2007). Impulsive responding has the advantage of speed, which may be essential, e.g., in life or death situations involving predators, at the cost of reducing the time to complete sophisticated but slow cognitive processing (Cunningham, Zelazo, Packer, & Van Bavel, 2007; Nieuwenhuys & Oudejans, 2012). This may lead to suboptimal choices: For instance, in a simulated shooting situation, increasing the threat associated with the task induced faster shooting and a bias to shoot versus refrain from shooting (Nieuwenhuys et al., 2012). It is therefore important to understand threat-induced impulsivity and the ways we measure it. One measure of impulsive responding is the stop signal reaction time, SSRT (Bari & Robbins, 2013; Verbruggen & Logan, 2008). This is the time required to cancel the execution of a response, when a stop signal is presented after a stimulus initiating a response. As expected, threat has been found to increase the SSRT (van Peer et al., 2018; Verbruggen & De Houwer, 2007), i.e., threat makes it more difficult to inhibited response execution, although this is not always found (Pawliczek et al., 2013; Sagaspe, Schwartz, & Vuilleumier, 2011). Also in line with a shift towards impulsive versus reflective responding, at a neurobiological level threat increases the excitability of the corticospinal tract (Coombes et al., 2009; Schutter et al., 2008) and reduces activity in regions associated with cognitive control (Bishop, 2008; Oei et al., 2012).

Of particular interest to the current study, Go-Nogo tasks are frequently used to measure impulsivity. Participants must respond quickly to one stimulus, and to refrain from responding to another stimulus. Threatening or highly arousing task-irrelevant distractor stimuli increase commission errors (De Houwer & Tibboel, 2010; Hartikainen et al., 2012), indicating that threat reduced the ability to inhibit responses. This could reflect a shift in cognitive resources away from the task (De Houwer & Tibboel, 2010; Hartikainen et al., 2012). No effect on Go-stimulus reaction time (RT) was found that would indicate a lowered response threshold; in one study, a reversed effect was found (Brown et al., 2015). This is surprising, as it contradicts the theory-based expectation that threat-induced commission errors should be caused by the shift towards speed versus accuracy discussed above, i.e., reducing the evidence required for response execution (Krypotos, Beckers, Kindt, & Wagenmakers, 2015). This is an issue either for the theory or for this method of measuring impulsivity.

The aim of the current paper is to address this issue, by exploring potentially important task factors in the Go-Nogo task. In Study 1, the effect of task-relevance of emotional distractors was tested. Previous work has shown that emotional stimuli have stronger effects when they must be processed to perform the task, in terms of behavioural effects (Lichtenstein-Vidne, Henik, & Safadi, 2012; Spruyt, De Houwer, & Hermans, 2009; Spruyt, Tibboel, De Schryver, & De Houwer, 2018) and neural responses (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). The automatic processes involved in emotional distraction may thus require at least some attention or goal-relevance to be evoked, even though the subsequent effects on performance would not be voluntary (Bargh, 1994; Bargh & Ferguson, 2000; De Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009). To extend this work to the Go-Nogo task, two versions of an emotional Go-Nogo task were used. In one version, the emotional stimulus was a task-irrelevant distractor: Go versus Nogo responses were signaled by probe stimuli independent from the emotional content. In the other version, the emotional stimulus was the task-relevant probe stimulus: participants had to perform Go versus Nogo responses based on the emotional content of the stimuli (Megías, Gutiérrez-Cobo, Gómez-Leal, Cabello, & Fernández-Berrocal, 2017). This allowed us to test whether task-relevant emotional, in this case threatening, stimuli would be more able to induce the theoretically expected threat-enhanced impulsivity: more commission errors and lower Go-RTs.

In Study 2, a further novel manipulation was introduced, namely the virtual relative proximity of the stimuli. Proximity plays a central role in defensive responses (Blanchard et al., 2001; Blanchard, Blanchard, & Griebel, 2005; Blanchard, Griebel, Pobbe, & Blanchard, 2011; Bradley, 2009; Kozlowska, Walker, McLean, & Carrive, 2015; Mobbs et al., 2007). The change in defensive responses as a threat, e.g., a predator, comes closer is termed the defensive cascade: as a threat draws physically nearer, responses shift from freeze to flight to fight (Blanchard et al., 2005). At long distances, movement is suppressed (Bracha, 2004; Fanselow, 1986; Gladwin, Hashemi, van Ast, & Roelofs, 2016; Roelofs, 2017; Sagliano, Cappuccio, Trojano, & Conson, 2014); as the threat comes closer, flight responses occurs; and at very close range, fight responses are activated. Associated neurocognitive changes occur with increasing proximity to threat (Mobbs et al., 2007). The defensive cascade would appear to be related to the concept of defensive space, the minimal distance people desire to maintain between themselves and other people and potential threats, i.e., before defensive responses are activated (Graziano & Cooke, 2006; Hayduk, 1983). Exposure to aggression (Vagnoni, Lewis, Tajadura-Jiménez, & Cardini, 2018), anxiety (de Vignemont & Iannetti, 2015; Sambo & Iannetti, 2013) and psychoticism (McGurk, Davis, & Grehan, 1981) have been shown to be related to a larger defensive space. Further, using fMRI study, veterans with anger and aggression problems showed abnormal brain activation in the cuneus, a region associated with the processing of emotionally salient stimulus features, when stimuli appeared closer versus further away (Heesink et al., 2017). Thus, the impulsivity expected to occur when confronted with threat could interact with perceived proximity. In Study 2 therefore, images were scaled to be larger or smaller to generate the impression of being closer or further away from the participant. This is termed “zoomed-in” versus “zoomed-out” below, but we note that there was no zooming animation: images were only relatively large or relatively small, within the task. Note that the relative rather than absolute size of a stimulus is likely important for whether a stimulus is perceived as far away or close, as the absolute size has little meaning for an on-screen emotional stimulus in this context. Task-relevance was also manipulated as in Study 1. We expected that stimuli appearing closer to participants would enhance threat-induced effects on impulsivity.

In Study 3, data are presented in which the hypotheses of Study 1 were tested again, but using a within-subject design in which all participants performed both the task-relevant and task-irrelevant tasks.

In Study 4, the same within-subject design as in Study 3 was used, but with increased proportions of go versus no-go trials (90% versus 10%). In the previous studies, go and no-go trials were equally likely. We note some reasons to use the 50-50 distribution, in particular for the aims of the current research questions on interactions with threat stimuli. First, testing whether threat-stimuli indeed induce impulsive responses does not depend on having a prepotent response induced by the non-emotional manipulation of go-likelihood. Second, the 50-50 distribution avoids the disadvantage of a relatively small number of trials in the no-go condition. Third, in the task-relevant version of the task, unequal go- and nogo-frequencies would result in strongly differing block-contexts, which would be confounded with trial type; and hence, results would be difficult to interpret. That is: threat-go trials only occur in threat-go blocks, in which participants would be exposed to primarily threatening stimuli; while on threat-nogo blocks, most stimuli would be non-threatening. Fourth, unequal go and nogo distributions have the disadvantage of confounding the nogo-manipulation with frequency and hence processes such as expectation or attention, which could also conceivably interact with emotional stimuli. Finally, it is not necessarily methodologically optimal to have a higher baseline level of impulsivity induced by go-frequency; this could for example lead to ceiling effects on commission errors and reduce the ability to detect additional emotional effects. However, Go-Nogo studies have tended to use increased proportions of go-trials to the aim of increasing response tendency, and the final Study may provide a possibly informative closer comparison to the existing literature.

Study 1

2. Method

2.1.Participants

Healthy participants were recruited and received study credits or a monetary reward for completing the study. Participants gave informed consent. The study was approved by the ethics review board. An analytical sample of 135 participants (88 female, 47 male, 23 years, *SD* = 7.1) completed the experiment with performance indicating at least minimal task engagement, quantified as accuracy over .5 in all analyzed trial types, excluding, for instance, participants who simply executed go responses without paying attention (*n* = 2 participants were removed who did not reach the criterion).

2.2. Emotional Go/Nogo Task (emoGNG)

The tasks were programmed using HTML5, JavaScript and PHP. Randomization used the seedrandom script by David Bau (https://github.com/davidbau/seedrandom). For each participant, the identifier assigned to them by the participant-pool system was converted to the numerical random-seed for the module. Software is available on request by emailing the communicating author. We acknowledge that a general limitation of online studies is some loss of control relative to a laboratory setting; however, online studies have been shown to be a valid method for psychological tasks (Chetverikov & Upravitelev, 2016; van Ballegooijen, Riper, Cuijpers, van Oppen, & Smit, 2016).

Facial stimuli subtended around 7.5 degrees visual angle; the precise visual angles varied depending on participants' screen size. Text stimuli had a visual angle of around 0.5 degrees. 14 pairs (neutral and angry) of computer-generated male faces were used from the Bochum Emotional Stimulus Set (Thoma, Soria Bauser, & Suchan, 2013).

The task consisted of 10 blocks of 48 trials (see Figure 1 for an illustration). Each participant performed one of two versions, with either task-relevant or task-irrelevant emotional stimuli. In both versions, trials began with a white fixation cross, for 250, 300, or 350 ms. Subsequently, a stimulus was presented consisting of an angry or neutral face stimulus and a small *x* or *o* symbol, placed at a random location on the face. In the Task-Relevant version, participants were instructed either to press space when an angry face appeared and to do nothing when a neutral face appeared; or to press space when a neutral face appeared and to do nothing when an angry face appeared. In the Task-Irrelevant version, participants were instructed either to press space when an *x* appeared and to do nothing when an *o* appeared; or to press space when an *o* appeared and to do nothing when an *x* appeared. In both conditions, the Go/Nogo mapping instructions alternated per block. Participants had 600 ms to respond before the stimuli disappeared. Feedback was presented after incorrect responses for 400 ms: A red "Incorrect!", or a red "Too late!"

<Figure 1>

Go and Nogo trials were equally frequency. Although previous Go-Nogo tasks have often used lower probabilities for Nogo stimuli, to the aim of increasing response likelihood and hence the probability of commission errors, please note that equal probabilities do not threaten evidence for threat-induced impulsivity (and the results will indeed show that relatively infrequent Nogo trials are not necessary to find such effects). A further advantage of equal probabilities is that there is no confound between stimulus type and frequency.

2.3. Procedure

Inclusion proceeded via an online participant-pool system. Participants could sign up for the study based on a brief description, after which they could read the extensive information and decide whether to continue. Participants performed one of the emoGNG versions selected at random. Other questionnaires and tasks were performed in the same session that were related to other studies.

2.4. Preprocessing and Statistical Analyses

The first block of the task, the first four trials per block and trials following errors were removed as these were considered to potentially deviate from normal task performance. Analyses were performed in order to test effects per task as well as to compare the effects between tasks. Effects per task were tested with a repeated measures ANOVA. The analyses were performed with the dependent variables median RT, and the asin-square transformation of mean accuracy scores. Median RTs were used to avoid effects of outliers which would require arbitrary cut-offs using the mean. The transformation of the mean accuracy scores was used to normalize the distribution. For RT, only go trials were included in the analysis. The within-subject factor was Threat (Angry face versus Neutral face). For accuracy, the within-subject factors were Threat and Go (Go versus Nogo). In a subsequent mixed design ANOVA, task version was used as an additional between-subject variable to test interactions involving task version. Note that we chose to present the results for each task separately, to prevent the presentation of information per task depend on the binary outcome of interactions involving the task version. All data and statistical output are available on request.

3. Results

66 participants performed the task-irrelevant emoGNG, and 69 participants performed the task-relevant emoGNG. Descriptive statistics are presented in Table 1.

Table 1. RT and accuracy on the emoGNG

1A. Reaction time on Go trials

Task version	Emotion	RT (SD)
Task-irrelevant	Neutral	449 (29)
	Angry	450 (31)
Task-relevant	Neutral	428 (33)
	Angry	419 (30)

1B. Accuracy

Task version	Emotion	Go/Nogo	Accuracy
Task-irrelevant	Neutral	Nogo	.93
		Go	.94
	Angry	Nogo	.92
		Go	.94
Task-relevant	Neutral	Nogo	.91
		Go	.92
	Angry	Nogo	.88
		Go	.93

Note. Mean and standard deviation of reaction time in ms and mean accuracy in proportion correct per condition of the emoGNG over participants. Task version refers to task-relevance of the emotional expression of the faces (Neutral or Angry).

3.1. Task-Irrelevant emoGNG

There was no effect of Threat on RT (p = .48) and no interaction between Go and Threat on accuracy (p = .092). Go trials were more accurate than Nogo trials, $F(1, 65) = 11$, p = .0013, $\eta_p^2 = 0.15$ (.94 versus .92).

3.2. Task-Relevant emoGNG

On RT, there was an effect of Threat, $F(1, 68) = 15$, p = .00027, $\eta_p^2 = 0.18$, responding to Angry faces being faster than responding to Neutral faces (419 ms versus 428 ms).

On accuracy, there was an interaction between Go and Threat, $F(1, 68) = 21$, $p < .0001$, $\eta_p^2 = 0.24$. This was due to lower accuracy for Angry than Neutral faces on Nogo trials, $F(1, 68) = 19$, $p < .0001$, $\eta_p^2 = 0.22$ (.88 versus .91 proportion correct), and higher accuracy for Angry than Neutral faces on Go trials, $F(1, 68) = 19$, $p = .044$, $\eta_p^2 = 0.058$ (.93 versus .92). Further, Go trials were more accurate than Nogo trials, $F(1, 68) = 20$, $p < .0001$, $\eta_p^2 = 0.22$ (.92 versus .90).

3.3. Between-Task Comparisons

The above difference in effects between the tasks were formally tested using a mixed design ANOVA. On RT, the interaction between Task version and Threat was significant, $F(1, 133) = 13$, p = .00052, $\eta_p^2 = 0.087$. No task-related interaction reached significant on accuracy, although the Task x Go x Threat interaction approached significance (p = .056).

4. Discussion

The aims of Study 1 were to provide further information on whether threatening social stimuli induce impulsivity and determine what the effect is of using a task in which the emotional cues are task-relevant versus task-irrelevant. Effects involving threat were only found for the Task-Relevant version. Most importantly, a speeding effect was found on RTs on go trials. Using task-irrelevant emotional cues or distractors was also not previously found to affect RT on go-trials

(De Houwer & Tibboel, 2010; Hartikainen et al., 2012). Making the emotional stimuli task-relevant appeared to allow them to induce impulsivity as detected via speeding, similarly to effects of task-relevance (although we note that the precise meaning of "task-relevance" varies) in other emotional tasks (Lichtenstein-Vidne et al., 2012; Spruyt et al., 2009, 2018).

Study 2

2. Method

2.1. Participants

Healthy participants were recruited and received study credits or a monetary reward for completing the study, which was performed fully online. Participants gave informed consent and the study was approved by the local ethics review board. 173 participants (151 female, 22 male; mean age 20, *SD* = 3.3) completed the experiment with performance indicating at least minimal task engagement, quantified as accuracy over .5 in all analyzed trial types (*n* = 2 participants were removed).

2.2. Proximity version of the Emotional Go/Nogo Task (proxemoGNG)

The proxemoGNG consisted of 9 blocks of 40 trials. Trials were identical to those of the emoGNG, with the exception of a random "zoom-in" effect that occurred with 0.5 probability on all trials. Note for clarity the zoom did not involve a movement animation: stimuli were simply presented at different sizes. The facial visual stimuli subtended around 7.5 degrees visual angle, except when zoomed-in in which case the angle was 15 degrees (as above, the precise visual angles will have varied somewhat). The proxemoGNG was also presented in either a Task-Relevant and Task-Irrelevant version.

2.3. Procedure

Inclusion proceeded via an online participant-pool system. Participants could sign up for the study based on a brief description, after which they could read the extensive information and decide whether to continue. Participants performed the Task-Relevant or the Task-Irrelevant version of the proxemoGNG, selected at random.

2.4. Preprocessing and Statistical Analyses

The first block of the task, the first four trials per block, and trials following errors were removed. Analyses were performed in order to test effects per task as well as to compare the effects between tasks. Effects per task were tested with a repeated measures ANOVA. The analyses were performed with the dependent variables median RT and the asin-square transformation of accuracy scores. For RT, only go trials were included in the analysis. The within-subject factors were Proximity (Zoomed-In versus Zoomed-Out) and Threat (Angry face versus Neutral face). For accuracy, the within-subject factors were Proximity, Threat and Go (Go versus Nogo).

In a subsequent mixed design ANOVA, task version was used as a between-subject variable to test interactions involving task version.

3. Results

89 participants performed the task-irrelevant proxemoGNG, and 84 participants performed the task-relevant proxemoGNG. Descriptive statistics are presented in Table 2.

Table 2. RT and accuracy on the proxemoGNG

2A. RT on Go trials

Task version	Emotion	Proximity	RT (SD)
Task-irrelevant	Neutral	Far	457 (31)
		Near	453 (32)
	Angry	Far	457 (32)
		Near	452 (31)
Task-relevant	Neutral	Far	434 (37)
		Near	433 (36)
	Angry	Far	436 (37)
		Near	413 (37)

2B. Accuracy

Task version	Emotion	Go/Nogo	Proximity	Accuracy
Task-irrelevant	Neutral	Nogo	Far	.94
			Near	.94
		Go	Far	.94
			Near	.95
	Angry	Nogo	Far	.93
			Near	.93
		Go	Far	.94
			Near	.95
Task-relevant	Neutral	Nogo	Far	.93
			Near	.91
		Go	Far	.91
			Near	.92
	Angry	Nogo	Far	.86
			Near	.91
		Go	Far	.92
			Near	.94

Note. Mean and standard deviation of reaction time in ms and mean accuracy in proportion correct per condition of the proxemoGNG over participants. Task version refers to task-relevance of the emotional expression of the faces (Neutral or Angry). Proximity refers to whether the face presented on the trial was zoomed in (Near) or not (Far).

3.1. Task-Irrelevant proxemoGNG

On RT, the only significant effect was of Proximity, $F(1, 88) = 9.9$, $p = .0022$, $\eta_p^2 = 0.10$, zoomed-in stimuli evoking a faster response than zoomed-out stimuli (453 ms versus 457 ms).

On accuracy, the only effect was of Go, $F(1, 88) = 7.7$, $p = 0.0069$, $\eta_p^2 = 0.080$, Go-responses being more accurate than Nogo-responses (.95 versus .94).

3.2. Task-Relevant proxemoGNG

On RT, effects were found of Threat, $F(1, 83) = 30$, $p < .0001$, $\eta_p^2 = 0.26$, Angry faces evoking faster responses than Neutral faces (424 ms versus 433 ms); Proximity, $F(1, 83) = 54$, $p < .0001$, $\eta_p^2 = 0.39$, zoomed-in stimuli evoking a faster response than zoomed-out stimuli (423 ms versus 435 ms); and, essentially for the research question, the Proximity x Threat interaction, $F(1, 83) = 63$, $p < .0001$, $\eta_p^2 = 0.43$, due to the effect of Threat only being significant for the zoomed-in stimuli, $F(1, 83) = 100$, $p < .0001$, $\eta_p^2 = 0.55$ (413 ms versus 433 ms).

On accuracy, effects were found of Go, $F(1, 83) = 7.8$, $p = .0064$, $\eta_p^2 = 0.086$, Go responses being more accurate than Nogo responses (.92 versus .90); Proximity, $F(1, 83) = 18$, $p < .0001$, $\eta_p^2 = 0.17$, responses to zoomed-in stimuli being more accurate than responses to zoomed-out stimuli (.92 versus .91); Go x Threat, $F(1, 83) = 35$, $p < .0001$, $\eta_p^2 = 0.30$, due to the effect of Go being significant only for Threat stimuli, $F(1, 83) = 26$, $p < .0001$, $\eta_p^2 = 0.24$; Proximity x Threat, $F(1, 83) = 32$, $p < .0001$, $\eta_p^2 = 0.28$, the effect of Angry versus Neutral faces reversing for zoomed-out (lower accuracy for Angry faces, .89 versus .92) versus zoomed-in faces (higher accuracy for Angry faces, .93 versus .92); and Go x Proximity x Threat, $F(1, 83) = 7.5$, $p = .0075$, $\eta_p^2 = 0.083$. For zoomed-out faces, there was a Go x Threat interaction, $F(1, 83) = 40$, $p < .0001$, $\eta_p^2 = 0.32$, due to an effect of Threat for Nogo trials only, with more commission errors for Angry faces. For zoomed-in faces, there was also a Go x Threat interaction, , $F(1, 83) = 8.1$, $p = .0056$, $\eta_p^2 = 0.089$, due to higher accuracy for Angry than Neutral faces for Go trials only.

3.3. Between-Task Comparisons

The above descriptive differences between task versions were tested using the mixed design ANOVA. On RT, the following interactions were found, all due to the within-subject effect being stronger in the Task-Relevant task version than in the Task-Irrelevant task version: Task version x Threat, $F(1, 171) = 15$, $p = .00012$, $\eta_p^2 = 0.083$; Task version x Proximity, $F(1, 171) = 9.9$, $p = .0020$, $\eta_p^2 = 0.055$; Task-Version x Proximity x Threat, $F(1, 171) = 30$, $p < .0001$, $\eta_p^2 = 0.15$.

On accuracy, the following interaction effects were found, all due to the within-subject effect being significant only for the Task-Relevant task version: Task-Version x Go x Threat, $F(1, 171) = 11$, $p = .00092$, $\eta_p^2 = 0.062$; Task-Version x Proximity x Threat, $F(1, 171) = 17$, $p = .00053$, $\eta_p^2 = 0.091$; Task-Version x Go x Proximity x Threat, $F(1, 171) = 6.2$, $p = .014$, $\eta_p^2 = 0.035$.

4. Discussion

The aims of the Study 2 were to test the effect of virtual stimulus proximity. The results also allowed a conceptual replication of the task-relevance effect on impulsivity found in Study 1. Threat-effects were again only found in the task-relevant version. Proximity was found to be related to enhanced effects of threat on impulsivity, but only for the Task-Relevant task version and most clearly for RT. This proximity effect for RT is in line with the defensive cascade (Blanchard et al., 2001, 2005; Bradley, 2009; Heesink et al., 2017; Mobbs et al., 2007), in which defensive responses depend on the distance to the threat. A threat appearing close by naturally requires faster responses to escape, as an attack at shorter distance leaves less time to respond. It would therefore be expected that proximity would enhance threat-induced impulsivity, as suggested by the RT results. Although an interaction was also found for accuracy, the pattern of these results was more difficult to interpret. The expected increase in commission errors for angry versus neutral faces was found for distant rather than nearby stimuli; while, more in line with expectations, for nearby stimuli fewer false negatives were found for angry versus neutral faces. One post-hoc interpretation of this phenomenon could be that the nearby presentation of faces has an effect of enhancing attentional engagement and thereby improving accuracy, but clearly this must be considered only speculative.

Study 3

2. Method

2.1.Participants

Healthy adult participants were recruited and received study credits for completing the study. Participants gave informed consent. The study was approved by the ethics review board. 95 participants completed the experiment (79 female, 16 male; 21 years, *SD* = 2.7) with accuracy above .5 on all conditions (*n* = 6 participants were removed).

2.2. Emotional Go/Nogo Task (emoGNG)

The same tasks as in Study 1 was used. The number of blocks per task was 5, and the number of trials per block were 24.

2.3. Procedure

Inclusion proceeded via an online participant-pool system. Participants could sign up for the study based on a brief description, after which they could read the extensive information and decide whether to continue. Participants performed both of the emoGNG versions, in random order. Other questionnaires and tasks were performed in the same session that were related to other studies.

2.4. Preprocessing and Statistical Analyses

Preprocessing and analyses were the same as in Study 1, with the exception of task version now being a within-subject variable.

3. Results

Descriptive statistics are presented in Table 3.

Table 3. RT and accuracy on the emoGNG, within-subject design

3A. Reaction time on Go trials

Task version	Emotion	RT (SD)
Task-irrelevant	Neutral	450 (29)
	Angry	452 (28)
Task-relevant	Neutral	423 (30)
	Angry	417 (31)

3B. Accuracy

Task version	Emotion	Go/Nogo	Accuracy
Task-irrelevant	Neutral	Nogo	.93
		Go	.95
	Angry	Nogo	.91
		Go	.95
Task-relevant	Neutral	Nogo	.90
		Go	.92
	Angry	Nogo	.87
		Go	.93

Note. Mean and standard deviation of reaction time in ms and mean accuracy in proportion correct per condition of the emoGNG over participants. Task version refers to task-relevance of the emotional expression of the faces (Neutral or Angry).

3.1. Task-Irrelevant emoGNG

There was no effect of Threat on RT and no interaction between Go and Threat on accuracy (p = .11). Go trials were more accurate than Nogo trials, $F(1, 94) = 30$, $p < .0001$, $\eta_p^2 = 0.24$ (.95 versus .92). Angry trials were less accurate than Neutral trials, $F(1, 94) = 5.5$, $p = 0.021$, $\eta_p^2 = 0.056$ (.93 versus .94).

3.2. Task-Relevant emoGNG

On RT, there was an effect of Threat, $F(1, 94) = 9$, $p = .0035$, $\eta_p^2 = 0.087$, responding to Angry faces being faster than responding to Neutral faces (417 ms versus 423 ms).

On accuracy, there was an interaction between Go and Threat, $F(1, 94) = 14$, $p = .0003$, $\eta_p^2 = 0.13$. This was due to lower accuracy for Angry than Neutral faces on Nogo trials, $F(1, 94) = 10$, $p = .00017$, $\eta_p^2 = 0.099$ (.92 versus .93 proportion correct), but higher accuracy on Go trials, $F(1, 94) = 4.6$, $p = .034$, $\eta_p^2 = 0.047$ (.93 versus .92 proportion correct). Further, Go trials were more accurate than Nogo trials, $F(1, 94) = 31$, $p < .0001$, $\eta_p^2 = 0.25$ (.93 versus .89).

3.3. Between-Task Comparisons

The above difference in effects between the tasks were formally tested using a repeated measures ANOVA. On RT, the interaction between Task version and Threat was significant, $F(1, 94) = 14$, $p = .00027$, $\eta_p^2 = 0.13$. On accuracy, the interaction between Task version, Go, and Threat was significant, $F(1, 94) = 4.9$, $p = .029$, $\eta_p^2 = 0.05$.

4. Discussion

The results replicated the main pattern of effects from Study 1, but in a within-subject rather than between-subject design. Again, only in the task-relevant task version were threat stimuli associated with faster responses. Further, the Threat x Go interaction was only found in the task-relevant version. The results of Study 3 this provide an important bridge to Study 4, in which 90-10 Go-Nogo proportions were used in a within-subject design.

Study 4

2. Method

2.1.Participants

Healthy adult participants were recruited and received study credits for completing the study. Participants gave informed consent. The study was approved by the ethics review board. 46 participants completed the experiment (40 female, 6 male, 21 years, *SD* = 6.2), with a minimum accuracy of .1 in all conditions. The minimum accuracy criterion used in previous studies (with equal go and nogo frequencies) was found to be too strict in this task variant, leading to rejection of the majority of participants. This was due to a large increase in the rate of commission errors. The more lenient criterion was used in order to attempt to restrict removal to participants who were most likely failing to try to inhibit responses at all (*n* = 6).

2.2. Emotional Go/Nogo Task (emoGNG)

The same tasks as in Study 3 were used, but with a 90% go, 10% nogo rate. For each task version, there was a practice task with 2 blocks of 24 trials. The full assessment versions of the tasks had 10 blocks of 24 trials.

2.3. Procedure

Inclusion proceeded via an online participant-pool system. Participants could sign up for the study based on a brief description, after which they could read the extensive information and decide whether to continue. Participants performed short practice versions of both emoGNG versions, and then assessment versions of both emoGNG versions, with the order of task-relevance randomized per participant.

2.4. Preprocessing and Statistical Analyses

The preprocessing and analyses were identical to Study 3. Only the assessment versions were used for analysis.

3. Results

Descriptive statistics are presented in Table 4.

Table 4. RT and accuracy on the emoGNG, 90-10 go-nogo rates version

4A. Reaction time on Go trials

Task version	Emotion	RT (SD)
Task-irrelevant	Neutral	416 (39)
	Angry	417 (38)
Task-relevant	Neutral	361 (45)
	Angry	362 (43)

4B. Accuracy

Task version	Emotion	Go/Nogo	Accuracy
Task-irrelevant	Neutral	Nogo	.56
		Go	.97
	Angry	Nogo	.55
		Go	.97
Task-relevant	Neutral	Nogo	.52
		Go	.97
	Angry	Nogo	.53
		Go	.96

Note. Mean and standard deviation of reaction time in ms and mean accuracy in proportion correct per condition of the emoGNG over participants. Task version refers to task-relevance of the emotional expression of the faces (Neutral or Angry).

3.1. Task-Irrelevant emoGNG

There was no effect of Threat on RT (p = .093, direction of effect in reversed direction) and no interaction between Go and Threat on accuracy (p = .86). Go trials were more accurate than Nogo trials, $F(1, 45) = 520$, $p < 0.0001$, $\eta_p^2 = 0.92$ (.97 versus .56).

3.2. Task-Relevant emoGNG

There was no effect of Threat on RT (p = .76) and no interaction between Go and Threat on accuracy (p = .12). Go trials were more accurate than Nogo trials, $F(1, 45) = 400$, $p < 0.0001$, $\eta_p^2 = 0.90$ (.97 versus .53).

3.3. Between-Task Comparisons

There were no interactions involving task version.

4. Discussion

With 90-10 rates of go and nogo trials, there was no sign of the threat-related effects found in previous studies. This was the case for both the task-relevant and task-irrelevant version. We reiterate one of the reasons for using equal versus unequal rates: the block-context strongly differs when Threat is mapped to go versus nogo responses (e.g., the frequency of Angry versus Neutral faces changes along with the current block's task instructions), which may well interact with effects of trial type. While there are clearly many possible variations involving go - nogo rates, the current study's rationale and results would appear to suggest that using 50-50 rates should be considered a potentially interesting and valid design choice. The consistent threat-related results found for the task-relevant version with 50-50 rates were lost with the 90-10 rates, and there is no indication that this change revealed threat-related effects that were absent in the previous task-irrelevant versions.

5. General Discussion

The current studies aimed to determine whether threat induces impulsivity as reflected in both speeding and commission errors on a Go-Nogo task. A number of task design choices were explored. As discussed in the introduction, there were various reasons to choose equal rates for go and nogo frequencies, and the null results of Study 4, which used 90-10 rates in contrast with the other three studies, suggest that the 50-50 design is more sensitive to threat effects. In the first three studies, but only in the task-relevant versions, the presence of angry faces caused faster responses and more commission errors. This is in line with a reduction in response threshold induced by threatening stimuli, as would be expected from their evolutionary significance. No significant effects involving threat-induced impulsivity were found in the task-irrelevant versions. It may be the case that the automatic bias due to threatening stimuli only induces impulsivity when the inducing stimuli are task-relevant, as has been found in previous work, with various broadly related conceptualizations of task-relevance (Lichtenstein-Vidne et al., 2012; Spruyt et al., 2009, 2018). Note that this does not entail a "non-automatic" effect - participants were not instructed to respond faster to Threat stimuli, but this occurred automatically when they had to process emotional information to perform the task. It may also be the case that when distractors were task-irrelevant, the effect of the facial expression was muted via selective attention. The ability to suppress, or treat as irrelevant, potentially distracting emotional information has been speculated to play a conceptually similar role in various effects related to attentional biases (Gladwin, 2017; Gladwin, Ter Mors-Schulte, Ridderinkhof, & Wiers, 2013). In this case, the ability to tune out task-irrelevant, potentially distracting information could reduce threat-evoked effects on task-irrelevant Go-Nogo tasks.

The impact of having the threatening stimuli appear to have closer proximity was as predicted for reaction times, although, again, effects required task-relevant stimuli. Although effects on accuracy were more difficult to interpret, relative proximity increased threat-induced speeding. This was expected given the view of a natural, evolutionarily preserved tendency to respond quickly, and hence with less extensive evaluation of response selection, to nearby threatening stimuli (Blanchard et al., 2001, 2005; Bradley, 2009). Proximal threat evokes psychophysiological activity related to acute emotional-physiological responses to threat (Löw, Lang, Smith, & Bradley, 2008; Mobbs et al., 2007). In line with this, neuroimaging results from the Fear and Escape Task (Montoya, Terburg, Bos, & van Honk, 2012) in a population of veterans indicate that abnormal reactions to proximity may be involved in anger and aggression problems (Heesink et al., 2017). A "looming" stimulus (Vagnoni, Lourenco, & Longo, 2012) was found to evoke abnormally strong activation in attention-related brain regions in participants with anger and aggression problems. It would appear that anger disorders are a particularly worthwhile clinical focus of further study of proximity-enhanced, threat-induced speeding.

The current study had a number of limitations. First, a sample of students was used for pragmatic reasons, rather than, e.g., potentially interesting clinical or forensic groups. It is possible that different effects would be found in groups with more dysfunctional responses to threat. Second, the study was online, which reduces the ability to control the testing environment, but has clear practical advantages in terms of the efficiency of acquiring data. In future studies, in particular using clinical populations, a different trade-off of concerns could indicate the use of laboratory settings. Third, although the results of Study 4 appear to point in a clear direction supporting the use of equal probabilities in this context, it is not certain to which extent the results will or will not generalize to Go/Nogo tasks with other specific proportions of nogo trials. Fourth, the numbers of blocks and trials were slightly different in different studies. There was no principled reason for the precise trial numbers, but this minor difference would not seem to substantially affect any conclusions drawn from the studies. Fifth, the study was focused on a specific stimulus type, namely faces with angry versus neutral expressions. While this was a conscious feature of the study and specifically extends the literature on emotional Go/Nogo tasks to these stimuli, the current results cannot say whether the differences between the Emotion-Relevant and Emotion-Irrelevant task versions will generalize to different stimuli. We also cannot specify the precise feature of the threatening stimuli that induced impulsivity, e.g., whether the angry faces were more arousing or more negative (note that threat itself as a concept is related to both arousal and negative valence). There is clearly scope for many lines of future research, exploring many more variations of task design and parameters; however, the current results provide a proof of principle that at least using the current stimuli and task parameters, task-relevance affects impulsivity evoked by stimuli involving threat.

In conclusion, angry versus neutral faces are able to induce impulsive responding, but significant effects were only found when these emotional stimuli were task-relevant and when go and nogo trials were equally frequent. With this task version, partial support was found in RT effects for the hypothesis that threat-induced impulsivity would be enhanced by increasing the perceived proximity of the threatening stimulus. Future research in which effects of impulsivity on RT are of interest could consider using this task design.

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Declaration of conflicting interests

The Authors declare that there is no conflict of interest.

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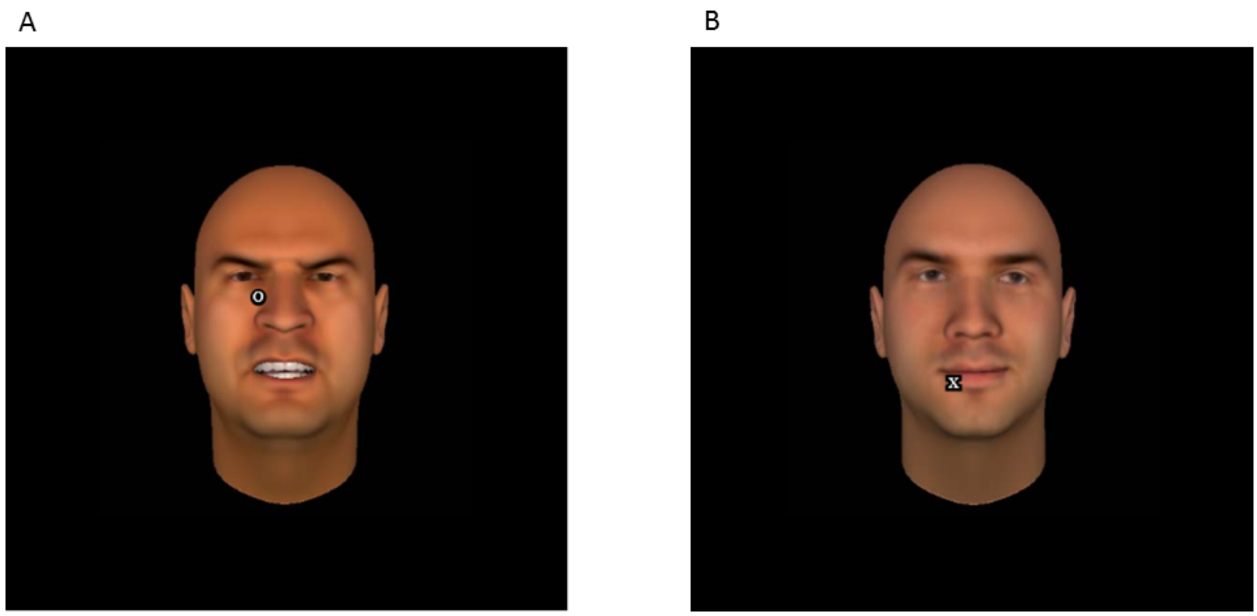
Figure 1. Illustration of stimuli during the Emotional Go-Nogo training task



Note. Stimuli were an Angry or Neutral face with an X or an O superimposed at a random location. Figures A and B show examples of an Angry face with an O and a Neutral face with an X, respectively.