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ORIGINAL ARTICLE

The effects of induced and trait anxiety on the sequential modulation of emotional conflict

Hee Jung Jeong[1] · Yang Seok Cho[2]

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Abstract

The current study aimed to investigate whether induced anxiety, as well as trait anxiety, would lead to the failure of the regulation of emotional conflict. To measure the regulation of emotional conflict, the congruency sequence effect (CSE), which is a reduced effect of task-irrelevant distractor after incongruent trials compared to congruent trials, was observed while participants performed an emotional conflict task. In Experiment 1, participants performed the task in a safe context and a threatening context where a couple of electric shocks were given randomly on two consecutive days. In Experiment 2, participants performed the same task in either a safe or threatening context to avoid a potential carryover effect of the threat. The CSE observed in the safe context disappeared in the threatening context as well as in participants with high-trait anxiety level even without the threat. The findings imply that induced anxiety causes a failure of cognitive control that engenders the CSE in emotional congruency tasks. Moreover, such failure driven by participants' trait anxiety level might be a potential predisposing factor leading to anxiety disorders. Overall, these results suggest that induced anxiety, as well as trait anxiety, has an adverse impact on the sequential modulation of emotional conflict.

Introduction

Difficulty in emotion regulation is a major pathophysiology of anxiety disorders (Etkin, Prater, Hoeft, Menon, & Schatzberg, 2010; Mennin, Heimberg, Turk, & Fresco, 2005). Various attempts have been made to understand the underlying mechanisms of deficits in emotion regulation in the anxious population. Among diverse aspects of emotion regulation, dynamic adjustments of emotion regulation have been investigated as a measure of cognitive flexibility (Aldao, Sheppes, & Gross, 2015). One way to assess cognitive flexibility is by measuring the extent of distractor interference caused by emotional stimuli. The degree of distractor interference can be measured using the congruency effect, which refers to increased response times or error rates when a distractor mismatch with the target stimulus in emotional content (i.e., incongruent trials) compared to non-conflict (i.e., congruent) trials (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006). The greater the congruency effect, the greater one is interrupted by emotional distractors. Moreover, this congruency effect is found to be modulated by previous-trial congruency. Specifically, the size of the congruency effect is reduced following incongruent trials compared to following congruent trials, widely known as the congruency sequence effect (CSE; Gratton, Coles, & Donchin, 1992). Among many accounts on the CSE, the conflict monitoring theory poses that the CSE occurs because a conflict monitoring system detects conflict and sends signals to other regions to reduce conflict in subsequent trials (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Kerns, Cohen, MacDonald, Cho, Stenger, & Carter, 2004; but see Hommel, Proctor, & Vu, 2004; Mayr, Awh, & Laurey, 2003; Schmidt & De Houwer, 2011; Schmidt & Weissman, 2016, for challenges to the conflict monitoring hypothesis).

To investigate the underlying mechanism of the CSE with emotional stimuli, Etkin et al. (2006) conducted an experiment, in which participants were asked to respond to the expression of a target face (happy or fearful) while ignoring a task-irrelevant emotional word ("HAPPY" or "FEAR") superimposed on the face. The CSE was found in the emotional conflict task, reflecting the resolution of emotional

✉ Yang Seok Cho
yscho_psych@korea.ac.kr

Hee Jung Jeong
hee.jung.jeong.2@vanderbilt.edu

1 Department of Psychology, Vanderbilt University, Nashville, TN, USA

2 Department of Psychology, Korea University, 145 Anam-ro, Seongbuk-gu, Seoul 02841, Korea

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conflict driven by previous-trial conflict. Since the behavioral adjustment in response to conflict was achieved without participants' awareness, the CSE obtained in the emotional conflict task was considered as reflecting cognitive flexibility (Robinson, Letkiewicz, Overstreet, Ernst, & Grillon, 2011) or implicit emotion regulation (Etkin et al., 2010). For neural correlates, the rostral part of the anterior cingulate cortex (rACC) was found to be associated with the resolution of conflict following conflict trials. Moreover, the activation of the rACC was further related to a reduction of amygdalar activity that was positively correlated with the amount of conflict. In a follow-up study, consistent with the idea that anxious individuals have difficulty in emotion regulation, the CSE disappeared in a generalized anxiety disorder (GAD) patient group while performing the emotional conflict task (Etkin et al., 2010). Along with the disappearance of the CSE, Etkin et al. also found that the interconnectivity between rACC and amygdala was absent in the GAD patients, possibly underlying the failure of conflict adjustment in this group.

On an epidemiological perspective, individuals with high-trait anxiety are more likely to develop anxiety disorders that may arise from cognitive vulnerability factors, including systematic biases in the processing of emotional events (Eysenck, 2013; Eysenck & Byrne, 1992). For instance, an attentional bias to threat, which is considered the major characteristic of anxiety disorder (Eysenck, 2013), is often found in people with high-trait anxiety as well (Cisler & Koster, 2010), indicating that anxiety may result from hypervigilance to a potential threat. Thus, investigating whether difficulty in emotion regulation would be observed in non-pathological individuals with high-trait anxiety could enable identification of a functional deficit in the regulation of emotional conflict as a vulnerability factor for anxiety disorders.

Even those without high-trait anxiety, people are also exposed to causal factors for anxiety in everyday life, ranging from minor occasions, such as a class presentation, to life-threatening incidents, like an industrial accident. Although it may not be as disruptive as in pathological cases, anxiety under such circumstances could cause interference in cognitive processing in non-pathological individuals as well (Cassady & Johnson, 2002; Choi, Padmala, & Pessoa, 2012; Robinson, Vytal, Cornwell, & Grillon, 2013). Therefore, understanding how people function in an anxious state is a relevant topic to everyday life. To observe performance under anxiety in non-pathological individuals, anxiety can be induced in an experimental setting through electric shocks and performance in the threatening and non-threatening contexts is compared (Robinson et al., 2013). Inducing anxiety through an experimental manipulation has advantages over measuring state anxiety scores because an observable effect in the threatening context can be attributed to the experimental manipulation of inducing anxiety given that other variables have been controlled.

Under the threat of shock, Robinson and colleagues investigated the impact of induced anxiety on the CSE while performing an emotional task in non-pathological individuals (Robinson et al., 2011). In their experiment, participants performed the emotional conflict task used in Etkin et al.'s (2006) study while alternatively experiencing safe and threatening contexts. In the threatening context, two doses of an electric shock, non-contingent on performance, were given to induce anxiety. Robinson et al. found that this anxiety manipulation caused an enhancement of aversive processing, but had no effect on conflict regulation; the CSE was observed in both the safe and threatening contexts. In contrast with Etkin et al.'s (2010) study, Robinson et al. concluded that the disruption to cognitive adjustment caused by emotional conflict is unique to the pathological disorder, and does not occur in non-pathological individuals.

From an alternative point of view, this null result could have arisen from several limitations of Robinson et al.'s (2011) experiment. Firstly, they used a task with only two stimulus and response alternatives so that the bottom-up repetition priming was not controlled (Hommel et al., 2004; Mayr et al., 2003). In two-alternative forced choice tasks, on congruent trials after a congruent trial (cC) and incongruent trials after an incongruent trial (iI), the features of stimulus and response alternatives are completely repeated or alternated, resulting in fast responses. In contrast, on congruent trials after an incongruent trial (iC) and incongruent trials after a congruent trial (cI), the features are partially repeated, resulting in a delayed response compared to the complete repetition or complete alternation trials. Consequently, without controlling the feature repetition, it is unclear whether the obtained CSE reflects top-down conflict resolution or bottom-up repetition priming. In this regard, the CSE observed in Robinson et al.'s experiment was possibly due to a bottom-up repetition priming effect that was not interrupted by the threat of electric shock.

Another potential caveat is that a carryover effect could not have been avoided in an experimental design employed in Robinson et al.'s (2011) study. Previous studies indicate that the effect of the threat of shock can be transferred to the safe context when performing an emotion regulation task (Barlow & Hayes, 1979; Pedersen & Larson, 2016). For instance, in Pedersen and Larson's experiment, in which participants were asked to regulate their emotion upon viewing negatively valenced pictures, they performed the task either in the safe context first and then the threatening context, in which electric shocks were given, or vice versa. Pedersen and Larson found that the participants in the safe-first condition reported higher anxiety in the threatening context than in the safe context, whereas those in the threatening-first condition showed no difference in anxiety between the safe and threatening contexts. Moreover, the late positive potential (LPP) amplitude, of which its increase and decrease reflect up- and down-regulation to emotional stimuli, respectively (Hajcak & Nieuwenhuis, 2006; Moser, Krompinger, Dietz, & Simons, 2009; Pedersen & Larson, 2016; Thiruchselvam, Blechert, Sheppes, Rydstrom, & Gross, 2011), increased in the safe context followed by the threatening context, which the authors interpreted as a carry-over effect of threat. Therefore, it is possible that the impact of the threat of electric shock could have been transferred to the safe context in Robinson et al.'s experiment, resulting in a null difference in performance between the two different contexts.

The present study aimed to examine the impact of induced anxiety on the CSE in emotional conflict tasks while circumventing the limitations of the previous research in the following ways. To avoid the bottom-up repetition priming effect, four emotional categories (happy, sad, surprise, and anger) were used in the present study. Each emotional category was associated with one response so that there were four stimulus alternatives and four response alternatives. Two emotional categories were paired as one task each, happy and sad as one task and surprise and anger as the other task, and these two tasks were presented alternatively in a trial-by-trial manner. In this way, no stimulus or response feature of the previous trial was ever repeated on a given trial, so that the influence of repetition confounding was minimized (Kim & Cho, 2014; Schmidt & Weissman, 2014). Such manipulation was critical to attribute the obtained CSE to top–down conflict adjustment, not to the bottom-up priming effect.

To avoid a potential carryover effect, participants performed the task in a safe context and a threatening context, in which a couple of electric shocks were given randomly to induce anxiety, on two consecutive days in Experiment 1. Specifically, half of the recruited participants performed the task in the safe context on the first day and then in the threatening context on the following day and the other half underwent the threatening context first and then the safe context to counterbalance a potential order effect. To further minimize a possible carryover effect, an additional experiment was conducted with a between-subject design in Experiment 2: Half of the participants performed the task in the safe context and the other half performed the task in the threatening context. To investigate the influence of trait anxiety, participants' trait anxiety level was measured through questionnaires and its impact on performance was observed in both the safe and threatening contexts.

Lastly, unlike previous experiments in which faces served as targets and words as distractors, participants were asked to respond to words while ignoring faces. In daily life, people must often deal with irrelevant facial expressions and struggle to suppress their interference with task performance, such as disapproval in a job interview or skepticism in a conference talk. Therefore, observing the modulation of interference caused by a facial expression is more relevant to the circumstances we face in daily experiences. Additionally, interference caused by facial stimuli has been found to be larger than that caused by word stimuli (Beall & Herbert, 2008). Thus, to intensify the interference effect, facial stimuli were used as distractors.

Experiment 1

In Experiment 1, participants performed an emotional conflict task under the safe and threatening contexts to assess the effect of threat on the CSE. Since a potential carryover effect of electric shocks might take place when participants undergo both contexts alternatively in one experimental setting (Pedersen & Larson, 2016), participants performed the task under each context one day apart. In the task, two pairs of two emotional categories—happy and sad as one pair and surprise and anger as the other pair—were presented in an alternating order so that the repetition of features between consecutive trials were avoided (Kim & Cho, 2014). If anxiety brings about an adverse effect on emotion regulation, the CSE, reflecting top-down adjustment, would disappear under the threat of shock while performing the emotional conflict task. In a similar vein, participants with high-trait anxiety were expected to demonstrate a deficit in the regulation of emotional conflict reflected through the failure of cognitive adjustment.

Methods

Participants

Thirty-six undergraduate students (seventeen females, mean age = 23.2) at Korea University with no history of the psychological disorder and free of medication voluntarily participated in exchange for KRW 9000 (about 8 USD) per hour. All participants were right-handed and had normal or corrected-to-normal visual acuity indicated by self-report. The demographic information of participants in Experiment 1 is listed in Table 1. The study was approved by Korea University Institutional Review Board (KU-IRB-16-177-P-1) and participants gave written consent prior to the experiment.

Table 1 Demographic information of Experiment 1 and Experiment 2

	Experiment 1 ($N=36$)		Experiment 2 ($N=72$)					
			Safe ($N=36$)		Threat ($N=36$)			
	N	%	*N*	%	*N*	%		
Female	17	47	18	50	18	50		
Right-handed	36	100	34	94	36	100		
	M	*SD*	*M*	*SD*	*M*	*SD*	Test	*p* value
Age (years)	23.2	1.99	23.27	3.28	22.72	2.67		
Spielberger state anxiety	38.31	9.37	38.64	9.22	37.92	8.27	$t=0.35$	0.7275
Spielberger trait anxiety	43.17	7.75	41.14	6.66	44.08	9.27	$t=1.55$	0.126

Test indicates independent *t* test conducted on questionnaire scores of participants in the safe context and the threatening context in Experiment 2

M mean, *SD* standard deviation

Personality questionnaires

Prior to the main experiment, participants completed the Spielberger State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) in a Korean translated version to observe any modulating effect of their trait anxiety level on the performance.

Stimuli and apparatus

Stimuli were controlled by Psychtoolbox 3 implemented in MATLAB 2008b. Each trial consisted of a fixation display and a target display. In the fixation display, a white cross (0.3° × 0.3° in visual angle) was presented at the center of the display as the fixation point. In the target display, a target word (2.63° × 0.66° in visual angle) was presented at the center of the display above an expressive face (3.58° × 3.58° in visual angle). "기쁨" (happy), "슬픔" (sad), "놀람" (surprise), and "분노" (anger) were used as target words in Korean characters. Facial stimuli showing happiness (valence = 6.44, arousal = 4.71, intensity = 6.42, accuracy = 97.79%, on average), sadness (valence = 1.57, arousal = 4.9, intensity = 3.24, accuracy = 95.89%, on average), surprise (valence = 3.57, arousal = 3.12, intensity = 5.71, accuracy = 93.04%, on average), and anger (valence = 1.88, arousal = 4.64, intensity = 5.72, accuracy = 94.62%, on average) were selected from the Korea University Facial Expression Collection-Second Edition (KUFEC-II; Kim et al., 2017). The mean valence, arousal, and intensity scores were rated on a 7-point Likert scale. Four grey-scaled faces (two females and two males), matched in mean luminance (115 cd/m^2) and contrast (55%) were used for each emotional category. Each face was arranged so that the eyes and mouths were aligned in the same positions across trials. The facial stimulus on each trial was selected pseudo-randomly to avoid repetition of the same facial stimulus presented on $n-2$ trials.

Responses were made by pressing one of four keys on a standard computer keyboard. Participants were asked to press the "j" key with their right index finger in response to the word "HAPPY", the "f" key with their left index finger in response to the word "SAD", the "k" key with their right middle finger in response to the word "SURPRISE", and the "d" key with their left middle finger in response to the word "ANGER". Congruency of the trial was determined by the match or mismatch between the meaning of the target word and the distracting facial expression. All stimuli were presented on a grey background on a 21.5 in. LCD monitor (LG 22EA53) with a screen resolution of 1280 × 768 pixels and viewed at a distance of 60 cm.

To avoid the repetition priming effect (Hommel et al., 2004; Mayr et al., 2003), two stimuli were paired as one task: Participants responded to the word "HAPPY" or "SAD" accompanied by happy or sad facial expression with their index fingers and responded to the word "SURPRISE" or "ANGER" accompanied by surprised or angry expression with their middle fingers. The two tasks were presented alternately in a trial-by-trial manner so that there was no repetition of any stimulus or response feature between a given trial and the previous trial (Kim & Cho, 2014).

Electric shock

An electric shock with a moderate intensity was administered for 500 ms on the left ring and little fingers with an electric stimulator (Coulbourn Instruments, PA, USA) in the threatening context. Participants were asked to adjust the intensity of the shock prior to the main experiment to be "irritating but not painful." Participants were informed that during the experiment, electric shocks would be given randomly. To maintain their level of anxiety and to preclude habituation, participants were asked to report the intensity of the electric shock during each break and its intensity was adjusted again if necessary. In each block, the electric shock was delivered two or three times randomly.

Skin conductance

During the main experiment, skin conductance (SC) data were collected with a PowerLab 4/30 amplifier with an ML116 GSR Amp (ADInstruments) through electrodes (MLT116F) attached to the ring and little fingers of the right hand at a sampling rate of 200 Hz to measure the impact of threat of shock on physiological arousal during task performance.

Procedure

Participants participated in the experiment for two consecutive days: Half of them were to perform the task in the safe context on the first day and in the threatening context on the following day and the other half in the opposite order to counterbalance a potential order effect. Participants performed the experiment individually in a dimly lit, soundproof chamber. The midline of the participant's body and the keyboard were aligned to the center of the monitor. Each experiment consisted of eight blocks, each followed by a break of 1 min. Each trial started with a fixation display presented for 500 ms followed by a blank display for 1000 ms. A target display was then presented for 250 ms. A feedback tone was given for 150 ms for an incorrect response or no response within 2000 ms. An additional blank display followed for 1000 ms before the next trial began. The experiment started with a 30-trial practice block. In the safe context, each block consisted of 82 trials. In the threatening context, each block consisted of 90 trials to compensate for the loss of trials due to shock administration. Trials were presented in a pseudorandom order to balance the proportions of trial types—congruent trials preceded by congruent trials (cC), congruent trials preceded by incongruent trials (iC), incongruent trials preceded by congruent trials (cI), and incongruent trials preceded by incongruent trials (iI)—as a function of current trial congruency and n-1 trial congruency. Trial sequences and experimental procedure are illustrated in Fig. 1.

Data preprocessing and statistical analyses

Behavioral data

The first trials of each block, error trials, and trials immediately following an error trial were removed from reaction time (RT) analyses (8.71% for the safe context, 9.08% for the threatening context) to include trials with $n-1$ trial congruency for analyses (Duthoo, Abrahamse, Braem, & Notebaert, 2014; Weissman, Jiang, & Egner, 2014). RTs shorter than 150 ms and longer than 1250 ms were excluded as RT outliers (4.74% for the safe context, 6.73% for the threatening context). For the threatening context, trials in which the shock was administered and the immediately following trials were removed from analyses (6.38%) to analyze trials that were influenced by threat of shock, not by the actual physical stimulation. This resulted in a total of 12.2% and 21.89% of trial exclusion for RT analyses for the safe context and the threatening context, respectively. After data trimming, mean correct RTs and percent errors were calculated for each participant as a function of current trial congruency (congruent or incongruent), $n-1$ trial congruency (congruent or incongruent), and context (safe or threatening). Analyses of variance (ANOVAs) were conducted on the mean correct RTs and percent errors with above-mentioned factors as within-subject variables.

Since the absence of the interaction between current trial congruency and $n-1$ trial congruency was of main interest, we further compared the likelihood of the interaction in the safe context and the threatening context by computing Bayes Factor. Bayes Factor in favor of the alternative hypothesis (BF_{10}) provides an odd ratio in favor of the alternative hypothesis (H_1; e.g., the presence of the interaction) against the likelihood of the null hypothesis (H_0; e.g., the absence of

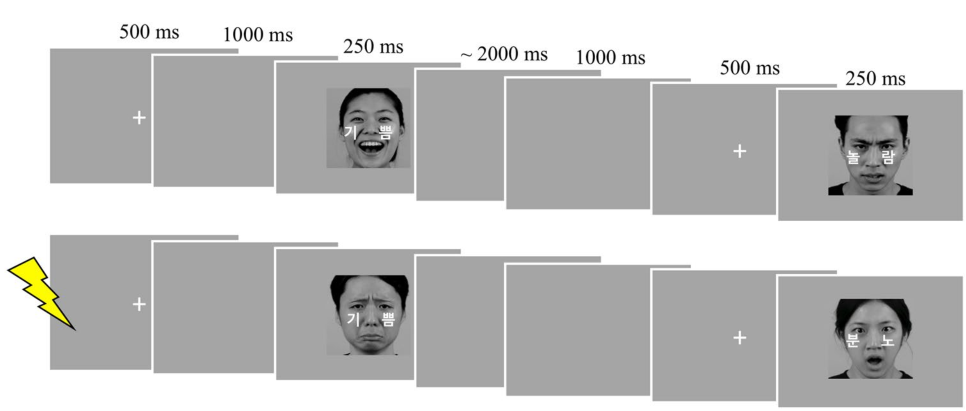


Fig. 1 Example of trial sequences. Happy–sad paired task and surprise–anger paired task were presented alternatively in a trial-by-trial manner. In the threatening context, a random electric shock could be given throughout a block

the interaction; Wagenmakers et al., 2018). The Bayes Factor of the interaction model is computed by the ratio of BF_{10} of interaction model and BF_{10} of the main effect model (i.e., $BF_{10\ \text{interaction model}}/BF_{10\ \text{main effect model}}$; Rey-Mermet, Gadea, & Steinhauser, 2019). For our purpose, the Bayes Factors of the interaction between current trial congruency and $n-1$ trial congruency were obtained for the safe and threatening contexts separately to compare them. The Bayes Factor in favor of the null hypothesis was computed by $1/BF_{10}$. As in previous studies (Raftery, 1995; Rey-Mermet et al., 2019), Bayes Factors between 1 and 3 were interpreted as weak evidence, between 3 and 20 as positive evidence, and between 20 and 150 as strong evidence.

Personality questionnaires

The size of the congruency effect (I–C) and the size of the CSE ([cI − cC] − [iI − iC]) were calculated as a function of context (safe or threatening) for RTs and percent errors. Pearson correlations were calculated to measure the relationships between questionnaire scores [state anxiety score (STAI-S) and trait anxiety score (STAI-T)] and the magnitudes of the congruency effect and the CSE (Table 2). We expected that the positive relationship between anxiety measures and the size of the congruency effect would indicate high interference by emotional stimuli whereas the negative relationship between anxiety measures and the size of the CSE indicates decreased cognitive flexibility in anxious individuals.

Skin conductance

Raw SC data were smoothed with a median filter over 40 samples to reduce high-frequency noise. Subsequently, the filtered data for 15 s following each shock were removed to ensure that the analysis would include only data reflecting anxiety caused by anticipation of a shock in the threatening context. The pre-processed data for each participant were averaged. Then, a dependent samples *t* test was conducted to compare skin conductance between the safe context and the threatening context. It was expected that SCR would be higher in the threatening context compared to the safe context.

Results

RT

To check for a potential order effect, a between-subject factor of order (safe or threatening context first) was included in the analysis. There was no significant main effect of order or interaction of order and any other variables ($ps > 0.1$). A main effect of context was observed, $F(1, 35) = 4.51$, $p = 0.0408$, MSE = 9192, $\eta_p^2 = 0.11$; the mean RT was shorter in the safe context (719 ms) than in the threatening context (743 ms), indicating that the threat of shock caused impairment on overall task performance. The main effect of current trial congruency was significant, $F(1, 35) = 57.57$, $p < 0.0001$, MSE = 532, $\eta_p^2 = 0.62$. The mean RT was shorter on congruent trials (721 ms) than incongruent trials (741 ms). Also, a main effect of $n-1$ trial congruency was observed, $F(1, 35) = 10.18$, $p = 0.003$, MSE = 161, $\eta_p^2 = 0.23$. The mean RT was longer following incongruent trials (733 ms) than following congruent trials (728 ms), indicating post-conflict slowing (Verguts, Notebaert, Kunde, & Wühr, 2011). Consistent with the prediction, a significant three-way interaction of current-trial congruency, $n-1$ trial congruency, and context was observed, $F(1, 35) = 6.5$, $p = 0.0153$, MSE = 169, $\eta_p^2 = 0.16$. To decompose this three-way interaction, two-way ANOVAs with current trial congruency and $n-1$ trial congruency as variables were conducted for the safe and threatening contexts separately. A significant interaction between current trial congruency and $n-1$ trial congruency was observed in the safe context (see Fig. 2), $F(1, 35) = 9.35$, $p = 0.0043$, MSE = 187, $\eta_p^2 = 0.21$. The congruency effect was smaller following incongruent trials (13 ms), $F(1, 35) = 11.85$, $p = 0.0015$, MSE = 258, $\eta_p^2 = 0.25$, than following congruent trials (27 ms), $F(1, 35) = 54.99$, $p < 0.0001$, MSE = 238, $\eta_p^2 = 0.61$. BF_{10} for the interaction was 7.75, indicating positive evidence of the interaction. On the other hand, in the threatening context, the interaction between current trial congruency and n-1 trial congruency failed to reach significance (see Fig. 2), $F < 0.5$, $p > 0.7$. BF_{01} for the interaction was 4.17, implying the evidence for the null interaction.

Table 2 Pearson correlations of questionnaire scores and the size of the congruency effect and the CSE in Experiment 1

	Safe				Threat			
	RT		PE		RT		PE	
	CE	CSE	CE	CSE	CE	CSE	CE	CSE
Spielberger state anxiety	0.12	0.03	0.17	0.06	0.13	0.32	− 0.04	− 0.08
Spielberger trait anxiety	− 0.09	0.16	0.02	0.10	− 0.06	0.20	0.04	− 0.32

RT reaction time, *PE* percent error, *CE* congruency effect, *CSE* congruency sequence effect

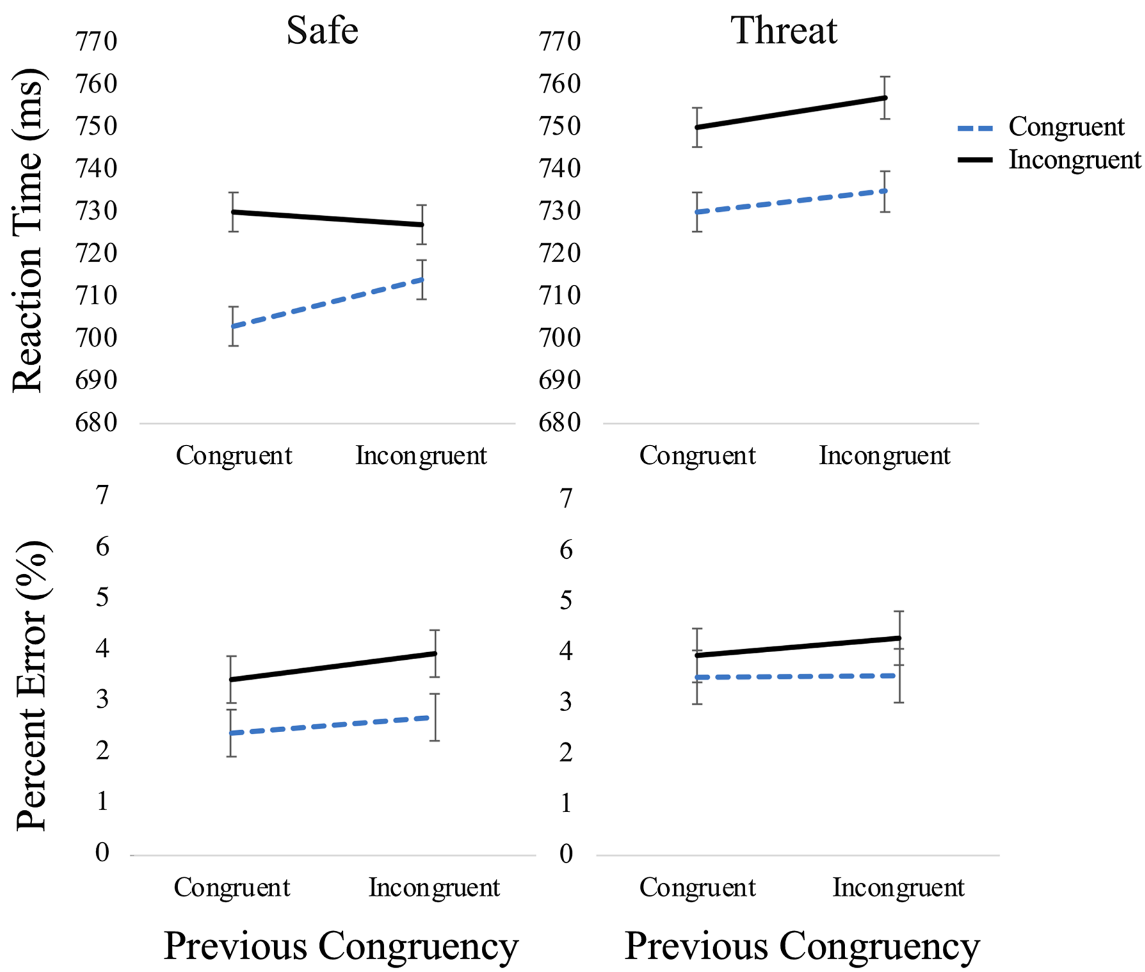


Fig. 2 Mean correct reaction times and percent error as a function of current trial congruency and n-1 trial congruency in the safe and threatening contexts in Experiment 1. Error bars indicate the 95% confidence interval around the mean (Loftus & Masson, 1994)

Percent error

A significant congruency effect was observed, $F(1, 35) = 17.26$, $p = 0.0002$, MSE = 3.15, $\eta_p^2 = 0.33$. Participants made more errors on incongruent trials (3.91%) than on congruent trials (3.04%). Also, a main effect of $n - 1$ trial congruency on percent errors was obtained, $F(1, 35) = 4.78$, $p = 0.0355$, MSE = 1.35, $\eta_p^2 = 0.12$. Participants made more errors following incongruent trials (3.62%) than following congruent trials (3.32%) indicating that the post-conflict slowing found in the RT data was not due to speed-accuracy trade-off. There was no significant interaction between current trial congruency and n-1 trial congruency, $F < 0.5$, $p > 0.4$, or three-way interaction, $F < 0.05$, $p > 0.8$.

Personality questionnaires

The raw scores of participants state anxiety (STAI-S) trait anxiety (STAI-T) data are presented in Table 1. A significant correlation between state anxiety score and trait anxiety score was observed, $r = 0.69$, $p < 0.001$. There was no significant correlation between questionnaire scores and RT indices ($ps > 0.07$) and percent error indices ($ps > 0.05$).

Skin conductance

A significant effect of context on SC data was observed, $t(35) = 2.42$, $p = 0.0208$, $d = 0.8$. The mean SC was higher in the threatening context (3.55 µS) than in the safe context (2.34 µS), indicating that participants were more physiologically aroused in the threatening context than in the safe context and our anxiety manipulation was effective.

Discussion

In Experiment 1, a significant CSE was obtained while participants performed the emotional conflict task under the safe context. Notably, such effect disappeared when participants performed the task under the threat of electric shocks in the RT data. This finding indicates that participants failed to adjust to the conflict, which is consistent with the prediction that anxiety disrupts cognitive adjustment involving emotional stimuli. Such interpretation is substantiated by the findings that the threat of shock caused a general response slowdown as well as heightened skin conductance responses in comparison to those in the safe context. Unlike induced anxiety, however, trait anxiety did not seem to have any modulatory effect on performance indices. This was rather unexpected given the previous accounts of deficiency in emotion regulation in high-trait anxious individuals (Bishop, Duncan, Brett, & Lawrence, 2004). One possibility for the lack of the modulation of the CSE by trait anxiety is that the failure associated with dynamic conflict regulation reflected through the CSE is specific to pathological anxiety disorders, like GAD. On the other hand, the experimental manipulation of context might have been conspicuous so that it nullified any difference associated with trait anxiety. Moreover, even though there was no significant modulation by the context order, there could have been a transfer effect of shock undetected. Thus, Experiment 2 was conducted to minimize any potential order effect.

Experiment 2

To examine the impact of induced anxiety on the CSE in emotional conflict tasks with further minimizing the carryover effect and other unknown effects associated with being exposed to both contexts, Experiment 2 was conducted as a between-subject design. Specifically, participants were randomly assigned to a safe or threatening context, respectively, and performance was compared between the contexts. Participants performed the same emotional conflict task used in Experiment 1: Two paired emotional tasks were presented in an alternating manner to avoid repetition of a stimulus and a response from previous trials. It was predicted that if anxiety interferes with emotion regulation, the CSE would disappear in the threatening context as well as in participants with high-trait anxiety.

Methods

Participants

Seventy-two newly recruited undergraduate students at Korea University with no history of the psychological disorder and free of medication voluntarily participated. Thirty-six participants were assigned to the safe context (eighteen females, mean age = 23.3) and the other thirty-six were assigned to the threatening context (eighteen females, mean age = 22.7). All participants had normal or corrected-to-normal visual acuity. Two participants were left-handed and the remaining were right-handed by self-report. The demographic information of participants in Experiment 2 is shown in Table 1.

Personality questionnaires

Prior to the task performance, participants completed the STAI to investigate the impact of state and trait anxiety on performance.

Stimuli and apparatus

All experimental stimuli and apparatus in Experiment 2 were adopted in the same manner as in Experiment 1.

Electric shock

For participants assigned to the threatening context, an electric shock was administered two or three times randomly during each block while performing the task. Participants were asked to adjust the intensity of the shock prior to the main experiment to be “irritating but not painful” and adjust it again during the break when they reported being habituated to the shock.

Skin conductance

For both the safe and threatening contexts, SC data were collected during the main experiment in the same manner as in Experiment 1.

Procedure

Experimental procedures were same as in Experiment 1 with the following exceptions. After completing the practice session consisting of 30 trials, participants performed the main task either in the safe context or in the threatening context. In the safe context, the main task consisted of eight blocks of 82 trials whereas in the threatening context, the main task consisted of eight blocks of 90 trials in which additional trials were added to compensate for trial loss due to shock administration.

Data processing and statistical analyses

The first trials of each block, error trials, trials immediately following an error trial were removed from RT analyses (9.32% for the safe context, 10.52% for the threatening context). RTs shorter than 150 ms and longer than 1250 ms were excluded as RT outliers (4.92% for the safe context, 4.67% for the threatening context). Trials in which shock was administered and the immediately following trials

(6.38%) in the threatening context were further removed from analyses. A total of 13.13% and 21.35% of trials were removed from analyses for RT analyses for the safe context and the threatening context, respectively. Mean correct RTs and percent errors were calculated for each participant as a function of current trial congruency and $n-1$ trial congruency. ANOVAs were conducted on the mean correct RTs and percent errors with current trial congruency and $n-1$ trial congruency as within-subject variables and context as a between subject-variable. The Bayes Factor for the interaction between current trial congruency and $n-1$ trial congruency was calculated in the same manner as in Experiment 1. Pearson correlations with questionnaire scores [state anxiety scores (STAI-S) and trait anxiety scores (STAI-T)] and the size of the congruency effect and the size of the CSE for RTs were calculated for the safe context and the threatening context separately (Table 3). For SC data, an independent samples *t* test was conducted to compare skin conductance between participants in the safe context and in the threatening context.

Results

RT

A significant congruency effect was observed, $F(1, 70)=124.0$, $p<0.0001$, MSE = 267, $\eta_p^2=0.64$: The mean RT was shorter on congruent trials ($M=705$ ms) than incongruent trials ($M=726$ ms). The main effect of $n-1$ trial congruency was also observed, $F(1, 70)=10.33$, $p=0.002$, MSE = 143, $\eta_p^2=0.13$, indicating longer mean RT following incongruent trials ($M=717$ ms) than following congruent trials ($M=713$ ms). Importantly, a significant three-way interaction of current-trial congruency, $n-1$ trial congruency, and context was observed, $F(1, 70)=7.5$, $p=0.0078$, MSE = 153, $\eta_p^2=0.1$. As in Experiment 1, two-way ANOVAs with current trial congruency and $n-1$ trial congruency as within-subject variables were conducted for the safe context and the threatening context separately to observe the pattern of the interaction. As expected, a significant interaction between current trial congruency and $n-1$ trial congruency was observed in the safe context, $F(1, 35)=8.76$, $p=0.0055$, MSE = 157, $\eta_p^2=0.2$, driven by a smaller congruency effect following incongruent trials, (14 ms), $F(1, 35)=17.82$, $p=0.0002$, MSE = 211, $\eta_p^2=0.34$, than following congruent trials, (27 ms), $F(1, 35)=67.28$, $p<0.0001$, MSE = 192, $\eta_p^2=0.66$ (see Fig. 3). BF_{10} of the interaction was 5.88, indicating positive evidence of the interaction. In the threatening context, the interaction between current trial congruency and $n-1$ trial congruency was not found, $F<0.5$, $p>0.5$. BF_{01} of the interaction was 3.33, suggesting the absence of the interaction.

Percent error

A significant congruency effect was observed, $F(1, 70)=22.49$, $p<0.0001$, MSE = 3.36, $\eta_p^2=0.24$. Participants made more errors on incongruent trials (4.7%) than on congruent trials (3.67%). Also, a main effect of $n-1$ trial congruency on percent errors was obtained, $F(1, 70)=4.39$, $p=0.0398$, MSE = 2.17, $\eta_p^2=0.06$. Participants made more errors following incongruent trials (4.37%) than following congruent trials (4%). Moreover, a significant interaction between current trial congruency and $n-1$ trial congruency was found, $F(1, 70)=4.42$, $p=0.0392$, MSE = 2.01, $\eta_p^2=0.06$. A separate analysis on the effect of current trial congruency while controlling $n-1$ trial congruency showed that a larger congruency effect was obtained following congruent trials (1.38%), $F(1, 71)=28.05$, $p<0.0001$, MSE = 2.43, $\eta_p^2=0.28$, than following incongruent trials (0.67%), $F(1, 71)=5.63$, $p=0.0203$, MSE = 2.91, $\eta_p^2=0.07$, indicating the presence of the CSE. There was no significant three-way interaction of current trial congruency, $n-1$ trial congruency, and context, $F<0.5$, $p>0.6$.

Personality questionnaires

The raw scores of participants state anxiety (STAI-S) and trait anxiety (STAI-T) data are presented in Table 1. There was no significant difference in state anxiety scores,

Table 3 Pearson correlations of questionnaire scores and the size of the congruency effect and the CSE in Experiment 2

	Safe				Threat			
	RT		PE		RT		PE	
	CE	CSE	CE	CSE	CE	CSE	CE	CSE
Spielberger state anxiety	0.13	− 0.19	0.01	0.32	0.11	0.10	− 0.18	− 0.05
Spielberger trait anxiety	0.29	− 0.37*	− 0.08	0.27	0.17	0.00	0.03	0.23

RT reaction time, *PE* percent error, *CE* congruency effect, *CSE* congruency sequence effect

*$p<0.05$

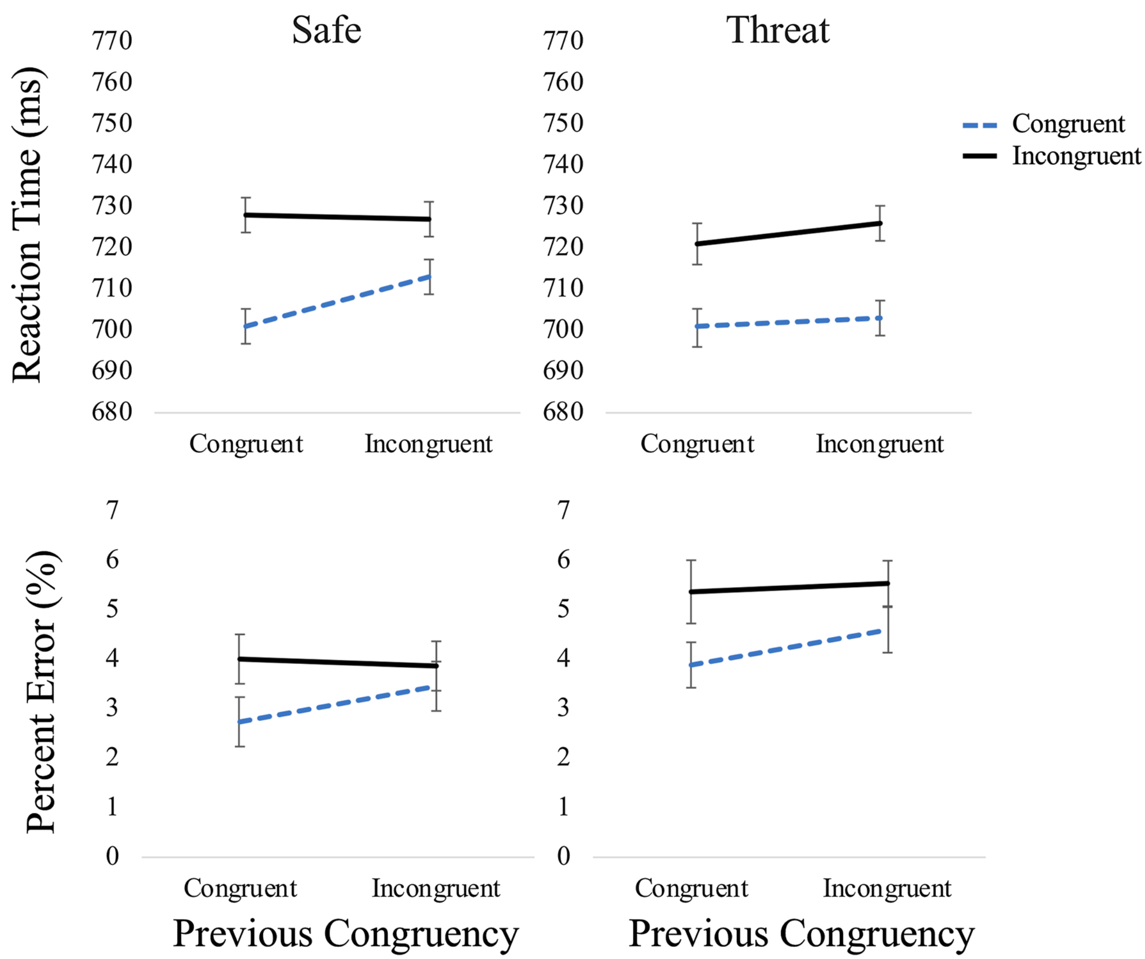


Fig. 3 Mean correct reaction times and percent error as a function of current trial congruency and *n* − 1 trial congruency in the safe and threatening contexts in Experiment 2. Error bars indicate the 95% confidence interval around the mean (Loftus & Masson, 1994)

$t(70) < 0.5$, $p > 0.7$, and trait anxiety scores, $t(70) = 1.55$, $p = 0.126$, between participants in the two contexts (Table 3). Significant correlations between questionnaire scores were observed both in the safe context ($r = 0.53$, $p = 0.001$) and in the threatening context ($r = 0.55$, $p = 0.0005$). For RT data, there were no correlations between questionnaire scores and performance indices for the congruency effect and the CSE in the threatening context (*p*s > 0.2). On the other hand, a significant negative correlation between the size of the CSE and trait anxiety score, $r = -0.37$, $p = 0.0274$, was observed in the safe context (see Fig. 4) indicating less cognitive flexibility as trait anxiety increases.

Since the correlations indicate that the size of CSE was influenced by trait anxiety scores, participants in the safe context were divided into those with high-trait anxiety scores and those with low-trait anxiety scores. Those who scored higher than 40 on trait anxiety score, which is the median trait anxiety score of the participants in the safe context, were classified as the high-trait anxiety group ($N = 15$, $M = 47.27$) and those who scored lower than 40 were classified as the low-trait anxiety group ($N = 15$, $M = 35.47$). The remaining six participants who scored 40 on the trait anxiety score were excluded from the analyses. Individuals' mean RTs were calculated as a function of current trial congruency and *n* − 1 trial congruency and two-way ANOVAs were conducted for the low-trait anxiety group and the high-trait anxiety group separately to examine a sequential modulation. Bayes Factor of the interaction was calculated for the interactive effect.

In the low-trait anxiety group, a significant CSE was observed (see Fig. 5), $F(1, 14) = 7.55$, $p = 0.0157$, $MSE = 132$, $\eta_p^2 = 0.35$, driven by a reduced congruency effect following incongruent trials (9 ms), $F(1, 14) = 2.57$, $p = 0.1310$, $MSE = 242$, $\eta_p^2 = 0.16$, compared to the effect following congruent trials (29 ms), $F(1, 14) = 21.93$, $p = 0.0004$, $MSE = 220$, $\eta_p^2 = 0.61$. BF_{10} of the interaction was 2.68, indicating weak evidence which is considered to arise from the small number of participants for analysis. In the high-trait anxiety group, the two-way interaction was not significant (see Fig. 5), $F < 1$, $p > 0.7$. BF_{01} of the interaction was 2.86.

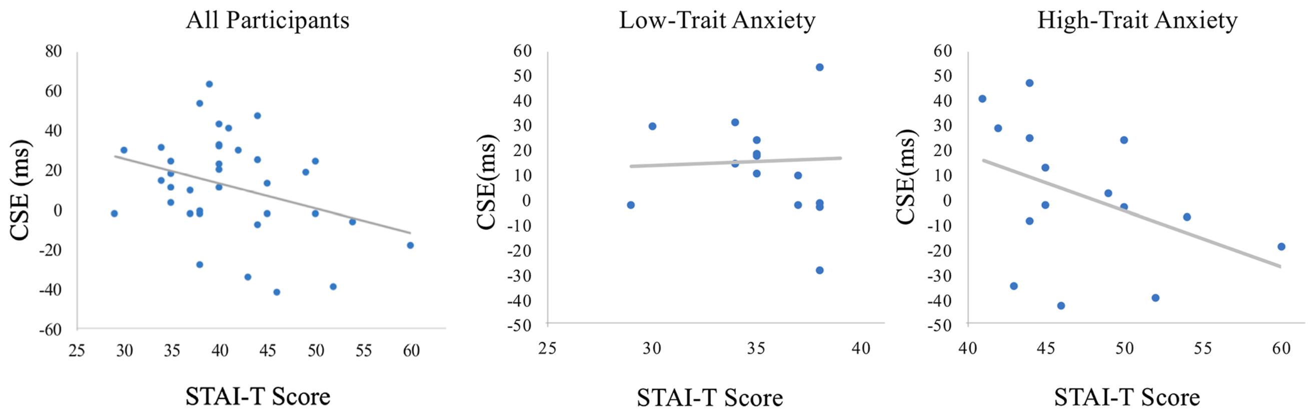
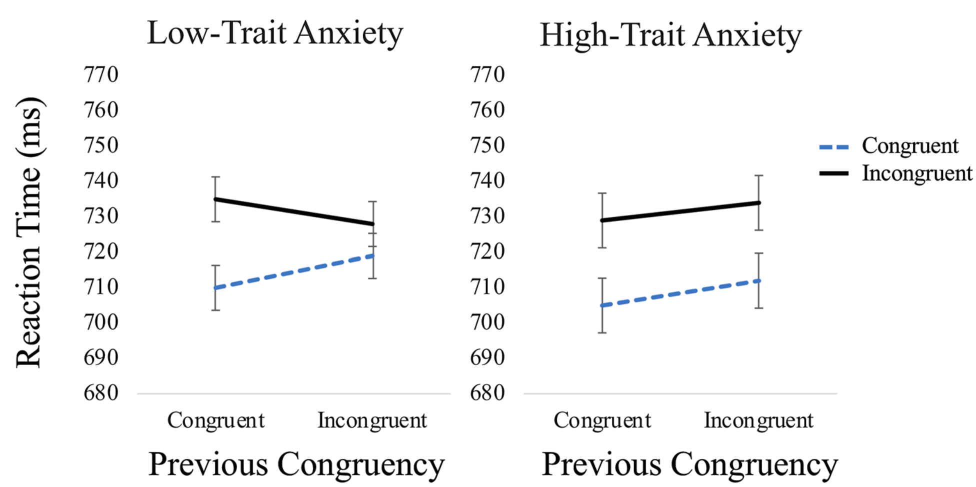


Fig. 4 Scatter plots with linear regression lines in Experiment 2. The regression lines indicate the relation between the size of the CSE and STAI-T scores in the safe context for all participants, low-trait anxiety group and high-trait anxiety group

Fig. 5 Mean correct reaction times as a function of current trial congruency and $n-1$ trial congruency for participants with low-trait anxiety scores and high-trait anxiety scores in the safe context in Experiment 2. Error bars indicate the 95% confidence interval around the mean (Loftus & Masson, 1994)



As for percent error data, no correlation between questionnaire scores and the congruency effect or the CSE was found in both the safe ($ps > 0.05$) and threatening contexts ($ps > 0.1$).

Skin conductance

One participant's data in the safe context and one participant's data in the threatening context were omitted due to a technical error. An independent *t* test revealed no difference in SC between the safe context and the threatening context, $t = 0.81$, $p = 4213$.

Discussion

As in Experiment 1, the CSE obtained in the safe context disappeared under the threatening context in Experiment 2 replicating the finding that induced anxiety caused the failure of cognitive adjustment while engaging in the emotional conflict task. Additionally, unlike in Experiment 1, trait anxiety scores were found to exert a negative influence on sequential adjustment which was specific under the safe context. Whereas participants with low-trait anxiety scores demonstrated an intact CSE, participants with high-trait anxiety failed to adjust following the conflict. The results are partly consistent with the prediction that individuals with high-trait anxiety who are relatively vulnerable to develop anxiety disorders (Eysenck, 2013) would demonstrate similar deficit as shown by GAD patients (Etkin et al., 2010). A manifestation of the negative impact of trait anxiety specific to the safe context but not to the threatening context may imply that induced anxiety eliminated the individual difference.

One limitation to note is that in contrast to Experiment 1, a general slowdown of responses or heightened skin conductance driven by the threat of shock was not observed in Experiment 2, so it may be argued that anxiety manipulation was not successful in Experiment 2. However, response times and skin conductance are known to be highly affected by inter-individual variability (Jensen, 2006; Lykken & Venables, 1971). Thus, the absence of the modulation by context on those variables could have been driven by limitations of the between-subject design implemented in Experiment 2.

General discussion

Modulation of sequential adjustment by induced anxiety

To investigate whether induced anxiety interferes with cognitive control that engenders the CSE of emotional congruency tasks in non-pathological individuals, emotional congruency effects were compared between the safe and threatening contexts. Participants' responses to emotional words were influenced by task-irrelevant facial expressions, regardless of context. However, the sequential modulation of the congruency effect was modulated by the manipulation of induced anxiety in both Experiments 1 and 2. Specifically, in the safe context, the congruency effect was found to be reduced after incongruent trials compared to the effect after congruent trials, while in the threatening context, the magnitude of interference from facial expressions did not vary according to the congruency of the previous trial. Since the CSE is regarded as reflecting top-down regulation to reduce distractor interference (Botvinick et al., 2001), the disappearance of the effect under the threat of shocks can be interpreted as driven by a disruption of top-down cognitive adjustment caused by induced anxiety. Previous accounts of the effect of anxiety on cognitive processing have suggested that worry over the task-irrelevant thoughts that induce anxiety competes for the cognitive resources required for task performance (Choi et al., 2012; Padmala, Bauer, & Pessoa, 2011; Pessoa, 2009). Consistent with this, the depletion of cognitive processing resources caused by the threat of shocks could have interfered with top-down regulatory processes.

Another intriguing finding was that there was no impact of trait anxiety on performance in the threatening context in both Experiments 1 and 2. The results indicate that the threat of shock alone caused the failure in top-down adjustment. From the methodological perspective, the degree to which extent the threat of shock can mimic cognitive impairments associated with pathological anxiety has been of interest in an effort to develop a human anxiety model in an experimental setting (Robinson et al., 2011, 2013). Whether the same mechanism underlie the failure of cognitive adjustment in GAD patients demonstrated in Etkin et al.'s (2010) study and non-pathological individuals under induced anxiety in the current study cannot be determined with the current study's paradigm. Nevertheless, the results of the current study suggest that the threat of electric shock caused a similar disruption of top-down adjustment found in patients with anxiety disorders when emotional stimuli were involved.

In contrast to the current results, Robinson et al. (2011) found a significant CSE in the threatening context. These divergent results could have been caused by several important differences between the tasks used in Robinson et al.'s and the current experiments. First, the task used in Robinson et al.'s experiment might have been relatively less difficult than the one used in the current study, because the former used two emotional categories with less time pressure (response within 4000 ms on average and 5000 ms at maximum), while the latter used four emotional categories and imposed more time pressure for response execution (response within 2000 ms). The adverse effect of anxiety may manifest only in difficult tasks and not in easy tasks, because anxious individuals can recruit additional resources to compensate for their performance deficit in easy tasks (Derakshan & Eysenck, 2009; Eysenck, Derakshan, Santos, & Calvo, 2007). Accordingly, previous studies found that the effects of external stimuli like stress were observed only when the task was difficult (Lupien, Gillin, & Hauger, 1999; Oei, Everaerd, Elzinga, van Well, & Bermond, 2006). Thus, task used in the previous study might not have been sufficiently difficult to reveal any difference between the safe and threatening contexts.

More critically, because a two-choice task was used in Robinson et al.'s (2011) study, a potentially confounding effect of repetition priming (Mayr et al., 2003) or feature integration (Hommel et al., 2004) was not controlled. According to Hommel et al., stimulus and response features in a trial are integrated into one event file. If one feature in the event file is present on the following trial, all other features in the event file are automatically retrieved. Consequently, if the retrieved response is an incorrect response, execution of the correct response is delayed. The sequences of iC and cI trials produce partial repetition costs because only some of the stimulus features are repeated and the other features are alternated. Thus, a previously presented stimulus feature could activate a previously associated response, resulting in a delay to the execution of a correct response to the following trial. On the other hand, the sequences of cC and iI trials result in complete repetition and complete alternation trials, in which stimulus and response features from the previous trial completely repeat or alternate on the following trial, so that there is less need to overcome the previously associated feature. Therefore, even if the complete repetition trials are removed from analyses, response execution is still easier for the complete alternation trials than for partial repetition trials. Thus, in Robinson et al.'s experiment, this bottom-up confound was unavoidable and may have persisted regardless of context.

Modulation of sequential adjustment by inherent anxiety

In Experiment 2, the relationship between trait anxiety and cognitive flexibility was observed in the safe context: The sequential adjustment of distractor interference was found to be modulated by participants' trait anxiety level. As hypothesized, participants with high-trait anxiety demonstrated a failure of cognitive adjustment demonstrated by a negative correlation between the size of the CSE in RT data and the trait anxiety score. Further analyses revealed that the CSE, which was evident in participants with low-trait anxiety scores, disappeared in participants with high-trait anxiety scores.

Individuals with high-trait anxiety are considered to have a lower level of cognitive control than individuals with low-trait anxiety (Derakshan & Eysenck, 2009; Eysenck et al., 2007). According to the ACT, this is because worrisome thoughts deprive attentional resources at the central executive stage, leading to inefficient top-down functioning in anxious individuals (Eysenck et al., 2007). Thus, such lowered cognitive control in the participants with high-trait anxiety scores might have led to the disappearance of the sequential modulation in the current study. Moreover, a number of studies indicate that simply being exposed to threatening stimuli can trigger anxious symptoms (Öhman & Soares, 1994) and hyper-response of the amygdala (Phan, Fitzgerald, Nathan, & Tancer, 2006; Straube, Kolassa, Glauer, Mentzel, & Miltner, 2004) in high-trait anxious individuals. In this regard, threatening stimuli in the emotional task, like an angry face, might have caused a failure to regulate conflict in participants with high-trait anxiety scores in the safe context even without the threat of the shock.

The inadequacy of conflict resolution over the emotional stimuli is consistent with previous neural results. For instance, rACC has been constantly found to play a critical role in emotional conflict resolution (Bishop et al., 2004; Bishop, 2009; Egner, Etkin, Gale, & Hirsch, 2008) and high-trait anxious participants were inadequate to activate rACC in emotional conflict resolution (Bishop et al., 2004; Comte et al., 2015; Klumpp, Ho, Taylor, Phan, Abelson, & Liberzon, 2011; Krug & Carter, 2010). It is possible that the inefficiency of rACC in regulating emotional conflict underlies the failure of conflict adjustment in participants with high-trait anxiety scores in the present study. Given that failure of the sequential modulation of emotional conflict in GAD patients were related to the absence of rACC activation (Etkin et al., 2010) the malfunctioning of rACC in the regulation of emotional conflict is possibly a predisposing characteristic in high-trait anxious individuals to develop anxiety disorders. Indeed, a growing body of research suggests that the deficit in regulation of emotional experiences contributes to the maintenance of anxiety (Cisler & Koster, 2010; Gross, 1999; Kashdan, Zvolensky, & McLeish, 2008), which may ultimately lead to anxiety disorders. In this regard, a deficit in the regulation of emotional conflict is potentially a predisposing factor for anxiety disorders.

However, the negative relationship between trait anxiety and the size of the CSE is not always observed. In Experiment 1, there was no relationship between trait anxiety and the size of the CSE in the safe context. One explanation for the absence of the relationship is that the presence of more threatening stimuli, like electric shocks, than facial stimuli could have caused participants to view the safe context as a "relief" state (Lohr, Olatunji, & Sawchuk, 2007). Such sense of relief could have enabled participants with high-trait anxiety in Experiment 1 to perform comparatively well in the safe context than those with high-trait anxiety in Experiment 2.

On the contrary to the present findings, some of the previous studies reported enhanced conflict adjustment in association with high-trait anxiety (Osinsky, Alexander, Gebhardt, & Hennig, 2010; Osinsky, Gebhardt, Alexander, & Hennig, 2012; Steudte-Schmiedgen, Stalder, Kirschbaum, Weber, Hoyer, & Plessow, 2014). For instance, Osinsky et al. (2012) found that both behavioral and electrophysiological indices of conflict adjustment were enhanced in their sample with high-trait anxiety in comparison to those with low-trait anxiety using the non-emotional stimuli. Osinsky et al. attributed the findings to the enhanced reactive control mechanism in high-trait anxious individuals (Braver, Gray, & Burgess, 2007; Fales et al., 2008). Specifically, whereas low-trait anxious individuals are thought to recruit cognitive control in a sustained manner, high-trait anxious individuals exert cognitive control in a reactive manner, such as after detecting conflict, to compensate for their generally low-level of cognitive control (Fales et al., 2008). Moreover, previous studies suggest that conflict trials are registered as an aversive signal conveying negative affect (Botvinick, 2007; Dreisbach & Fischer, 2012, for review) and high-anxious individuals may show a heightened response to conflict driven by a negative bias.

The concept of the hierarchy of threat may provide an explanation to integrate the findings on the divergent effects of anxiety-invoking stimuli on conflict adjustment. In one aspect, the threat level of a stimulus can be determined by the extent of psychophysiological arousal that it causes (Bandura & Rosenthal, 1966). Electric shocks incurring actual physical pain is speculated to be more threatening than angry or fearful faces. In support, in a study by Glenn et al. (2012) which assessed startle responses toward a stimulus associated with electric shock or a fearful female face paired with shrieking scream, participants reported the stimulus associated with shock to be more aversive than the female face associated with screaming. The interfering effect of electric shocks on cognitive adjustment has also been found when participants perform non-emotional conflict tasks (Jeong & Cho, 2019). Overall, evidence suggest that high-intensity electric shocks are capable of causing performance interference regardless of participants' trait anxiety level or the presence of emotional stimuli.

Threatening faces are also known to induce psychophysiological arousal possibly due to its socio-emotional saliency (Avram, Balteş, Miclea, & Miu, 2010). The current finding suggests that threatening faces might cause intense psychophysiological arousal to the extent that it interferes with cognitive adjustment in high-trait anxious individuals but not strong enough to affect performance in low-trait anxious individuals. Lastly, conflict can also bring about psychophysiological arousal (Kobayashi, Yoshiono, Takahashi, & Nomura, 2007) possibly due to negative affect or the fear of making an error which high-trait anxious individuals might react to more readily. In this regard, conflict also possesses a threatening value but will be placed at the bottom of the hierarchy compared to electric shock or threatening faces in terms of psychophysiological arousal it causes.

Conclusion

In conclusion, in both Experiments 1 and 2, induced anxiety caused the failure of cognitive control involving emotional stimuli in the threatening context in comparison to the safe context. Under the threatening context, participants' trait anxiety did not modulate performance indicating that induced anxiety alone could trigger the failure in the sequential modulation of emotional conflict in non-pathological individuals regardless of their trait anxiety level. On the other hand, when participants were exposed to the safe context only, high-trait anxiety was associated with failure in the regulation of emotional conflict. Overall, the current study indicates that anxiety brings about an adverse impact on emotion regulation in non-pathological individuals.

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References

Aldao, A., Sheppes, G., & Gross, J. J. (2015). Emotion regulation flexibility. *Cognitive Therapy and Research, 39*(3), 263–278.

Avram, J., Balteş, F. R., Miclea, M., & Miu, A. C. (2010). Frontal EEG activation asymmetry reflects cognitive biases in anxiety: Evidence from an emotional face Stroop task. *Applied Psychophysiology and Biofeedback, 35*(4), 285–292.

Bandura, A., & Rosenthal, T. L. (1966). Vicarious classical conditioning as a function of arousal level. *Journal of Personality and Social Psychology, 3*(1), 54.

Barlow, D. H., & Hayes, S. C. (1979). Alternating treatments design: One strategy for comparing the effects of two treatments in a single subject. *Journal of Applied Behavior Analysis, 12*(2), 199–210.

Beall, P. M., & Herbert, A. M. (2008). The face wins: Stronger automatic processing of affect in facial expressions than words in a modified Stroop task. *Cognition and Emotion, 22*(8), 1613–1642.

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience, 12*(1), 92–98.

Bishop, S., Duncan, J., Brett, M., & Lawrence, A. D. (2004). Prefrontal cortical function and anxiety: Controlling attention to threat-related stimuli. *Nature Neuroscience, 7*(2), 184–188.

Botvinick, M. M. (2007). Conflict monitoring and decision making: Reconciling two perspectives on anterior cingulate function. *Cognitive, Affective, & Behavioral Neuroscience, 7*(4), 356–366.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108*(3), 624–652.

Braver, T. S., Gray, J. R., & Burgess, G. C. (2007). Explaining the many varieties of working memory variation: Dual mechanisms of cognitive control. In A. R. A. Conway, C. Jarrold, M. J. Kane, A. Miyake, & J. N. Towse (Eds.), *Variation in working memory* (pp. 76–106). New York: Oxford University Press.

Cassady, J. C., & Johnson, R. E. (2002). Cognitive test anxiety and academic performance. *Contemporary Educational Psychology, 27*(2), 270–295.

Choi, J. M., Padmala, S., & Pessoa, L. (2012). Impact of state anxiety on the interaction between threat monitoring and cognition. *NeuroImage, 59*(2), 1912–1923.

Cisler, J. M., & Koster, E. H. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clinical Psychology Review, 30*(2), 203–216.

Comte, M., Cancel, A., Coull, J. T., Schön, D., Reynaud, E., Boukezzi, S., et al. (2015). Effect of trait anxiety on prefrontal control mechanisms during emotional conflict. *Human Brain Mapping, 36*(6), 2207–2214.

Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance: New developments from attentional control theory. *European Psychologist, 14*(2), 168–176.

Dreisbach, G., & Fischer, R. (2012). Conflicts as aversive signals. *Brain and Cognition, 78*(2), 94–98.

Duthoo, W., Abrahamse, E. L., Braem, S., & Notebaert, W. (2014). Going, going, gone? Proactive control prevents the congruency sequence effect from rapid decay. *Psychological Research Psychologische Forschung, 78*(4), 483.

Egner, T., Etkin, A., Gale, S., & Hirsch, J. (2008). Dissociable neural systems resolve conflict from emotional versus nonemotional distracters. *Cerebral Cortex, 18*(6), 1475–1484.

Etkin, A., Egner, T., Peraza, D. M., Kandel, E. R., & Hirsch, J. (2006). Resolving emotional conflict: A role for the rostral anterior cingulate cortex in modulating activity in the amygdala. *Neuron, 51*(6), 871–882.

Etkin, A., Prater, K. E., Hoeft, F., Menon, V., & Schatzberg, A. F. (2010). Failure of anterior cingulate activation and connectivity with the amygdala during implicit regulation of emotional processing in generalized anxiety disorder. *American Journal of Psychiatry, 167*(5), 545–554.

Eysenck, M. W. (2013). *Anxiety: The cognitive perspective*. New York: Psychology Press.

Eysenck, M. W., & Byrne, A. (1992). Anxiety and susceptibility to distraction. *Personality and Individual Differences, 13*(7), 793–798.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*(2), 336–353.

Fales, C. L., Barch, D. M., Burgess, G. C., Schaefer, A., Mennin, D. S., Gray, J. R., et al. (2008). Anxiety and cognitive efficiency: Differential modulation of transient and sustained neural activity during a working memory task. *Cognitive, Affective, and Behavioral Neuroscience, 8*(3), 239–253.

Glenn, C. R., Lieberman, L., & Hajcak, G. (2012). Comparing electric shock and a fearful screaming face as unconditioned stimuli for fear learning. *International Journal of Psychophysiology, 86*(3), 214–219.

Gratton, G., Coles, M. G., & Donchin, E. (1992). Optimizing the use of information: Strategic control of activation of responses. *Journal of Experimental Psychology: General, 121*(4), 480–506.

Gross, J. J. (1999). Emotion regulation: Past, present, future. *Cognition and Emotion, 13*(5), 551–573.

Hajcak, G., & Nieuwenhuis, S. (2006). Reappraisal modulates the electrocortical response to unpleasant pictures. *Cognitive, Affective, and Behavioral Neuroscience, 6*(4), 291–297.

Hommel, B., Proctor, R. W., & Vu, K. P. L. (2004). A feature-integration account of sequential effects in the Simon task. *Psychological Research Psychologische Forschung, 68*(1), 1–17.

Jensen, A. R. (2006). *Clocking the mind: Mental chronometer individual differences*. Amsterdam: Elsevier.

Jeong, H. J., & Cho, Y. S. (2019). Cognitive control under high threat: The effect of shock on the congruency sequence effect. *Motivation and Emotion*, *43*(6), 906–916.

Kashdan, T. B., Zvolensky, M. J., & McLeish, A. C. (2008). Anxiety sensitivity and affect regulatory strategies: Individual and interactive risk factors for anxiety-related symptoms. *Journal of Anxiety Disorders, 22*(3), 429–440.

Kerns, J. G., Cohen, J. D., MacDonald, A. W., Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science, 303*(5660), 1023–1026.

Kim, S., & Cho, Y. S. (2014). Congruency sequence effect without feature integration and contingency learning. *Acta Psychologica, 149*, 60–68.

Kim, S., Kwon Y., Jung S., Kim M., Cho Y.S., Kim H.T., & Choi J.S. (2017) Development of the Korean facial emotion stimuli: Korea University facial expression collection 2nd edition. *Frontiers in Psychology, 8*(769).

Klumpp, H., Ho, S. S., Taylor, S. F., Phan, K. L., Abelson, J. L., & Liberzon, I. (2011). Trait anxiety modulates anterior cingulate activation to threat interference. *Depression and Anxiety, 28*(3), 194–201.

Kobayashi, N., Yoshino, A., Takahashi, Y., & Nomura, S. (2007). Autonomic arousal in cognitive conflict resolution. *Autonomic neuroscience, 132*(1–2), 70–75.

Krug, M. K., & Carter, C. S. (2010). Adding fear to conflict: A general purpose cognitive control network is modulated by trait anxiety. *Cognitive, Affective, and Behavioral Neuroscience, 10*(3), 357–371.

Loftus, G. R., & Masson, M. E. (1994). Using confidence intervals in within-subject designs. *Psychonomic Bulletin & Review, 1*(4), 476–490.

Lohr, J. M., Olatunji, B. O., & Sawchuk, C. N. (2007). A functional analysis of danger and safety signals in anxiety disorders. *Clinical Psychology Review, 27*(1), 114–126.

Lupien, S. J., Gillin, C. J., & Hauger, R. L. (1999). Working memory is more sensitive than declarative memory to the acute effects of corticosteroids: A dose–response study in humans. *Behavioral Neuroscience, 113*(3), 420.

Lykken, D. T., & Venables, P. H. (1971). Direct measurement of skin conductance: A proposal for standardization. *Psychophysiology, 8*(5), 656–672.

Mayr, U., Awh, E., & Laurey, P. (2003). Conflict adaptation effects in the absence of executive control. *Nature Neuroscience, 6*(5), 450–452.

Mennin, D. S., Heimberg, R. G., Turk, C. L., & Fresco, D. M. (2005). Preliminary evidence for an emotion dysregulation model of generalized anxiety disorder. *Behaviour Research and Therapy, 43*(10), 1281–1310.

Moser, J. S., Krompinger, J. W., Dietz, J., & Simons, R. F. (2009). Electrophysiological correlates of decreasing and increasing emotional responses to unpleasant pictures. *Psychophysiology, 46*(1), 17–27.

Oei, N. Y., Everaerd, W. T., Elzinga, B. M., van Well, S., & Bermond, B. (2006). Psychosocial stress impairs working memory at high loads: An association with cortisol levels and memory retrieval. *Stress, 9*(3), 133–141.

Öhman, A., & Soares, J. J. (1994). " Unconscious anxiety": Phobic responses to masked stimuli. *Journal of Abnormal Psychology, 103*(2), 231–240.

Osinsky, R., Alexander, N., Gebhardt, H., & Hennig, J. (2010). Trait anxiety and dynamic adjustments in conflict processing. *Cognitive, Affective, and Behavioral Neuroscience, 10*(3), 372–381.

Osinsky, R., Gebhardt, H., Alexander, N., & Hennig, J. (2012). Trait anxiety and the dynamics of attentional control. *Biological Psychology, 89*(1), 252–259.

Padmala, S., Bauer, A., & Pessoa, L. (2011). Negative emotion impairs conflict-driven executive control. *Frontiers in Psychology, 2*, 192.

Pedersen, W. S., & Larson, C. L. (2016). State anxiety carried over from prior threat increases late positive potential amplitude during an instructed emotion regulation task. *Emotion, 16*(5), 719–729.

Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in Cognitive Sciences, 13*(4), 160–166.

Phan, K. L., Fitzgerald, D. A., Nathan, P. J., & Tancer, M. E. (2006). Association between amygdala hyperactivity to harsh faces and severity of social anxiety in generalized social phobia. *Biological Psychiatry, 59*(5), 424–429.

Raftery, A. E. (1995). Bayesian model selection in social research. *Sociological Methodology, 25*, 111–164.

Rey-Mermet, A., Gade, M., & Steinhauser, M. (2019). Sequential conflict resolution under multiple concurrent conflicts: An ERP study. *NeuroImage, 188*, 411–418.

Robinson, O. J., Letkiewicz, A. M., Overstreet, C., Ernst, M., & Grillon, C. (2011). The effect of induced anxiety on cognition: Threat of shock enhances aversive processing in healthy individuals. *Cognitive, Affective, & Behavioral Neuroscience, 11*(2), 217–227.

Robinson, O. J., Vytal, K., Cornwell, B. R., & Grillon, C. (2013). The impact of anxiety upon cognition: Perspectives from human threat of shock studies. *Frontiers in Human Neuroscience, 7*, 203.

Schmidt, J. R., & De Houwer, J. (2011). Now you see it, now you don't: Controlling for contingencies and stimulus repetitions eliminates the Gratton effect. *Acta Psychologica, 138*(1), 176–186.

Schmidt, J. R., & Weissman, D. H. (2014). Congruency sequence effects without feature integration or contingency learning confounds. *PLoS ONE, 9*(7), e102337.

Schmidt, J. R., & Weissman, D. H. (2016). Congruency sequence effects and previous response times: Conflict adaptation or temporal learning? *Psychological Research Psychologische Forschung, 80*(4), 590–607.

Spielberger, C. D., Gorsuch, R. L., Lushene, R. E., Vagg, R. E., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory*. Palo Alto: Consulting Psychologists Press.

Steudte-Schmiedgen, S., Stalder, T., Kirschbaum, C., Weber, F., Hoyer, J., & Plessow, F. (2014). Trauma exposure is associated with increased context-dependent adjustments of cognitive control in patients with posttraumatic stress disorder and healthy controls. *Cognitive, Affective & Behavioral Neuroscience, 14*(4), 1310–1319.

Straube, T., Kolassa, I. T., Glauer, M., Mentzel, H. J., & Miltner, W. H. (2004). Effect of task conditions on brain responses to threatening faces in social phobics: An event-related functional magnetic resonance imaging study. *Biological Psychiatry, 56*(12), 921–930.

Thiruchselvam, R., Blechert, J., Sheppes, G., Rydstrom, A., & Gross, J. J. (2011). The temporal dynamics of emotion regulation: An EEG study of distraction and reappraisal. *Biological Psychology, 87*(1), 84–92.

Verguts, T., Notebaert, W., Kunde, W., & Wühr, P. (2011). Post-conflict slowing: Cognitive adaptation after conflict processing. *Psychonomic Bulletin & Review, 18*(1), 76–82.

Wagenmakers, E. J., Love, J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., & Meerhoff, F. (2018). Bayesian inference for psychology. Part II: Example applications with JASP. *Psychonomic Bulletin & Review*, *25*(1), 58–76.

Weissman, D. H., Jiang, J., & Egner, T. (2014). Determinants of congruency sequence effects without learning and memory confounds. *Journal of Experimental Psychology: Human Perception and Performance, 40*(5), 2022–2037.