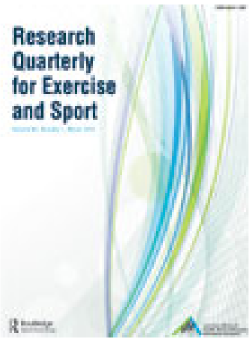

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Stereotype Threat Effect on a Simple Motor Task: An Investigation of the Visuo-Spatial Working Memory

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RESEARCH NOTE

Stereotype Threat Effect on a Simple Motor Task: An Investigation of the Visuo-Spatial Working Memory

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ABSTRACT

Purpose: Based on the Chalabaev et al. (2013) study showing that in a Stereotype Threat (ST) situation the velocity of force production in a simple motor task can be affected, this study aimed to replicate this result and tested the role of Visuo-Spatial Working Memory (VSWM) in the ST effect. **Method**: Twenty one female athletes performed maximum voluntary contractions of the knee extensor muscles on an isokinetic dynamometer (Biodex), under neutral, ST, and ST with mental imagery conditions. The Rate Force of Development (RFD), a velocity indicator, was measured under each condition. VSWM and avoidance-related processes were measured in at a separate time. **Results**: Data confirmed that the RFD decreased when the stereotype threat was introduced, but also that mental imagery of the movement in the pre-contraction stage prevented this effect. Moreover, in the ST condition avoidance-related processes did not affect the RFD. In contrast, higher VSWM performance was associated with higher RFD. **Conclusion**: These findings suggest that the ST effects on a simple motor task can be explained by an alteration of working memory which impairs movement preparatory processes in the pre-contraction stage.

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Mental imagery; motor performance; Stereotype Threat (ST); Working Memory (WM)

Purpose

Stereotype Threat (ST) is an apprehension state manifested when a person believes he or she is evaluated on the basis of a negative stereotype characterizing a social group to which he or she belongs (Steele & Aronson, 1995). Since the first study by Stone et al. (1999) showing ST effects on Black and White athletic performance, an increasing number of studies have focused on the effects of ST on motor performances (see Chalabaev et al., 2012; Gentile et al., 2018; Smith & Martiny, 2018; Spencer et al., 2016for review). Many of these studies have focused on complex motor acts, such as a free-throw basketball task (Laurin, 2013), a soccer-dribbling task (Hermann & Vollmeyer, 2016), a rhythmic ball bouncing task (Huber et al., 2015), a golf-putting task (Beilock et al., 2006; Stone, 2002). Recently, Chalabaev et al. (2013) revealed that even on a simple motor task (contractions of the quadriceps) ST could impair motor performance. This study aimed to test these results and to test an explanatory hypothesis for this effect.

Chalabaev et al. (2013) report an ST effect on a female population that had to produce maximal muscle contraction of the quadriceps. This effect was shown on the speed at which the force is produced (Rate Force Development, RFD) but not on the maximum force produced. This result is interesting because this stage of rise in strength (< 100ms) takes place before attentional control is possible. The authors assume that this effect is due to an alteration of preparatory processes (Raghavan et al., 2006), whose explanation would be motivational. A negative stereotype should induce a prevention focus state of vigilance, with participants avoiding errors (Seibt & Förster, 2004). Indeed, numerous studies use a motivational approach to explain the processes underlying ST. A recent study (Grimm et al., 2009), based on regulatory focus theory (Higgins, 2000) proposes that regulatory focus states interact with goal-pursuit strategies to influence performance in ST situations. On a motor task, when a negative stereotype is activated (prevention focus) in a task that emphasizes gains (promotion focus) participants experience a regulatory mismatch that can explain a decrease in performance (Chalabaev et al., 2016; Grimm et al., 2016).

Others studies have focused on attentional processes to explain the effects of ST on motor tasks. Attention, defined as the set of cognitive processes responsible for the increase or decrease of the level of activation of representations is dependent on working memory (WM), the latter modifying the sensitivity of the neural circuits that will in turn alter information processing (Gazzaley & Nobre, 2012). Yet, Schmader et al. (2008), in their integrated process model of ST effects, reported

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that the threat could lead to *explicit monitoring*, that is, either monitoring the environment for stereotype-related cues or monitoring one's own performance for mistakes. This hypothesis was based on the Beilock et al. (2006) study which showed that golf putting is not harmed when WM is reduced for putting experts, but is harmed when the attention of the individual is focused on a process that normally runs outside WM. Thus, on a complex task, attentional processes dependent on WM can influence performance in a ST situation because participants experiencing a threat focus attention on performance that has been proceduralized and should be running outside of conscious awareness. Also, one-step skills should be unaffected by explicit monitoring of task execution because they do not involve the sequencing of multiple steps. Nevertheless, as reported previously, Chalabaev et al. (2013) showed that even on a simple motor task a ST situation could impair motor performance, which questions the possible role of WM in the explanation of this effect.

Considering the importance of WM as a central cognitive mechanism, it seems essential to systematically investigate the WM system in the field of motor performance. WM is the cognitive mechanisms capable of retaining a small amount of information in an active state for use in ongoing tasks (Baddeley & Hitch, 1974). Its role in motor learning and performance under pressure is recognized (see Furley & Wood, 2016 for review). According to the Processing Efficiency theory (Eysenck & Calvo, 1992) pressure induces an anxiety state that will mobilize the athlete's WM and create a dual-task condition in which negative thoughts are processed alongside the information required for motor execution. Additionally, high levels of anxiety under pressure overwhelm WM and can thus create a level of processing inefficiency that cannot be overcome by effort alone (Williams et al., 2002; Wilson, 2008).

In their study, Chalabaev et al. (2013) report that on this simple motor task the effects of ST on the RFD occurred during the movement planning stage. However, the visuo-spatial component of working memory (VSWM) seems to be mobilized in movement preparatory processes and more generally in the implicit information processes (Buszard et al., 2016). Moreover, it seems that there is a close link between VSWM and mental imagery (Murphy et al., 2008). Some studies employing transcranial magnetic stimulation over early visual cortex further show that disruption of visual cortical activity can impair imagery tasks (Kosslyn et al., 1999) and behavioral work has provided strong evidence that visual imagery is contingent on activity in early visual cortex (Pearson et al., 2011). In addition, studies on mental imagery show that at the cortical level the areas similar to those involved in motor execution in real conditions are activated (Guillot et al., 2007). Thus, even under pressure, the use of mental imagery in the pre-contraction phase, respecting the chronometry specific to the action to be performed, could pre-activate the cortical zones responsible for the movement and potentially favor the movement planning stage.

To test the hypothesis that in a ST condition with a simple motor task the alteration of the RFD is due to a lack of movement planning in the pre-contraction stage, explained by a decrease in the efficiency of VSWM, we propose a two-step procedure. First, we have manipulated the performance conditions of a simple motor act. Participants were asked to carry out a simple motor act in three situations—in a neutral, ST and ST/mental imagery condition designed to eliminate a distraction effect. If the explanation for ST effects is related to a distraction effect, the RFD performance should be worse in the ST condition than in the neutral and ST/mental imagery conditions. Secondly, we tested how VSWM influenced performance in the ST condition. If the explanation for the movement planning difficulties is related more to attentional distraction than to motivational avoidance (as supposed by Chalabaev et al., 2013), we expected VSWM, but not avoidance-related processes, would affect RFD in the ST condition.

Method

Participants

Twenty one females licensed in an athletics club participated in this research (*M* age = 37.2, *SD* = 13.3). They were competitive athletes. Their average time of practice was 12.9 years (*SD* = 5.8), they trained an average of 3.25 hours per week (*SD* = 1.08). Prior to their participation we made sure that each considered their athletic abilities as important, based on the physical self-worth sub-scale from the French version (Ninot et al., 2000) of the Physical Self-Perception Profile. A score equal to or greater than 4 was required for participating in the study. All participants gave informed consent and were debriefed at the end of the experiment. This study was approved by the Review Board of the Department of Psychology. A sensitivity analysis of the obtained power of the design conducted with the R software 2 (package "pwr") showed that the design was able to detect a .35 effect size (large effect) with a power of .81 and an α of .05 (or a power of .87 with an α of .10). Therefore, despite its small sample size the design still had a reasonable chance of detecting a large effect.

Procedure

Our procedure is based on the Chalabaev et al. (2013) study, but, as in the Deshayes et al. (2019) study, a within subject design was used. Participants were run individually by a male experimenter. Upon arriving at the laboratory, they signed an informed consent form and completed five 7-point items assessing physical self-worth, from the Physical Self-Perception Profile. Next they were informed they had to perform four sets of three-second isometric maximal voluntary contractions of the quadriceps, interspersed with 40 seconds of recovery, as fast and as forcefully as possible. The time between the three conditions was 3 minutes. The participants were free to trigger the contraction when they wished. As reported by Maffiuletti et al. (2016), it is recommended to keep explosive ("fast and hard") contractions short. This minimizes any fatigue or discomfort and enables achievement of a larger number of trials (≥ 10) in a short period of time (e.g., 15–20-s rest periods between efforts) which may facilitate reliable and representative measures of RFD. In agreement with these recommendations we therefore decided to reduce the time of contractions to 3-s (5 seconds in Chalabaev et al. study) and to take a longer recovery time than that recommended to be sure to avoid a fatigue effect (40 seconds).

At first, participants were placed according to the established experimental conditions (positions, angles, detailed in the apparatus and measures section) and carried out a warm-up of 8 to 10 isometric contractions in the same order as the experiment proper to familiarize them with the testing protocol. All the participants began with the neutral condition then the ST condition and the ST/mental imagery condition.

In the neutral condition, participants were previously informed that the study was starting and were simply invited to perform the three contractions "as fast and as forcefully as possible". In the ST condition they were verbally informed that "this study is interested in gender differences on isometric maximal voluntary contractions and that women were generally less efficient than men in this task". In the ST/mental imagery condition, the stereotype threat was repeated and participants used pre-contraction imagery. The time spent on imaging respected the chronometry of the contraction, namely 3 to 4 seconds. The instructions were to visualize and feel the contraction before to performing it. Then, participants completed the two rating scales of the Movement Imagery Questionnaire 3 (Williams et al., 2012).

Next, as a check on the stereotype manipulation, participants rated whether "according to the information we have given you, do you think that men are better than women on the task you have just completed?", on a 7-point Likert scale scored from 1 point (strongly disagree) up to 7 points (strongly agree). All participants reported a score of 6 or 7, signifying that they had correctly understood the instructions. Then, they completed the measure of avoidance and spatial working memory. Finally, they were thanked and fully debriefed.

Apparatus and measures

RFD

An isokinetic dynamometer (Biodex) with a 110° hip angle and a 60° knee angle (with 0° corresponding to the full extension of the knee) measured the maximal voluntary isometric torque of the knee extensor muscles, the axis of the dynamometer being aligned with the anatomical knee flexion-extension axis. Straps placed around the waist and two crossover shoulder harnesses limited hip motion during the contractions. The free leg was also strapped at the quadriceps. Participants had to keep their arms crossed on the chest and hands open during contractions to avoid any traction on the armrests or the straps. The RFD value (newton meters per second) was defined as the slope of the torque–time curve (i.e., Δtorque/Δtime) in 10 incrementing time periods of 0–10, 0–20, up to 0–100 ms from the onset of contraction. The RFD values reflected the peak slope during the first 100 ms of the contraction.

Avoidance-related processes

The six items of the avoidance subscale of the Approach-avoidance Temperament Questionnaire (Elliot & Thrash, 2010), was used to measure the avoidance-related processes. Each item is scored from 1 point (strongly disagree) up to 7 points (strongly agree) and was adapted to ascertain their state during the experience (e.g. "I was scared during the experience" or "I was afraid of failing during the experience")[1].

Visuo-spatial working memory

The Corsi Blocks task was used to assess the visuospatial component of WM (Kessels et al., 2000). The process of the Corsi block tapping task requires the participant to observe the sequence of blocks lit up on a computer screen, and then repeat the sequence back in order. The task starts with a small number of blocks, gradually increases (in length up to nine blocks) and becomes more complex until the participant's performance suffers. This number is known as the Corsi Span and ranges from 1 to 9.

Results

Repeated measures ANOVA showed that RFD differed between the three condition, F (2, 40) = 8.37, p < .001, $\eta 2$ = .29. T tests for paired samples were conducted to test our first hypotheses. As expected results show a difference between the neutral (M = 388.59, ST = 163.91) and ST (M = 303.20, ST = 115.35) conditions, t (20) = 5.95, $p < .001$, $d = .61$). Females' peak rate of force development was significantly lower when the negative stereotype was induced. Moreover, additional analyzes did not show differences between the neutral and the ST/imagery condition (M = 403.22, ST = 154.25), t (20) = −0.5, p = .62). Furthermore, results showed a significant difference between the ST condition (M = 303.20) and the ST/imagery condition (M = 403.22), t (20) = −3.11, p = .006, d = .74. When the negative stereotype was induced, females' peak rate of force development was significantly lower than when it was induced with an imagery task.

Finally the avoidance-related processes and VSWM effects on performance in the ST condition were analyzed. A multiple linear regression analysis was conducted controlling for performance in the neutral condition. VSWM and avoidance related process scores were entered as independent variables (IV), the performance in the neutral condition and physical self-worth were entered as covariates and the performance in the ST condition was the dependent variable (DV). First, the analysis showed a significant effect of the performance in the neutral condition on the performance in in the ST condition, $\beta = .93$, t (20) = 21.54, $p < .001$, $\eta 2 = .97$, but no effect of physical self-worth, $\beta = -.02$, t (20) = −.65, $p > .05$. Importantly, the analysis revealed a positive effect of VSWM on the performance in the ST condition, $\beta = .12$, t (20) = 2.95, $p = .01$, $\eta 2 = .31$, and no effect of the avoidance related process $\beta = .03$, t (20) = .81, $p > .05$. The model accounted for 98% of the variance of the performance, F (4, 16) = 197.4, $p < .001$.

Discussion

This study replicated the Chalabaev et al. (2013) result showing that inducing the negative stereotype that females have poor strength leads to a decrease in the rate of force development on a simple motor task that involves an isometric muscle contraction. These results support the hypothesis that ST may affect performance on simple motor tasks by influencing the movement planning stage. As supposed by Chalabaev et al. (2013), it seems that the influence of stereotype threat is not limited to motor tasks that involve explicit monitoring processes.

Moreover, because Rate of Force Development is modulated by anticipatory processes (Raghavan et al., 2006), Chalabaev et al. (2013) supposed that ST inhibited RFD by influencing the preparatory processes that occurred before task execution and that the explanation was motivational- the ST triggered avoidance responses. In this study we proposed a cognitive explanation related to the role VSWM plays on the anticipatory processes that affect the planning stage of force production. This hypothesis was based on the recent study highlighting the effect of VSWM on movement preparatory processes and more generally on implicit information processing (Buszard et al., 2016). As predicted, in the ST situation the Rate Force of Development was not affected when females had to imagine the movement before the contraction. This result supports the studies showing the relationships between VSWM and mental imagery and shows that when the alteration of VSWM is compensated by a mental imagery strategy, the pre-contraction planning stage is unaffected. The role of VSWM in the ST effects associated with this task were confirmed by a second result showing that participants with higher VSWM in the ST condition had a higher RFD, whereas avoidance scores appeared independent of RFD, contrary to the presumption of Chalabaev et al. (2013).

Despite the clarity of the findings, it is important to note the study has certain limitations. The first is the lack of counterbalancing of conditions. Though fatigue and learning are unlikely to play a role in the findings that are reported, order effects can arise from a number of different factors, including primacy and recency effects or changes in attention. Secondly, although it is able to detect a large effect the sample size is small. Replicating this experience with a larger sample would make the results obtained even more reliable. Thirdly, the neutral condition is different than the one used by Chalabaev et al. (2013). In this study, nothing was said, all mention of gender was avoided (usually named control condition) while in the Chalabaev et al. study counterarguments were presented to commonly held stereotypes (usually named nullified stereotype condition). However, a recent study (Deshayes et al., 2019), comparing the effect of stereotype threat on performance with a nullified-stereotyped group and a control group in the motor domain showed no significant difference between the two conditions. This suggests that reporting "there is no gender difference on the task" or stating nothing seems to have the same effects on performance during motor tasks. Finally, in light of recent results reported by Deshayes et al. (2019) showing a facilitating effect of a ST situation on the motor performance of women performing a simple task, our results, confirming a negative effect on a similar task, raise questions. However, it seems that this contradiction highlights one of the main limitations of the work looking at the effects of ST on motor performance and opens up interesting avenues for future work. Indeed, most of the studies characterize and distinguish the motor acts according to their degree of “complexity” in a binary way (simple/complex). However, it seems to us that the reality of the cognitive and physiological processes involved in the performance of a motor act is much more complex and that this difficulty in refining the description of the processes involved in the performance of a task prevents us from exploring more precisely the role of mediators in the effects of ST on motor performance. The recent study by Deshayes et al. (2019) highlights perfectly this state of facts. Indeed, their task and that of this study can be considered similar if we consider their complexity. Nevertheless, they appear different if we consider the intensity with which they are produced. Moreover, the cognitive and physiological processes involved in a strength or endurance task differ and that this certainly explains the different effects of an ST situation on the performances produced.

What does this article add?

This article shows that even the motor performance of a simple act can be affected by a situation perceived as threatening, that the explanation of these effects seems to be linked to the dysfunction of VSWM and that a preventive strategy for these effects consists of soliciting, prior to execution, a mental representation of the act to be performed. More generally, this article sheds light on the effects of ST situations, and it seems that the literature on the anxiety–performance relationship (see Hill et al., 2010b, for a review on chocking under pressure, or Buszard et al., 2017, for a review of working memory capacity in sport) provide perspectives to better understand the explanatory mechanisms of the negative stereotype induction effects on motor performance, whether the task is simple or complex.

Note

ATQ items specific adaptation (in italic):

By nature, I am a very nervous person.
I was nervous during the experience
It doesn’t take much to make me worry.
I was a little worried during the experience
I feel anxiety and fear very deeply.
I felt anxiety during the experience
I react very strongly to bad experiences.
I was scared during the experience
When it looks like something bad could happen, I have a strong urge to escape.
I wanted to escape during the experience
It is easy for me to imagine bad things that might happen to me.
I was afraid of failing during the experience

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