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Not all anxious individuals get lost: Trait anxiety and mental rotation ability interact to explain performance in map-based route learning in men

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ABSTRACT

Navigation through an environment is a fundamental human activity. Although group differences in navigational ability are documented (e.g., gender), little is known about traits that predict these abilities. Apart from a well-established link between mental rotational abilities and navigational learning abilities, recent studies point to an influence of trait anxiety on the formation of internal cognitive spatial representations. However, it is unknown whether trait anxiety affects the processing of information obtained through externalized representations such as maps. Here, we addressed this question by taking into account emerging evidence indicating impaired performance in executive tasks by high trait anxiety specifically in individuals with lower executive capacities. For this purpose, we tested 104 male participants, previously characterised on trait anxiety and mental rotation ability, on a newly-designed map-based route learning task, where participants matched routes presented dynamically on a city map to one presented immediately before (same/different judgments). We predicted an interaction between trait anxiety and mental rotation ability, specifically that performance in the route learning task would be negatively affected by anxiety in participants with low mental rotation ability. Importantly, and as predicted, an interaction between anxiety and mental rotation ability was observed: trait anxiety negatively affected participants with low—but not high—mental rotation ability. Our study reveals a detrimental role of trait anxiety in map-based route learning and specifies a disadvantage in the processing of map representations for high-anxious individuals with low mental rotation abilities.

1. Introduction

Navigation is important in many day-to-day tasks, be it planning a driving route to a new location, or finding your way within a building. Navigation activities can rely on internal representations derived from sensory experience and on externalized representations such as maps or diagrams (Wolbers & Hegarty, 2010). Although humans greatly differ in their navigational abilities (Wolbers & Hegarty, 2010), the factors that explain these differences are not well understood.

Most of the early efforts to characterise inter-individual variability in navigational abilities highlighted the existence of important group differences, especially related to gender (Driscoll, Hamilton, Yeo, Brooks, & Sutherland, 2005; Lawton, 1994; Montello, Lovelace, Golledge, & Self, 1999) and age (Driscoll et al., 2005; Head & Isom, 2010; Wilkniss, Jones, Korol, Gold, & Manning, 1997). Although much less is known about factors that define large individual differences in navigational abilities that exist within the same gender and age groups, variance in spatial aptitude seems to play a prominent role (Malinowski, 2001; Shah & Miyake, 1996). Using performance measures in the Vandenberg and Kuse (1978) mental rotation test (MRT) as a proxy of spatial aptitude, several studies have shown that individual differences in mental rotational abilities correlate with participants' learning abilities to navigate in virtual mazes (Moffat, Hampson, & Hatzipantelis, 1998) and performance in map-based route learning tasks (Galea & Kimura, 1993).

Aside from spatial aptitude, emerging evidence in animals and humans suggest that trait anxiety contributes to the variance in navigational abilities. Trait anxiety—a personality characteristic related to the degree to which the world in general is perceived

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as threatening by the individual (Spielberger, 1972)—is known to be related to cognitive functioning in different domains (e.g., Bishop, 2009; Bishop, Duncan, Brett, & Lawrence, 2004; Eysenck & Calvo, 1992; Robinson & Petchenik, 1976; Sandi & Richter-Levin, 2009). Specifically, when trained in a spatial learning task, high-anxious rats displayed a slower learning rate than low-anxious rats (Herrero, Sandi, & Venero, 2006). In humans, existing evidence was obtained using virtual environments through which individuals were exposed to different trajectories and subsequently asked to draw a map (Viaud-Delmon, Berthoz, & Jouvent, 2002) or to locate landmarks on an aerial view of the previously seen environment (Burles et al., 2014). High-anxious individuals were impaired in both tasks (Burles et al., 2014; Viaud-Delmon et al., 2002) but their performance did not differ from low-anxious individuals when they had to reproduce a learned trajectory with their own movements during the exposure to the virtual scenario (Viaud-Delmon et al., 2002). These data are in line with a reported preference in high-anxious individuals for the use of an egocentric—as opposed to allocentric—strategy for spatial orientation (Viaud-Delmon, Siegler, Israël, Jouvent, & Berthoz, 2000; Viaud-Delmon et al., 2002). These studies link trait anxiety with individuals' capability to rely on internal representations in order to construct global representations of space (i.e. to form cognitive maps). However, at this time, it is not known whether trait anxiety affects the processing of information obtained through externalized representations such as maps.

In order to address this question, we investigated the link between trait anxiety and a map-based route-learning task. For this purpose, we invited 104 male individuals to perform a navigation task, in which they were shown computer animations of specific routes on a map and asked whether they matched a route that had been shown to them shortly before. The response time had a limit of 4 s. Thus, in each trial, participants had to process spatial information about a particular trajectory in a newly presented map, to hold it briefly in memory, and to then assess whether a subsequently displayed trajectory presented at a faster rate than originally matched the former route.

Gender differences are frequently reported both in performance (Burles et al., 2014; Driscoll et al., 2005; Vandenberg & Kuse, 1978), strategies (Galea & Kimura, 1993; Lawton, 1994) and confidence in spatial tasks (Nardi, Newcombe, & Shipley, 2012), and sex hormones have been shown to influence mental rotation ability (Hausmann, Slabbekoorn, Van Goozen, Cohen-Kettenis, & Güntürkün, 2000; Schöning et al., 2007). For this reason, we chose to conduct the experiment only with male participants.

First, and in order to validate this task in the context of the related literature (Fields & Shelton, 2006; Galea & Kimura, 1993; Moffat et al., 1998; Pazzaglia & De Beni, 2001; Tom & Tversky, 2012), we aimed to evaluate the link between mental rotation ability, using the MRT, and navigation performance in the map-based route learning task. Second, we assessed the potential contribution of trait anxiety in navigation performance. Furthermore, given that trait anxiety affects behaviour, and cognitive function does not fully explain inter-individual variation (e.g., Castro et al., 2012; Salehi, Cordero, & Sandi, 2010), we predicted that navigation performance would be modulated by the interaction between individuals' mental rotation ability and their level of trait anxiety. Specifically, we hypothesized that trait anxiety would play a detrimental role in participants with low, but not high, MRT scores. This prediction stems from the following converging lines of evidence: (i) our task involves a working memory component and, in males, performance in the MRT has been shown to strongly correlate with spatial—but not verbal—working memory performance (Christie et al., 2013; Shah & Miyake, 1996); (ii) substantial evidence and theoretical approaches to anxiety (e.g., the Attentional Control Theory; Eysenck, Derakshan, Santos, & Calvo, 2007) propose that anxiety disrupts working memory processes (Bishop, 2009; Eysenck & Calvo, 1992; Eysenck et al., 2007); (iii) an interaction between trait anxiety and working memory capacity was recently reported to explain a large amount of variance in cognitive performance in tasks involving executive function: whereas anxiety did not have an influence in individuals with average working memory capacity, it was negatively related to test performance in individuals with low working memory capacity (Edwards, Moore, Champion, & Edwards, 2015; Johnson & Gronlund, 2009; Owens, Stevenson, Hadwin, & Norgate, 2014).

As the impact of trait anxiety in behavioural and cognitive performance is strengthened under arousing conditions (e.g., Goette, Bendahan, Thoresen, Hollis, & Sandi, 2015; Herrero et al., 2006; Salehi et al., 2010), we tested participants under slight time constraint and in groups of four. Moreover, given that monetary motivation has been shown to be effective in inducing mild stress in individuals (Buckert, Schwieren, Kudielka, & Fiebach, 2015), we primed participants during recruitment indicating that test performance could affect their final payoff. Prior to the experimental session, participants were assessed on online versions of the State-Trait Anxiety Inventory, trait subscale (STAI-T; Spielberger, 1983) and the Vandenberg and Kuse (1978) mental rotation task (MRT). During the experimental session, state anxiety was measured through the State subscale of the STAI questionnaire and saliva samples were collected to measure cortisol. Given the reported link between trait anxiety and confidence (Goette et al., 2015), we also obtained confidence ratings in individual judgments.

2. Materials and methods

2.1. Participants

A total of 120 male, French-speaking students of the Ecole Polytechnique Fédérale de Lausanne (EPFL) and the University of Lausanne took part in the study. Due to a computer problem, some of the participants could not complete the whole experiment, and their data were therefore excluded from the analyses. The analysed sample consists thus of 104 participants (mean age = 20.8 years, *SD* = 2.6).

During recruitment, participants were told that their total reimbursement could depend on their test performance during the experimental session. Specifically, they were told that in addition to a guaranteed reimbursement of CHF 25 (1 CHF = 1.10 USD), one participant in each group of four would win a further bonus ranging between CHF 5 and CHF 30, and that this person would either be selected randomly or based on their performance in the task. This study was approved by the Brain Mind Institute (BMI) Ethics Committee for Human Behavioural Research of the EPFL.

2.2. General procedure

The experimental procedure is outlined in Fig. 1. Participants completed questionnaires individually, administered using the online platform *www.qualtrics.com*. This included demographics questionnaires, a French version of the *State-Trait Anxiety Inventory* (STAI; Spielberger, 1983), and a French version of the *Vandenberg and Kuse Mental Rotations task* (Albaret & Aubert, 1996; Vandenberg & Kuse, 1978). In the Mental Rotations Task (MRT), the participant is shown a line drawing of a block figure. Participants have to match two out of four additional block images to the target. These two represent rotated versions of the target; the other two are either mirror images or novel configurations of blocks. Two blocks of ten trials were used, and a time limit of 3 min was imposed on each block. Three days after completing