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The Influence of an Anxious Mood on Human Directional Choice by Enhancing Focused Attention

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The current study aimed to examine how the anxious mood state affects human directional choice. For this purpose, we employed a version of the spatial Stroop task and tested the effect of the induced anxious mood state on the facilitation and interference effects. In an experiment, neutral and anxious picture-and-sound sets were employed to manipulate different moods between two groups. After the mood induction, participants performed a version of the spatial Stroop task that included congruent, neutral, and incongruent trials. The results showed that an anxious mood enhanced the facilitation effect, but reduced the interference effect. In contrast, the conflict adaptation effect was not influenced by the anxious mood. These findings suggest that an anxious mood can accelerate target processing through enhancing focused attention but not inhibitory control. The practical implications for human directional choice in an evacuation situation are discussed.

Keywords: the spatial Stroop task, the facilitation effect, the interference effect, an anxious mood, evacuation behavior

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In our daily lives, we are frequently faced with various situations that require us to coordinate our thoughts and actions in order to achieve internal goals. This ability is referred to as cognitive control (Miller & Cohen, 2001). In laboratory experiments, a congruency task is typically used to investigate participants' cognitive control. For example, in the Stroop task (MacLeod, 1991; Stroop, 1935), reaction times (RTs) are slower for incongruent trials (e.g., "RED" printed in blue ink) than for congruent trials (e.g., "RED" printed in red ink), which is called the Stroop effect. Importantly, the Stroop effect is modulated by the transition between the trials, which is referred to as the conflict adaptation effect (CAE) (Egner, 2007; Gratton, Coles, & Donchin, 1992). Namely, RTs are faster for incongruent trials that follow incongruent trials than for those that follow congruent trials, and RTs for congruent trials that are preceded by congruent trials are faster than those preceded by incongruent trials. According to the conflict monitoring theory, which is the predominant theory of cognitive control, the CAE is a result of the temporary up-regulation of control in response to the level of conflict (Botvinick, Braver, Barch, Carter, & Cohen, 2001).

Interestingly, the Stroop effect and CAE were observed in our previous study that used left- and right-heading running-man exit signs in the context of a spatial version of the Stroop task (Kim, Hur, Oh, Choi, & jeong, 2016). In this study, the participants were asked to press a left or right button during a modified spatial Stroop task, which was an unforced-choice task that was

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manipulated by combining the running man's direction and the sign's installed location (e.g., a leftward running man in the left location for congruent trials and a rightward running man in the left location for incongruent trials). The results demonstrated a significant Stroop-like effect and CAE, which suggests that top-down cognitive control contributes to human directional choice even when there is no correct answer (note that the leftward or rightward direction of the running-man exit sign used in the previous study was not associated with the correct exit route).

However, whether the aforementioned effects can be observed consistently in a real-world evacuation situation should be addressed. One possible way to examine these effects is to test the influence of anxiety on human directional selection. This idea is based on the fact that negative emotional states can lead people to focus on the current situation (Schuch & Koch, 2015). Although it is well known that emotional states affect cognitive control processes (see Gray, 2004), some studies suggest that emotional states can also modulate the Stroop effect in different ways. For instance, Phillips et al. (2002) reported that a positive mood was associated with impaired performance whereas other studies have found increases in the Stroop effect in relation to negative emotion (Kazen & Kuhl, 2005; Kuhl & Kazén, 1999) or there has been no influence on the Stroop effect (Padmala Bauer, & Pessoa, 2011). Moreover, other studies have demonstrated that the CAE is associated with emotional states in different ways. For example, Padmala et al. (2011) reported a decrease in the CAE in relation to negative emotion whereas other studies have suggested that negative emotional states contribute to an increase in the CAE (e.g., Schuch & Koch, 2015; van Steenbergen Band, & Hommel, 2009, 2010).

The aforementioned studies of the relationship between the emotional state and cognitive control used congruent and incongruent conditions to measure the Stroop effect (i.e., by subtracting the RTs of the congruent trials from those of the incongruent trials). However, it is important to note that the Stroop effect consists of facilitation and interference that can be measured in a task involving a neutral condition, in which the facilitation effect refers to faster RTs for congruent trials than for neutral trials and the interference effect indicates slower RTs for incongruent trials than for neutral trials (Lindsay & Jacoby, 1994; MacLeod, 1991; Stroop, 1935). However, to the best of our knowledge, it is unknown how anxiety influences the facilitation and interference effects; knowing this would explain the divergent effects of the emotional states on the Stroop or CAE that have been reported in the previous studies.

Therefore, the present study aimed to examine the effect of anxiety on the two types of Stroop effect (i.e., the facilitation and interference effects) and the CAE. Investigating this should provide evidence that can explain human directional choice when escaping a disaster, such as a fire. For this purpose, we employed a spatial version of the Stroop task with three conditions (i.e., the congruent, neutral, and incongruent conditions) and two mood induction groups, which included an anxiety group and a control group (i.e., the neutral group). The group differences were compared in the context of interference and facilitation effects and CAE. We expected that higher anxiety would yield a higher facilitation effect but a lower interference effect since narrowed attention evoked by negative emotions can heighten the focus of visuospatial attention (Fredrickson & Branigan, 2005). In contrast, as negative emotional states appear to be related to the current situation (Schuch & Koch, 2015), it is expected that the CAE would not be affected by higher anxiety.

METHOD

Participants

A total of 120 volunteers (60 females and 60 males) aged from 18 to 29 years (mean [*M*] = 23.04, standard deviation [*SD*] = 2.29) participated in this study. The participants were randomly assigned to either the anxiety or neutral group and each group included 30 females and 30 males. Six participants, which included five from the anxiety group and one from the neutral group, were excluded from the analyses because of their low accuracy rates (lower than 70%), which resulted in 55 participants for the anxiety group and 59 participants for the neutral group. All participants provided written informed consent prior to participating in this study and the study was approved by the institutional review board at Kyungpook National University. They received monetary compensation for their participation.

Materials and Procedure

The spatial Stroop task. All stimuli were displayed on a 17" LCD monitor with a resolution of 1024 × 760 pixels. The monitor was placed approximately 60 cm in front of the participants. The experimental task programming, stimulus presentation, and data collection were conducted via E-Prime 2.0. The spatial Stroop task was manipulated through the combination of an arrow (i.e., the target) and its horizontal location (i.e., the distractor). The arrow pointed in either a left or right direction and it was presented in one of three locations: the left or right (visual angle 4.8 degree), or middle. The target arrow was presented in white in the middle of the vertical dimension of the screen with a black background.

There were three types of trial: congruent, neutral, and incongruent. In the congruent trials, the direction of the arrow was consistent with its location (e.g., a left-pointing arrow located in the left side) whereas in the incongruent trials, the direction of the arrow and its location were opposite (e.g., a left-pointing arrow located in the right side). In the neutral trials, the arrow was presented in the middle of the screen. These three types of trial were intermixed, resulting in nine types of trial transition through the combination of the current and preceding trial types, and these were pseudo-randomly presented to ensure that the nine trial types were in equal numbers. In order to control for additional factors that could confound the CAE, such as repetition priming effects (Mayr Awh, & Laurey, 2003), the stimulus repetition and the stimulus alternation were counterbalanced for each trial type.

The stimuli were presented for 1,000 ms until a response was made and the inter-stimulus intervals (ISIs) were fixed at 2,000 ms, with a white fixation cross at the center of the screen. A total of 324 experimental trials were included in the experiment, with 108 trials for each of the congruent, neutral, and incongruent trial types. The experimental task was divided into two sessions in order to ensure that the mood induction was successfully manipulated between the groups. For each session, 54 trials were included for each of the congruent, neutral, and incongruent trial types. To ensure that there was the same number of the nine types of trial transition, an additional trial was added at the start of each session and these were excluded from the data analysis.

All participants were required to perform a practice session before starting the experiment. They were asked to respond to the direction of the arrow while ignoring its location. Responses were made by pressing either the “z” key on the keyboard for the left response or the “m” key for the right response with their left or right index fingers. Participants were also asked to respond as quickly and accurately as possible and to stare at the fixation cross during the ISIs.

Mood induction. To induce an emotional state efficiently, emotional pictures and sounds were combined as multi-sensory stimuli (Baumgartner et al., 2006) and they were simultaneously presented to the participants. For the emotional pictures and sounds, the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 1997) and International Affective Digitized Sounds-2 (IADS-2) (Bradley & Lang, 2007) were used. Two sets of stimuli were selected to induce anxiety and a neutral emotion as follows: pictures from the IAPS that could arouse aversion and sounds from the IADS-2 that contained voices were excluded, and the remaining photos and sounds were sorted by their valence and arousal ratings in order to select the anxious and neutral stimuli, which were similar to a previous study (Birk, Dennis, Shin, & Urry 2011). For the anxious emotion stimuli, pictures and sounds with ratings above 5.0 in the arousal dimension and with ratings under 5.0 in the valence dimension were selected. For the neutral (or calm) stimuli, pictures and sounds with arousal ratings under 5.0 and with valence ratings above 5.0 were selected based on the previous cross-cuntural validation study (Choi, Lee, Choi, Jung, Park, & Kim, 2015). As a result, 14 photos (normative valence ratings: *M* = 3.03, *SD* = 0.18; normative arousal ratings: *M* = 6.26, *SD* = 0.11) and 14 sounds (normative valence ratings: *M* = 3.01, *SD* = 0.19; normative arousal ratings: *M* = 6.80, *SD* = 0.19) were employed for the anxiety group. For the neutral group, 14 photos (normative valence ratings: *M* = 5.06, *SD* = 0.27; normative arousal ratings: *M* = 2.74, *SD* = 0.15) and 14 sounds (normative valence ratings: *M* = 5.88, *SD* = 0.27; normative arousal ratings: *M* = 4.27, *SD* = 0.27) were used. Each of the photo and sound pairs were matched as precisely as possible in terms of their meanings.

The mood induction procedure was programmed and presented via E-Prime 2.0. The auditory-visual stimulus was presented for 6,000 ms with ISIs of 3,000 ms. Participants were asked to look at the visual stimuli presented on the screen and to listen to the auditory stimuli through the headphones. The mood induction procedure lasted for 126 s for both the anxiety group and neutral group. In order to check the manipulation, participants were required to rate their current mood on the two dimensions of arousal and pleasure (Yik, Russell, & Barrett, 1999), using a questionnaire that had a 7-point Likert scale, before the mood induction (baseline), after the mood induction and immediately before the task (before-task), and finally after the task (after-task).

Data Analyses. To calculate the mean accuracy rate, the first trial of each session was excluded. For the analyses of the RTs, the first trial of each session, error trials, and trials immediately following error trials were excluded. In order to analyze the Stroop effects between the groups, a trial type (congruent, neutral, and incongruent) × group (anxiety and neutral groups) mixed analysis of variance (ANOVA) was conducted for the accuracy and RTs. For the analysis of CAE between the groups, a preceding trial type (congruent and incongruent) × current trial type (congruent and incongruent) × group (anxiety and neutral groups) mixed ANOVA was conducted for the RTs. For the mood manipulation check, each of the arousal and pleasure dimensions were analyzed using a 3 × 2 (measurement time × group) mixed ANOVA. The statistical analyses were conducted using IBM SPSS Statistics 21.

RESULTS

Mood Manipulation Check

Before analyzing the spatial Stroop task data, the arousal and pleasure scores of the anxiety and neutral groups were analyzed using mixed ANOVAs in order to identify whether the mood induction was successfully manipulated for the anxiety group. Table 1 shows the mood scores of the participants of the two groups.

In the analysis of the arousal, the main effects of the measurement time ($F(2, 224) = 50.67$, $p < .001$, $\eta^2 = 0.31$) and group ($F(1, 112) = 9.95$, $p < .01$, $\eta^2 = 0.08$) and the interaction between the measurement time and group ($F(2, 224) = 9.33$, $p < .001$, $\eta^2 = 0.08$) were all significant. Post-hoc contrasts showed that the significant interaction was caused by an increased group difference in the arousal levels between the sessions ($F(1, 112) =$

Table 1. Self-reported arousal and pleasure scores (mean and standard deviation) by measurement time for the anxiety group and neutral group.

Group	Baseline		Before-task		After-task	
	Arousal	Pleasure	Arousal	Pleasure	Arousal	Pleasure
Anxiety	4.16 (1.05)	4.31 (0.69)	4.64 (0.92)	2.81 (0.82)	3.04 (1.38)	3.38 (0.79)
Neutral	3.88 (1.23)	4.44 (0.75)	3.52 (1.01)	4.10 (0.58)	2.91 (1.26)	3.44 (1.06)
Total	4.02 (1.15)	4.38 (0.72)	4.06 (1.18)	3.47 (0.96)	2.97 (1.31)	3.41 (0.79)

Note. Before-task = after the mood induction and immediately before the task; After-task = after the task

20.00, $p < .001$, $\eta^2 = 0.13$) and a decreased group difference in the arousal after the sessions (F(1, 112) = 19.92, $p < .001$, $\eta^2 = 0.13$).

The analysis of the pleasure levels showed a similar pattern of results. In detail, significant main effects of measurement time (F(2, 224) = 87.11, $p < .001$, η^2 = 0.44) and group (F(1, 112) = 23.75, $p < .001$, η^2 = 0.18) were observed. In addition, a significant interaction (F(2, 224) = 34.96, $p < .001$, $\eta^2 = 0.24$) was found due to an increased group difference in pleasure between the sessions (F(1, 112) = 49.64, $p < .001$, $\eta^2 = 0.31$) and a decreased group difference in the pleasure levels after the sessions (F(1, 112) = 60.84, $p < .001$, $\eta^2 = 0.35$). These results indicate that the arousal levels between the sessions were higher in the anxiety group than in the neutral group and the pleasure levels between the sessions were lower in the anxiety group than in the neutral group, whereas these differences between the groups decreased after the sessions.

The Spatial Stroop Task Results. First, the accuracy and RTs of the spatial Stroop task were analyzed to test for group differences in the facilitation and interference effects (Figure 1). The analysis of the accuracy showed a significant main effect of the trial type (F(2, 224) = 76.242, $p < .001$, $\eta^2 = 0.405$). The follow-up pair-wise contrasts indicated that the accuracy of the congruent trials (M = 97.60%, standard error of the mean [*SEM*] = 0.41) was higher than that of the neutral trials (M = 96.95%, *SEM* = 0.47, $p < 0.01$) and that the accuracy of the incongruent trials (M = 91.36%, *SEM* = 0.76) was lower than that of the neutral trials ($p < 0.001$), which represents the traditional facilitation and interference effects, respectively, for the accuracy. In contrast, the main effect of group was not significant (F(1, 112) = 0.200, $p > 0.05$, $\eta^2 = .002$). Furthermore, there was no interaction between the trial type and group (F(2, 224) = 0.585, $p > 0.05$, $\eta^2 = 0.005$).

For the analysis of the RTs, the main effect of trial type was significant (F(2, 224) = 157.484, $p < .001$, η^2 = 0.584) (see the right panel of Figure 1). Post-hoc comparisons showed that the RTs were faster for the congruent trials (M = 402.51 ms, *SEM* = 3.98) than for the neutral trials (M = 413.80 ms, *SEM* = 4.18) and were slower for the incongruent trials (M = 445.79 ms, *SEM* = 5.17) than for the neutral trials (*ps* < 0.001), which indicates that there were significant Stroop facilitation and interference effects for the RTs. In addition, a significant interaction between trial type and group was observed (F(2, 224) = 4.136, *ps* $< .05$, η^2 = 0.036). Post-hoc comparisons showed that the facilitation effect was larger in the anxiety group (M = 15.23 ms, *SEM* = 2.59) than in the neutral group (M = 7.60 ms, *SEM* = 2.5, $p < .05$) whereas the interference effect was smaller in the anxiety group (M = 24.50 ms, *SEM* = 3.76) than in the neutral group (M = 38.98 ms, *SEM* = 3.63, $p < .01$). Meanwhile, the main effect of group was not significant (F(1, 112) = 1.970, $p > 0.05$, η^2 = .017).

Second, in order to examine the difference of the CAE between the two groups, a preceding trial type (congruent

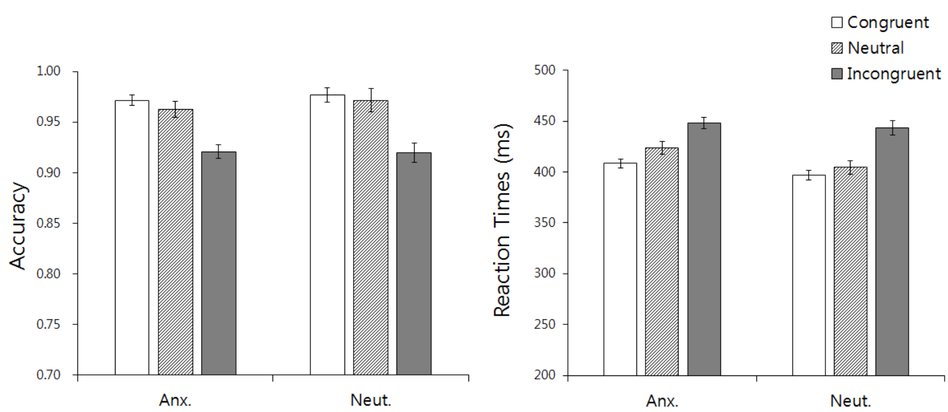

Figure 1. Mean accuracy and reaction times for the anxiety and neutral groups according to the current trial congruency. Error bars represent the standard errors of the means. Anx. = anxiety; Neut. = neutral.

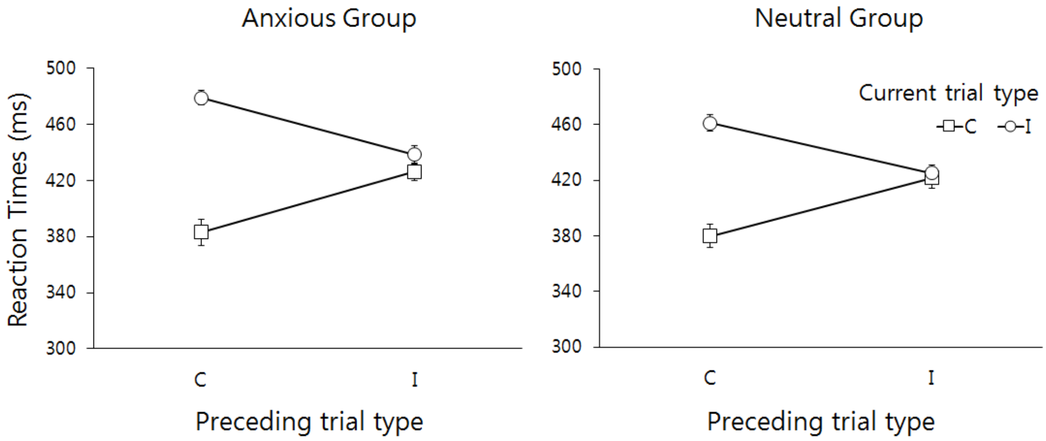

Figure 2. Mean reaction times for the anxiety and neutral groups as a function of the preceding and current trial type. Error bars represent the standard errors of the means. C: = congruent; I = incongruent.

and incongruent) × current trial type (congruent and incongruent) × group (anxiety and neutral group) mixed ANOVA was conducted for the RTs. As shown in Figure 2, although the overall CAE across the groups (i.e., a two-way interaction between the preceding and current trial types) was significant (F(1, 112) = 251.421, $p < .001$, $\eta^2 = 0.692$), the significant main effect of the group (F(1, 112) = 1.240, $p > .05$, $\eta^2 = 0.011$) and the three-way interaction were not significant (F(1, 112) = 0.383, $p > .05$, $\eta^2 = 0.003$), indicating that the CAEs were not different between the groups.

DISCUSSION

The purpose of the current study was to test whether an anxious mood can differently influence the Stroop facilitation and interference effects and the CAE, and whether these effects can be extended to a real-world evacuation situation (Kim et al., 2016). The results demonstrated that an anxious mood enhanced the facilitation effect while it reduced the interference effect. However, an anxious mood had no influence on the CAE. We have discussed these findings in detail below and consider their implications in the context of human behavior in terms of directional choice under an anxious mood.

First, participants in the anxiety group showed a higher facilitation effect compared to those in the neutral group, indicating that the anxiety group was able to effectively respond to targets in congruent trials compared to the neutral group. Considering that the facilitation effect is observed when the task-relevant stimulus (i.e., the direction of the arrow) is congruent with its position, and that the position, which is a dominant feature, can cause automatic processing (Lu & Proctor, 1995), this result suggests that anxiety can lead to enhanced automatic processing. Alternatively, faster responses in the congruent trials could result from enhanced focused attention to the target evoked by the anxious mood (Fredrickson & Branigan, 2005).

If an increase in the facilitation effect is associated with enhanced automatic processing of the position, the interference effect should also increase because higher automatic processing of the position requires greater inhibitory control for overcoming the response to the position, resulting in increases in the RTs of the incongruent trials. In contrast, if the increase in the facilitation effect results from enhanced focused attention, the interference effect should decrease because it can result in faster target processing. However, our results showed that an anxious mood caused an increase in the facilitation effect with a decrease in the interference effect, suggesting that the anxious mood state is closely associated with enhanced focused attention.

Previous studies support this interpretation. For example, a study that employed a modified version of the attention network test (Fan, McCandliss, Sommer, Raz, & Posner, 2002) demonstrated that exposure to fearful faces, compared to neutral faces, enhanced participants' performance in terms of executive control efficiency (Birk et al., 2011). Similarly, in a study using a dual-task method that required participants to shield representations of a prior task, the interference between the tasks was reduced under an anxious mood (Zwosta, Hommel, Goschke, & Fische, 2013). In addition, Hristova and Kokinov (2011) reported that individuals who have high state anxiety showed faster responses in recognizing identical relations between two sets of figures than those in a control group.

Second, our results showed that the CAE scores were not different between the groups, which indicates that anxiety has no influence on the trial-by-trial adjustment in cognitive control. This is inconsistent with previous studies that reported that the CAE was associated with a negative emotional state (Padmala et al., 2011; van Steenbergen et al., 2010). For example, in a study by van Steenbergen et al. (2010) that employed an Eriksen flanker task to measure the CAE between groups, they induced different mood states prior to the task. Their results indicated that participants in a sad or anxious mood showed greater adaptation effects than those in a happy or calm mood. However, the task paradigm used in the current study is different from that used in their study with respect to the inclusion of the neutral condition, which might have resulted in enhanced focused attention to the target stimuli associated with higher anxiety, as stated above. In addition, Padmala et al. (2011) employed trial-by-trial mood induction in which negative figures were presented between trials and they found that exposure to these negative figures resulted in a decrease in conflict adaptation. However, the exposure to irrelevant emotional distractors between the consecutive trials used in their task paradigm could have evoked attentional capture (Glickman & Lamy, 2018; Hodsoll, Viding, & Lavie, 2011). Thus, it is possible that their results might reflect the effect of attentional capture by irrelevant emotional distractors rather than the effect of a negative emotional state.

Our interpretation that an increase in the facilitation effect and a decrease in the interference effect would be closely associated with enhanced focused attention raises the possibility that the opposite influences on focused attention would be evoked by a positive mood. Consistent with this expectation, previous studies have suggested that a positive mood is likely to impair focused attention (Dreisbach & Goschke, 2004; Rowe, Hirsh, & Anderson, 2007). For instance, Rowe et al. (2007) demonstrated that participants in a positive mood were influenced by spatially adjunct flanking distractors while performing the Eriksen flanker task and suggested that a positive mood could widen visuospatial attention. Further, a positive mood has been frequently associated with enhanced performance in tasks that require unfocused attention, such as cognitive flexibility (Isen, Niedenthal, & Canto, 1992), creative uses (Phillips, Bull, Adams, & Fraser, 2002), and remote associates in memory (Bolte, Goschke, & Kuhl, 2003). These studies also support our suggestion that an anxious mood can enhance focused attention.

Meanwhile, in terms of the practical aspects, the current study provides an important implication in the context of human behavior regarding directional choice under an anxious mood. For instance, in a previous study (Kim et al., 2016), we demonstrated that the direction of the emergency exit sign and its location can evoke both facilitation and interference effects. According to the current findings that an anxious mood state increases focused attention, and thus affects both the facilitation and interference effects, it is more important to provide clear and unambiguous exit signs for people when they are in a highly anxious state, such as when escaping from a disaster.

Overall, the current study found that an anxious mood resulted in an increase in the facilitation effect and a decrease in the interference effect. We suggest that an anxious mood has a positive influence on the processing of the target by enhancing focused attention, but it has no influence on inhibitory control in a sequential manner. Therefore, it is important that these findings should be considered when designing and/or installing standardized exit signs for a real-world evacuation situation.

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불안상태가 초점주의 향상에 의한 방향선택 수행에 미치는 영향

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본 연구는 불안한 정서상태가 방향선택 수행에 미치는 영향을 확인하고자, 불안상태를 유발한 후 공간 스트룹 과제에서 측정한 스트룹 촉진효과와 간섭효과에 미치는 영향을 확인하고자 하였다. 이를 위해, 한 집단에게는 불안수준이 높은 그림 및 소리 세트를 제시하고, 다른 집단에게는 중성적인 그림 및 소리 세트를 제시하여 기분상태를 조작하였다. 정서유발 절차가 끝난 후, 참가자들은 일치, 중성 및 불일치 시행들이 포함된 공간 스트룹 과제를 수행하였다. 실험 결과, 불안상태는 스트룹 촉진효과를 증가시키지만, 간섭효과는 감소시키는 것을 확인하였다. 반면, 갈등적응효과는 불안상태에 의해 영향을 받지 않았다. 이러한 결과는 불안한 정서상태가 초점주의를 향상시켜 목표자극에 대한 처리를 가속시키지만, 억제적 통제에 대해서는 그러한 효과가 없음을 시사한다. 또한 피난 상황에서 방향선택과 관련하여 본 연구의 함의를 논의하였다.

주제어: 공간 스트룹 과제, 촉진효과, 간섭효과, 불안, 피난행동