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# Moderate state-anxiety differently modulates visual and auditory response times in normal- and very low trait-anxiety subjects

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## Abstract

Because relationships between mood states, personality and motor performances remain ambiguous, we investigated in very low trait-anxiety (VLTA) and normal trait-anxiety (NTA) subjects, the effects of moderate state-anxiety, tension and fatigue induced by the video-recorded Stroop Color-Word Interference Test on reaction time and movement time in visual and auditory tasks. Our results show that visual response time performances were improved in NTA subjects, while auditory response time performances were improved in VLTA subjects. In both groups, improvement of performance occurred at the reaction time and movement time level. Our results show that allocation of attentional resources can be modulated by personality traits, such as trait-anxiety, and furthermore highlight personality and individual differences as regards to the human/environment interaction.

*Keywords:* Trait-anxiety; State-anxiety; Mood states; Reaction time; Movement time; Response time; Sensory modalities

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A complex and contrasted relationship has been highlighted between mood states, anxiety and motor performances [2,4,5,7,11]. In tasks with high information content, such as psychomotor ability or complex reaction time tasks, state-anxiety, central fatigue or confusion can produce a slowing down of the information processing and motor strategies [5,8,11]. Alternatively, in more simple tasks depending greatly on automatic abilities, state-anxiety improves attention [1,5,16] leading to better performances. Furthermore previous data have provided insight into the interactions between trait-anxiety and motor performances [3,14]. Trait-anxiety favours the processing of information of stimulus-response tasks, but not that of controlled tasks that required strategic processes [3].

As stated by Spielberger [18], while state-anxiety is transitory, trait-anxiety may be conceived as latent dispositions to perceive and to behave in a specific manner. According to Spielberger, personality traits will be manifested in behaviour particularly if they are triggered by appropriate stimulus [18]. In this way, a study comparing groups of different trait-anxiety level during normal and anxiogenic conditions has indicated

that arousal and the impairment of the accuracy in performing a motor task increase with trait-anxiety, particularly when the intensity of the stressor elevates [14].

In order to investigate the influence of trait-anxiety on response time performances in anxiogenic condition, the present study was designed to examine whether moderate state-anxiety levels and adverse mood states, such as tension and fatigue, influence reaction time or movement time in simple response time tasks of different sensory modalities. Adverse mood changes as well as moderate state-anxiety levels were induced by the Stroop Color-Word Test with interference combined with video recording. This association has been shown to induce transitory physiological modifications [17,20,21], such as heart rate changes, considered as a good physiological indicator of the anxiogenic response [20].

Sixty-five potential subjects (28 women, 37 men) studying for a degree in Sport Sciences at the University of Metz were recruited. All of them declared to be free of psychiatric or neurological diseases and to possess normal hearing and vision. All gave their full informed consent. Trait-anxiety was assessed using the Y2 form of the Spielberger's State-Trait Anxiety Inventory (STAI [19]). After sorting by sex, the right-handed subjects whose scores were at the extremes of the distribution were assigned in two separate groups. According

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to the Spielberger's classification [19], individuals were shifted as subjects with a very low trait-anxiety (VLTA) level (score range: 22–39; mean score:  $32.1 \pm 4.4$ , mean age:  $19.6 \pm 1.4$ ; male ( $n=9$ ) mean score:  $30.1 \pm 1.7$ , mean age:  $19.1 \pm 1$ ; female ( $n=9$ ) mean score:  $34.1 \pm 5.4$ , mean age:  $20.2 \pm 1.5$ ) and as subjects with a normal trait-anxiety (NTA) level (score range: 42–58; mean score:  $48.5 \pm 5.7$ , mean age:  $20 \pm 1.4$ ; female ( $n=9$ ) mean score:  $49.8 \pm 6.6$ , mean age:  $19.5 \pm 1.3$ ; male ( $n=9$ ) mean score:  $47.3 \pm 4.8$ , mean age:  $20.4 \pm 1.4$ ).

State and trait-anxiety were assessed using the STAI Y1 and Y2 forms [19], respectively. These two self-evaluated questionnaires consist of 20 items, each scored in a four-point scale. Mood states were evaluated using two subscales taken from the "profile of mood states" (POMS; [13]). Because the full version of the POMS is a long test, and the anxiogenic condition provided by the Stroop Color-Word Test with interference is of short duration, the assessment of mood states was limited to tension and fatigue, which are mood factors that may interact with either reaction or movement time in healthy subjects [5,23]. These self-evaluated questionnaires consisted of nine adjectives for tension and seven adjectives for fatigue each rated in a five-point scale. Changes in heart rate were recorded throughout the experiment using a Polar heart rate monitor (Polar Electro Inc., Medical Division, NY, USA), in order to provide a physiological index of anxiety response.

Response time tasks were performed using two simple unimodal tasks with neutral stimuli, i.e. a red circle for the visual task and a pure tone of 1000 Hz for the auditory task. Because state-anxiety induced by the anxiogenic condition is moderate and transitory, each task was reduced to 20 signals. Each signal occurred in a random delay within 1.4 and 2 s after positioning the hand on the home button. When the stimulus occurred, the subjects were required to press as quickly as possible the response button. Using a behavioral paradigm [10], response time was distinguished as: (i) reaction time, i.e. the time required to evaluate the stimulus, and to select and trigger the motor response; this corresponds to the time spent from the stimulus occurrence to the release of the home button; and (ii) movement time, i.e. the time required to execute the motor response; this corresponds to the time spent from the release of the home button to the subsequent press of the response button. Performances in reaction time and movement time were assessed in milliseconds by calculating the median value for the 20 responses. All tests were programmed with E-prime (Psychology Software Tools, Inc.) and performed on the serial response box.

State-anxiety was induced by using the Stroop Color-Word Test with interference, which consisted in color words printed in incongruent colors. The subjects had to say as quickly as possible the color of the ink used to print a color name. Hesitations or errors were indicated with a strident sound. The task had to be completed within 2 min. Moreover, as used in procedures that simulate public performance, the subjects' performance was video recorded and showed on a TV screen placed in the visual field of the subject in order to increase state-anxiety and tension [17]. During control experiments, the subjects were asked to perform a Stroop-like Color-Word Test with no interference that was made of color words printed in congruent colors; the subjects had to name the color, and were submitted to neither video recording nor error signals.

Our experimental procedure is shown in Fig. 1. Individuals were asked to perform the control condition first, and then were exposed to the anxiogenic condition. In each condition, the subjects had (i) to name the first 50 words of the test, (ii) to execute two response time tasks, and (iii) to name the last 50 color words. The two response time tasks were counterbalanced across subjects in order to avoid an order effect. Rest periods were given to the subjects before between and after the experimental sessions. The subjects were asked to complete psychometric questionnaires for state-anxiety and mood states before the experiment (state-anxiety, tension and fatigue), after the control condition (state-anxiety) and after the anxiogenic condition (state-anxiety, tension and fatigue). After each condition, questionnaires for mood states and anxiety were immediately completed. Before the experiment, the subjects were allowed to practice a training session.

Two-way ANOVAs were applied to state-anxiety, tension, fatigue, heart rate changes (as compared to heart rate mean during the baseline first rest period taken as a 100% value) with moments (state-anxiety and heart rate: baseline, control condition, anxiogenic condition; tension and fatigue: baseline, anxiogenic condition) and group (NTA and VLTA subjects) as factors. Response time performances were analyzed with a four-way ANOVA using group (NTA and VLTA subjects), condition (control and anxiogenic), modality (visual and auditory) and sequence of response time (reaction and movement times) as factors. Following a significant *F*-value, post hoc comparisons were performed to determine pair wise differences using Tukey's test.

Changes in state-anxiety, mood states and heart rate are shown in Table 1. Statistical analysis on state-anxiety as

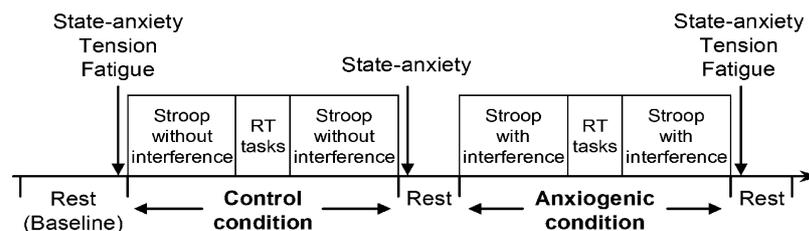


Fig. 1. Procedure of the experiment. Psychometric questionnaires were performed during the first rest period (baseline) and after the control and the anxiogenic conditions. Heart rate was assessed throughout the experiment. All subjects performed the control condition first and then were exposed to the anxiogenic condition. The two response time (RT) tasks were counterbalanced across subjects.

Table 1

State-anxiety, mood states and heart rate (mean  $\pm$  S.D.) for the two groups measured in the first rest period (baseline), in the control condition and in the anxiogenic condition

	Baseline	Control condition	Anxiogenic condition
State-anxiety			
VLTA group	28.2 $\pm$ 5.8	30.1 $\pm$ 6.7	35.5 $\pm$ 9.5 } <sup>**††</sup>
NTA group	36.0 $\pm$ 8.2	38.4 $\pm$ 10.7	44.4 $\pm$ 14.2 }
Tension			
VLTA group	4.4 $\pm$ 2.5	–	11.4 $\pm$ 6.4 } <sup>***</sup>
NTA group	8.5 $\pm$ 5.1	–	18.3 $\pm$ 9.9 }
Fatigue			
VLTA group	4.1 $\pm$ 2.5	–	5.5 $\pm$ 4.0
NTA group	5.9 $\pm$ 4.3	–	5.8 $\pm$ 3.9
Heart rate (%)			
VLTA group	100 $\pm$ 0	120 $\pm$ 13.8 } <sup>***</sup>	129 $\pm$ 15.4 } <sup>***,†</sup>
NTA group	100 $\pm$ 0	119 $\pm$ 10.5 }	122 $\pm$ 10.4 }

State-anxiety, tension and fatigue were evaluated by the STAI [19] and two subscales of the POMS [13], respectively.

\*\* Significantly different from baseline ( $p < 0.001$ ).

\*\*\* Significantly different from baseline ( $p < 0.0001$ ).

† Significantly different from control condition ( $p < 0.05$ ).

†† Significantly different from control condition ( $p < 0.001$ ).

measured by the STAI showed main effects for moment ( $F_{(2,68)} = 18.19$ ;  $p < 0.0001$ ) and group ( $F_{(1,34)} = 8.92$ ;  $p < 0.01$ ) factors, but no interaction between factors. Post hoc analysis carried out on both groups showed a significant higher level of anxiety in the anxiogenic condition as compared to the baseline ( $p < 0.001$ ) and control ( $p < 0.001$ ) period. A main effect was found for tension as measured by the POMS for moment ( $F_{(1,34)} = 52.87$ ;  $p < 0.0001$ ) and group ( $F_{(1,34)} = 8.93$ ;  $p < 0.01$ ) factors, but no interaction was found between factors. Post hoc analysis indicated that tension level was higher in the anxiogenic condition as compared to baseline ( $p < 0.0001$ ). No significant effect was found for the fatigue factor. Heart rate showed main effect for moment factor ( $F_{(2,68)} = 95.2$ ;  $p < 0.0001$ ), but no group effect or interaction effect between factors were found. Statistical analysis showed that mean heart rate was significantly higher during the anxiogenic condition compared to control condition ( $p < 0.05$ ).

Analysis of performances for response time tasks revealed a significant interaction between group, condition and modality factors ( $F_{(1,34)} = 9.58$ ;  $p < 0.01$ ), but not with sequence of response time factor. Because sequence of response time as a factor did not interact with other factors, post hoc analysis was carried out on response time, i.e. the sum of reaction time and movement time. In VLTA subjects, performance in response time was significantly improved in the anxiogenic condition for the auditory task ( $p < 0.01$ ), but not for the visual task (Fig. 2B). Conversely, in NTA subjects, performance in response time was significantly improved for the visual task ( $p < 0.05$ ), but not for the auditory task (Fig. 2A). No significant effect for task order or gender was observed for response times, psychological changes, and heart rate. Therefore, these factors were excluded in analyses.

The purpose of this study was to determine the effects of moderate state-anxiety levels and adverse mood states on visual and auditory response time in subjects possessing different lev-

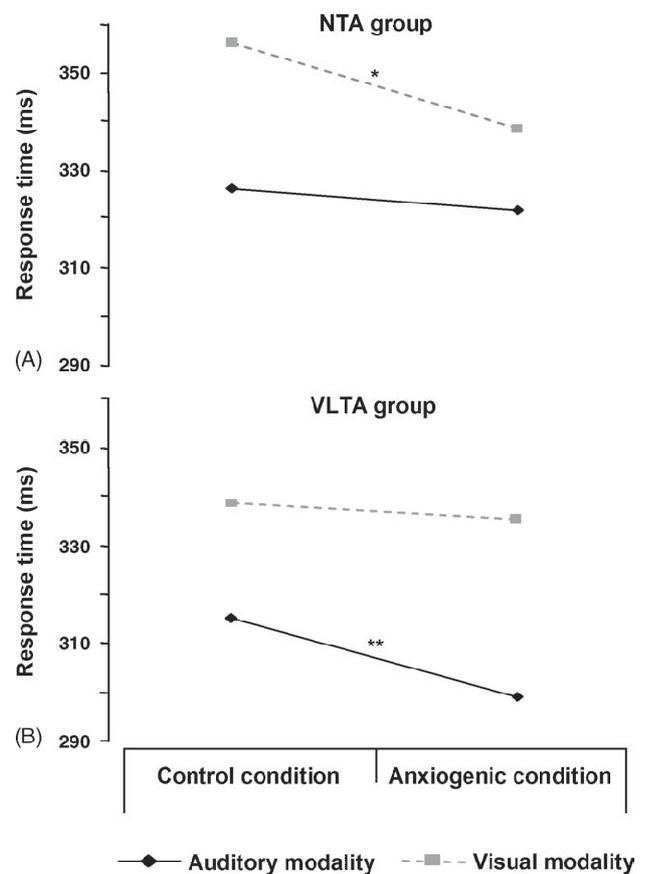


Fig. 2. Response time performances (mean in ms), i.e. the sum of the reaction time and the movement time, in the control condition and the anxiogenic condition for the normal trait-anxiety subjects (NTA;  $n = 18$ ; A) and the very low trait-anxiety subjects (VLTA;  $n = 18$ ; B). \* $p < 0.05$ , \*\* $p < 0.01$ , significant differences between the control condition and the anxiogenic condition.

els of trait-anxiety. Changes in state-anxiety and adverse mood states were induced using the video recorded Stroop Color-Word Test with interference. As previously reported, this resulted in moderate, but significant increases in heart rate, state-anxiety and tension (but not in fatigue), level [17,20,21].

The main finding of the present study is that moderate state-anxiety differentially improves performance in individuals possessing normal trait-anxiety or very low trait-anxiety level; while VLTA subjects improved performance in auditory response time, NTA subjects improved performance in visual response time. In both groups, improvement of performance in response time occurred at the reaction time and movement time level; this agrees with previous data that have demonstrated that state-anxiety increases muscular tension [9], arousal [15] and attention [1,5,16], which can modulate sensory processing (for review [6]).

As stated above, NTA, but not VLTA, subjects improved performance in visual response time. This agrees with previous data [22] that have demonstrated in a non-anxiogenic condition that subjects with normal level of trait-anxiety show a greater visual dependence than subjects with a very low trait-anxiety level while performing a perceptual-motor task. In addition, given that behaviours associated with trait-anxiety are manifest during anxiogenic conditions [18], it is likely that improved performance in visual response time produced by moderate state-anxiety in NTA subjects may have resulted from a greater arousal [15] and attention for visual stimuli. Alternatively, VLTA, but not NTA, subjects improved performance in auditory response time. This suggests that VLTA subjects exposed to anxiogenic conditions may focus on auditory stimuli rather than on visual stimuli. However, the mechanisms by which this sensory processing and threshold occurs still remains to be determined.

In conclusion, our results show that allocation of attentional resources can be modulated by personality traits, such as trait-anxiety, and furthermore highlight personality and individual differences as regards to the human/environment interaction. We found that moderate levels of state-anxiety improve performance in auditory response time in VLTA subjects and in visual response time in NTA subjects. However, according to the inverted-U hypothesis [12,24] and given the human limits of adaptation, it is possible to hypothesize that in contrast with our findings, performance may decline in conditions eliciting high levels of state-anxiety levels. This needs to be investigated.

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