Reducing stereotype threat with embodied triggers: A case of sensorimotor-mental congruence

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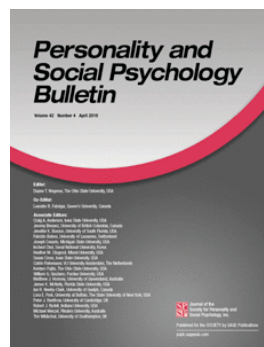
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Abstract

In four experiments, we tested whether embodied triggers may reduce stereotype threat. We predicted that left-side sensorimotor inductions would increase cognitive performance under stereotype threat, because such inductions are linked to avoidance motivation among right-handers. This sensorimotor–mental congruence hypothesis rests on regulatory fit research showing that stereotype threat may be reduced by avoidance-oriented interventions, and motor congruence research showing positive effects when two parameters of a motor action activate the same motivational system (avoidance or approach). Results indicated that under stereotype threat, cognitive performance was higher when participants contracted their left hand (Study 1) or when the stimuli were presented on the left side of the visual field (Studies 2-4), as compared to right-hand contraction or right-side visual stimulation. These results were observed on math (Studies 1, 2, and 4) and Stroop (Study 3) performance. An indirect effect of congruence on math performance through subjective fluency was also observed.

Keywords: stereotype threat; embodied cognition; regulatory fit; motor congruence; avoidance motivation.

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congruence

Stereotype threat theory (Steele, 1997) has become a predominant approach to analyzing achievement gaps between social groups. Interest in stereotype threat may stem from its emphasis on the situational origin of achievement gaps: it is the threat experienced by individuals facing negative ingroup stereotypes that explains poor performance in high-stakes settings, through the mediating role of negative thoughts, worries, ruminations, and arousal (for a review see Schmader, Johns, & Forbes, 2008). This hypothesis is appealing because it implies that achievement gaps could be reduced by changing the evaluative context.

Accordingly, researchers have sought interventions to counteract stereotype threat. Drawing on evidence that this phenomenon results from interpretative processes, most studies have focused on reappraisal strategies that reframe the self or the performance situation, in order to prevent the occurrence of this stereotype-induced psychological state. These studies indicate that stereotype threat can be lessened by prompting people to view the testing situation as a challenge (Alter, Aronson, Darley, Rodriguez, & Ruble, 2010), encouraging them to affirm a valued attribute (Martens, Johns, Greenberg, & Schimel, 2006), reappraising physiological arousal (John-Henderson, Rheinschmidt, & Mendoza-Denton, 2015), or avoiding fixed organizational lay theories (Emerson & Murphy, 2015).

These interventions have important implications. However, because they require effortful reappraisal processes, they may not be easy to implement and may tax working memory resources. Because stereotype threat acts partly by reducing such resources (Schmader et al., 2008), interventions that do not tax them further would be helpful. In line with this idea, there is evidence that stereotype threat can be alleviated by heavily practicing math problems so that they can be retrieved directly from long-term memory rather than working memory (Beilock, Rydell, & McConnell, 2007). However, again, this strategy

requires a large amount of effort. Here, we test an intervention that does not necessitate effortful reappraisal. Drawing on embodied cognition research, we test if simple sensorimotor inductions can counteract stereotype threat.

Sensorimotor Experience and Higher-Order Cognition

Embodied cognition considers that all cognition, including high-level processes, is grounded in the brain's modality-specific systems, including the sensory systems underlying perception of the environment, the motor systems underlying action, and the introspective systems underlying phenomenological experiences of motivation, emotion, and cognitive operations (e.g., Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). As a consequence, how people think may be affected by external and internal cues. In a seminal demonstration of this tenet, Cacioppo, Priester, and Berntson (1993) showed that simple motor movements can influence higher-order evaluative processes. In this study, neutral stimuli were evaluated more positively when presented during arm flexion than during arm extension. To explain this effect, the authors proposed that arm movements activate specific motivations: arm flexion, an action with a force directed toward the body, is associated with approach motivation, and arm extension, a force directed away from the body, is associated with avoidance motivation. Numerous other findings have linked both sensory experiences and motor movements to higher-order cognition: People evaluate groups as powerful if those groups' names are presented high rather than low in the visual field (Schubert, 2005); people imbue objects with importance if those objects feel heavy (Jostmann, Lakens, & Schubert, 2009); people are less creative after performing rigid rather than fluid arm movements (Slepian & Ambady, 2012) and after performing arm extension rather than arm flexion (Friedman & Förster, 2000); and people rationalize less when they are in a supine body posture (E. Harmon-Jones, Price, & C. Harmon-Jones, 2015). We hypothesized that this link between sensorimotor experience and higher-order cognition holds implications for stereotype

threat.

More particularly, the present research focuses on one specific embodied trigger: the laterality of sensorimotor experience. Past research indicates that among right-handers, contracting muscles on the left side of the face or contracting the left hand is associated with negative feelings and stimuli evaluations (Bassel & Schiff, 2001; Schiff & Lamon, 1989, 1994), while the reverse is observed when contracting the right hand or muscles on the right side of the face (e.g., Root, Wong, & Kinsbourne, 2006). These associations seem to occur because unilateral muscle contractions activate contra-lateral motor cortices located near regions involved in emotional processing (Davidson, 1992). The electrical and chemical processes spread locally to adjacent cortical sites, activating in turn approach and avoidance motivations (e.g., E. Harmon-Jones, 2006; Peterson, Schackman, & E. Harmon-Jones, 2008).

Regulatory Fit and Sensorimotor Congruence: Two Cases of Motivational Congruence

The present research combines work on embodied cognition and stereotype threat by investigating whether sensorimotor experience interacts with mental representations (i.e., stereotypes) to affect performance on tasks requiring higher cognitive processes. Specifically, we predicted that sensorimotor-induced avoidance motivation would reduce stereotype threat effects. Our hypothesis is based on the phenomenon of *motivational congruence*, which has been observed in both embodied cognition (e.g., Cretenet & Dru, 2004, 2009) and regulatory fit (Higgins, 2000) literatures.

Regulatory fit (Higgins, 2000) occurs when the means of goal pursuit is congruent with the goal or mindset of the individual, resulting in greater motivation and performance (e.g., Freitas & Higgins, 2002). For example, encouraging individuals to avoid failure during an academic test may be beneficial to those who are prevention-oriented (i.e., focused on potential losses), because the manner of task engagement matches their regulatory focus (e.g., Keller & Bless, 2006). This phenomenon has also been observed under stereotype threat,

which is reduced when the task reward structure is framed in terms of losses (e.g., Barber &

Mather, 2013; Chalabaev, Major, Sarrazin, & Cury, 2012; Grimm, Markman, Maddox, &

Baldwin, 2009). In these studies, performance increased because framing the task in terms of

losses is congruent with the goal to avoid failure typically adopted by individuals under

stereotype threat (e.g., Brodish & Devine, 2009; Chalabaev, Sarrazin, Stone, & Cury, 2008;

Seibt & Förster, 2004). For example, in Grimm et al.'s (2009) study, the task had either a loss

structure (participants lost fewer points for correct than for incorrect responses) or a gain

structure (participants gained more points for correct than for incorrect responses). Stereotype

threat was reduced when the emphasis was placed on losses, because this negative reference

point matched the sensitivity to failure that is activated by stereotype threat situations. This

finding is known as stereotype fit (Grimm et al., 2009) and represents a form of *mental*

motivational congruence.

In the embodied cognition approach, *sensorimotor* motivational congruence occurs

when two aspects of sensorimotor experience activate the same motivational system.

Research in this area has tended to focus on motor movements as motivational triggers.

Relevant motor parameters include the type of angular motion (flexion vs. extension) and the

side of the body in which motion occurs (left vs. right). Both of these motor parameters can

activate either approach or avoidance motivational systems. For example, both muscle flexion

(e.g., contracting an arm) and movements on the right side of the body activate approach

motivation, while both muscle extension (e.g., extending an arm) and movements on the left

side of the body activate avoidance motivation (e.g., E. Harmon-Jones, 2006; Peterson et al.,

2008; Schiff & Lamon, 1989). Sensorimotor motivational congruence occurs when the

multiple parameters of a motor action each activate the same motivational system. Thus,

sensorimotor motivational congruence occurs when performing a left-arm extension, which

involves two triggers of avoidance motivation, or a right-arm flexion, which involves two

triggers of approach motivation (Cretenet & Dru, 2004, 2009). In one of the first demonstrations of this phenomenon, Cretenet and Dru (2004) showed that performing congruent actions led to positive judgments of neutral stimuli, whereas performing incongruent actions (i.e., right-arm extension or left-arm flexion) led to negative evaluations of the same stimuli. These congruence effects have been extended to various judgment tasks (Mullet, Cretenet, & Dru, 2014), as well as cognitive tasks (Cretenet & Dru, 2009).

The Sensorimotor–Mental Congruence Hypothesis

Based on the similarities between these paradigms, we wondered whether stereotype threat effects on cognitive performance may be alleviated when coupled with a sensorimotor trigger of avoidance motivation. Because prior work has shown stereotype threat to (mentally) induce an avoidance motivation (Brodish & Devine, 2009; Chalabaev et al., 2008; Seibt & Förster, 2004), the addition of a sensorimotor trigger of avoidance motivation during stereotype threat may produce a motivational congruence effect that benefits cognitive performance. Whether this is true remains an open question, as motivational congruence effects have only been observed with same-modality inductions: two sensorimotor triggers during sensorimotor motivational congruence, and two mental triggers (i.e., stereotypes and task frame) during stereotype fit. To our knowledge, no study has examined whether motivational congruence effects can occur when one sensorimotor trigger and one congruent mental trigger are combined.

The Present Research

We tested this sensorimotor–mental congruence hypothesis in four experiments, by manipulating stereotype threat and sensorimotor laterality. Studies 1-3 examined this hypothesis based on different manipulations. Study 4 went a step further by examining if this specific form of motivational congruence is driven by the metacognitive mechanisms involved in regulatory fit and motor congruence.

More particularly, left-side sensorimotor activity was introduced via motor movements (left hand contractions; Study 1) and sensory experience (presenting stimuli in the left visual field; Studies 2-4). Stereotype threat was induced by highlighting negative ingroup stereotypes about performance on a modular arithmetic task (Studies 1, 2, and 4) and the Stroop task (Study 3). We predicted that under stereotype threat conditions, left-side (avoidance) sensorimotor inductions would increase cognitive performance compared to right-side (approach) inductions on both executive tasks. Studies 1-3 included a control condition in which positive stereotypes were highlighted. While one study has shown a fit effect between positive stereotypes and a gain reward structure (Grimm et al., 2009, Study 2), other studies have not observed such an effect (Barber & Mather, 2013; Grimm et al., 2009, Study 1). As shown by Pavlova, Weber, Simoes, and Sokolov (2014), positive stereotypes may be weaker than negative ones, explaining why regulatory fit may not be observed with the former. These inconsistent results make analyses more exploratory with regard to positive stereotypes. In Study 4, the control condition involved nullifying negative stereotypes instead of activating positive ones, in order to examine if the motivational congruence effect holds when using a control condition that is more typical to the stereotype threat paradigm.

Study 1

Study 1 served as an initial test of whether sensorimotor activity (e.g., simple motor movements) and higher-order mental activity (e.g., stereotype threat) can combine to produce motivational congruence effects. Participants worked on an arithmetic task, with some doing so under stereotype threat. Participants also engaged in left or right lateral motor movements, which served to activate approach and avoidance motivations, respectively. We predicted that the combination of stereotype threat and left-side motor movements (both involving avoidance motivations) would produce a motivational congruence effect that would increase arithmetic performance, thereby alleviating stereotype threat effects.

Method

Participants and design. An a priori power analysis was conducted with G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). Relevant published studies on stereotype fit and motor congruence (Barber & Mather, 2013; Barber, Mather, & Gatz, 2015; Chalabaev et al., 2012; Cretenet & Dru, 2009) reported effect sizes ranging from $\eta^2_p=.09$ (Chalabaev et al., 2012, Study 1) to $\eta^2_p=.23$ (Cretenet & Dru, 2009, Study 2), with a mean effect size of $\eta^2_p=.16$. Based on these effect sizes, an alpha of .05, and 80% power, analyses indicated sample sizes ranging from 24 participants ($\eta^2_p=.23$) to 68 participants ($\eta^2_p=.09$), with a mean sample size of 36 participants ($\eta^2_p=.16$). Based on these analyses, we decided to recruit at least 36 participants, with a maximum of 56 participants to achieve 95% power. The same a priori power analysis was conducted in all three studies.

Fifty right-handed students in human movement sciences (6 women, $M_{age}=19.02$) participated for course credit. Two participants who indicated their suspicion during debriefing were excluded from the analyses, as well as two participants with a rate of correct responses on the test (<35%) that was much below chance level, leaving 46 participants. Participants were randomly assigned to a 2 (stereotype threat / control) × 2 (right / left hand contraction) mixed-factorial design, with stereotypes as the between-subject variable and laterality of hand contraction as the within-subject variable. Informed consent was provided by all participants and ethical guidelines of the institution where the research was conducted were followed.

Participants had to give at least five out of six appropriate responses for right-handedness on the lateral preferences questionnaire (Porac & Cohen, 1981) to be included in the study (e.g., Cretenet & Dru, 2004). In addition, and in line with the assumption that negative stereotypes are more likely to affect individuals who are skilled and who value the stereotyped domain (Steele, 1997), participants had to report at least moderate math skills and

importance of these skills (an average greater than or equal to 4, of two 7-point items: "I am

good at math" and "It is important to me that I am good at math") (e.g., Beilock et al., 2007).

Procedure and measures. Participants completed the experiment individually. They

were introduced to a modular arithmetic task via computer. They were asked to assess as

accurately as possible the validity (true or false) of problems such as "36≡18 (Mod 4)". To do

this, the middle number is subtracted from the first number (i.e., 36–18), and the result is

divided by the last number (i.e., 18/4). If the result is a whole number, the problem is "true".

To ensure that problems were sufficiently cognitively demanding, they contained a borrowing

operation, and all numbers were higher than 10 (see Beilock et al., 2007). After two practice

trials, participants performed a baseline block of 10 problems. Half of these problems were

"true" and order was randomized for each participant. Each trial began with a 500 ms fixation

point, followed by a problem displayed for 15 s. The timing of problem presentation was

fixed in order to control for duration of motor actions performed in subsequent blocks.

Following presentation of the problem, a screen with the word "response" appeared during 4

s, signaling participants to respond verbally (i.e., with "true" or "false"). An oral response

precluded arm movements that could have interfered with the motor induction.

After baseline assessment of participants' math performance, the stereotype threat

manipulation was introduced via computer. Based on previous work (e.g., Croizet et al., 2004;

Ståhl, Van Laar, & Ellemers, 2012), participants were told of research establishing that

students in human movement sciences perform worse in maths than students of the exact

sciences (stereotype threat condition) or better in maths than humanities students (control

condition).[1] Individuals then completed two other blocks of 10 problems each, during which

the laterality induction was introduced. Participants were asked to squeeze a foam ball until

they could feel their palm and to maintain that pressure during problem completion. They

squeezed the ball with their left (left-side block) or right hand (right-side block) while their

opposite hand remained flat and palm down (e.g., E. Harmon-Jones, 2006). The order of the

left-side and right-side blocks was counterbalanced across participants. The computer

signaled to start squeezing the ball 2 s before each problem was presented and to stop

squeezing after they responded verbally.

At the end of each block, evaluations of the hand contraction were measured,

including agreeableness ("To what extent was the motor action agreeable to perform?"),

fluency ("To what extent was the motor action easy to perform?"), and effort ("How much

effort did the motor action require?") (e.g., Cretenet & Dru, 2009). Responses were provided

on 7-point scales, along with mood ("How do you feel right now?" from (1) very unhappy to

(7) very happy). We wanted to ensure that participants did not infer an internal state from the

actions performed via self-perception mechanisms (Bem, 1967). Finally, they completed a

manipulation check ("You were told that students in human movement sciences perform": (1)

worse than students of the exact sciences, or (2) better than humanities students) and

background questions (sex, age) before being thanked and debriefed.

Results

Detailed results are presented in the supplemental materials file (Table 1).

Math performance. Preliminary analyses showed no significant differences in

baseline performance between stereotype threat (M=7.25, SE=1.89) and control conditions

(M=6.82, SE=2.15), $t(44)$=0.72, p=.473. Next, a 2 (stereotype threat) × 2 (laterality of hand

contraction) × 2 (task order) mixed-factorial ANCOVA controlling for baseline performance

was conducted on the number of correct responses. Results showed a significant stereotype

threat × laterality interaction effect, $F(1, 41)$=5.67, p =.022, η^2_p=.12. This interaction was not

qualified by the stereotype threat × laterality × task order interaction, $F(1, 41)$=0.18, p=.67,

η^2_p=.00. Specifically, in the stereotype threat condition, performance was significantly higher

when contracting the left hand (Adj$M$=7.39, SE=0.35) than the right hand (Adj$M$=6.19,

SE=0.37), $F(1, 41)$=9.11, p=.004, η^2_p=.18. In contrast, in the control group, the performance difference between the left hand (*M*=7.56, *SE*=0.37) and right hand (*M*=7.73, *SE*=0.39) conditions was non-significant, $F(1, 41)$=0.17, p=.679, η^2_p=.004 (see Figure 1).

Concerning main effects, the ANCOVA indicated a marginal effect of stereotype condition, $F(1, 41)$=3.76, p=.059, η^2_p=.08, performance being marginally lower in the stereotype threat (Adj*M*=6.79, *SE*=0.30) than in the control (Adj*M*=7.65, *SE*=0.32) condition. There was no main effect of laterality, $F(1, 41)$=0.56, p=.45, η^2_p=0.01, performance being similar in right hand (*M*=6.96, *SE*=0.27) and left hand (*M*=7.47, *SE*=0.26) conditions.

Motor action evaluations and mood state. Results from 2×2×2 mixed-factorial ANOVAs showed main effects of laterality: compared to left hand contractions, right hand contractions prompted increased evaluations of agreeableness ($M = 4.12$, $SE = 0.18$, and *M*=4.55, *SE*=0.15, respectively), $F(1, 42)$=5.20, p=.028, η^2_p=.11, increased action fluency (*M*=5.22, *SE*=0.19 and *M*=5.69, *SE*=0.16), $F(1, 42)$=6.61, p=.014, η^2_p=.13, and marginally less physical effort (*M*=3.41, *SE*=0.19 and *M*=3.05, *SE*=0.18), $F(1, 42)$=2.86, p=.098, η^2_p=.06). The stereotype × hand contraction interactions were not significant, indicating that these variables did not mediate the interaction effect on performance. The main effect of stereotype threat and the interactive effect on mood state were not significant.

Discussion

Study 1 indicates that stereotype threat effects were alleviated by clenching the left fist, suggesting a motivational congruence effect. Movements on the left activate avoidance motivation (for right-handers), which is a congruent motivational state with the loss avoidance that is triggered by stereotype threat. Overall, these results are in line with past studies on stereotype fit (Barber & Mather, 2013; Grimm et al., 2009, Study 1), showing motivational congruence effects on math performance when avoidance motivation is induced under stereotype threat. The novel finding in the present study is that motivational congruence

during stereotype threat can be achieved via simple motor movements. Merely by clenching one fist versus the other, the negative effect of stereotypes on performance can be alleviated.

The influence of motor movements was seen only in the stereotype threat condition. In the control group for whom a positive stereotype was made salient, laterality of motor action did not affect performance. In other words, there was no motivational congruence effect when a positive stereotype was coupled with an approach sensorimotor cue. These results are in line with past research on stereotype fit (Barber & Mather, 2013; Grimm et al., 2009, Study 1), and may be due to the positive stereotype being weaker than the negative one (Pavlova et al., 2014).

Study 2

The congruence hypothesis was tested again in Study 2. Moreover, we used a sensory induction of laterality, with arithmetic problems being presented on the right or left side of the screen. This operationalization was based on research connecting lateral spatial attention and approach/avoidance tendencies (Nash et al., 2010; Maxwell & Davidson, 2007; Phaf & Rotteveel, 2009). This induction allowed us to ascertain that the effects found in Study 1 were not contaminated by participants having to perform a double-task (i.e., solving problems while contracting their hand). It is also possible that contracting the dominant hand not only induced avoidance or approach motivation, but also inhibited imagining calculating the solution with the dominant hand, which may have hampered performance through embodied interference (e.g., Alibali & Nathan, 2012). In addition, this novel induction allowed us to examine whether congruence effects may be extended to another sensorimotor laterality induction.

Method

Participants and design. Thirty-eight right-handed students in human movement sciences (17 women, M_{age}=20.5) who met the aforementioned criteria, participated for course

credit. They were randomly assigned to a 2 (stereotype threat / control) × 2 (right / left stimulus location) mixed-factorial design, with stereotypes as the between-subject variable and the laterality of stimulus location as the within-subject variable. Informed consent was provided by all participants and ethical guidelines of the institution were followed.

Procedure and measures. Study 2 was identical to Study 1 with the exception of the laterality manipulation. Following work by Marble and Proctor (2000), laterality was induced by presenting each block of 10 problems at the center of either the left side or right side of a 15-in VGA computer screen. Participants sat on a fixed seat positioned in front of the monitor at a viewing distance of 60 cm, with hands flat and palm down, and were asked to remain still and look straight ahead. The rest of the procedure was similar to Study 1 (except that we did not include evaluations of the action performed).

Results

Detailed results are presented in the supplemental materials file (Table 2).

Math performance. First, a Student *t*-test showed no significant differences in baseline performance between stereotype threat (M=5.80, SE=2.48) and control conditions (M=6.72, SE=1.93), $t(36)$=-1.27, p=.213. Next, a 2 (stereotype threat) × 2 (laterality of stimulus location) × 2 (task order) mixed-factorial ANCOVA controlling for baseline performance showed a significant interaction, $F(1, 33)$=5.82, p=.022, η^2_p=.15. Again, this interaction was not qualified by the stereotype threat × laterality × task order interaction, $F(1, 33)$=1.02, p=.319, η^2_p=.03. Specifically, in stereotype threat conditions, left-side stimuli increased performance (Adj$M$=6.95, SE=0.34) compared to right-side stimuli (Adj$M$=5.91, SE=0.38), $F(1, 33)$=7.99, p=.008, η^2_p=.20. As in Study 1, in control groups the difference in performance between left-side (Adj$M$=6.43, SE=0.36) and right-side (Adj$M$=6.69, SE=0.41) conditions was not significant, $F(1, 33)$=0.46, p=.503, η^2_p=.01 (see Figure 2).

Finally, the ANCOVA showed no significant main effect of stereotype threat or laterality (Fs<1).

Mood. A 2×2×2 mixed-factorial ANCOVA controlling for baseline mood showed a significant stereotype threat × laterality interaction effect , $F(1, 33)=4.15$, $p=.049$, $\eta^2_p=.11$. Specifically, in the control group, participants felt happier in the right-side ($M=5.29$, $SE=0.11$) than in the left-side condition ($M=4.93$, $SE=0.18$), $F(1, 33)=6.88$, $p=.013$, $\eta^2_p=.17$. In contrast, in the stereotype threat group, mood was similar in the right-side ($M=5.09$, $SE=0.10$) and left-side ($M=5.12$, $SE=0.17$) conditions, $F(1, 33)=0.04$, $p=.846$, $\eta^2_p=.00$. There were no significant main effects of stereotypes and laterality.

Discussion

Study 2 provided converging evidence that motivational congruence can be achieved in a stereotype threat context via a manipulation of sensorimotor experience. As in Study 1, motivational congruence was observed in the stereotype threat condition, where performance increased with left-side (avoidance) as compared to right-side (approach) sensorimotor experience. Again, this effect occurred irrespective of task order. Whereas Study 1 used motor movements, Study 2 used sensory input to produce a motivational congruence effect. Again, sensorimotor experience affected performance only in the stereotype threat condition but not in the control condition that highlighted a positive stereotype, and this effect was not driven by self-perception mechanisms. Study 2 provided further support that a simple manipulation of sensorimotor experience can reduce stereotype threat.

Study 3

To assess replicability of the results in Studies 1 and 2, we tested the congruence hypothesis in a third study. We used a different stereotype induction (i.e., related to sex differences) and another cognitive task (i.e., a Stroop task) that relies on inhibition, the ability to exert mental effort to suppress prepotent responses that are considered "incorrect" (Miyake,

Friedman, Emerson, Witzki, Howerter, & Wager, 2000). Several studies reported that performance on the Stroop task may be reduced under stereotype threat (Carr & Steele, 2010; Inzlicht, McKay, & Aronson, 2006; Rydell, Van Loo, & Boucher, 2014).

Method

Participants and design. Forty-seven right-handed students in human movement sciences (25 females, M_{age}=21.5) participated for course credit. The study comprised a 2 (male / female) × 2 (right / left stimulus location) mixed-factorial design. Informed consent was provided by all participants and ethical guidelines of the institution were followed.

Procedure and measures. Study 3 was identical to Study 2 with the exception of the stereotype induction and experimental task. We used the Stroop task that has been utilized in past stereotype studies (e.g., Inzlicht et al., 2006; Ståhl et al., 2012). Participants were instructed to name as quickly and accurately as possible the colors in which strings of letters were printed while ignoring the meaning of the letter strings. Responses were provided verbally to preclude arm movement. The task consisted of three blocks of twenty-five stimuli: in the incongruent block, each word's color did not match its semantic meaning (e.g., *grey* in blue ink); in the congruent block, each word's color matched its semantic meaning (e.g., *grey* in grey ink); and in the neutral block, stimuli had no semantic meaning (i.e., *XXXX*). Completion of each block was timed (experimenters were blind to hypotheses and conditions in order to avoid experimenter effects). Because this task requires maintaining the goal of naming each word's color while inhibiting the tendency to read it, it is thought to require attentional self-regulation (Engle, 2002). The time taken to inhibit this automatic tendency is known as the interference effect. Given that participants responded verbally in order to avoid arm movements that could have interfered with our laterality induction, we were not able to record response time per trial. Instead, we used the procedure of Inzlicht et al. (2006), in which time to complete each block was recorded with a stopwatch by an experimenter that

was blind to hypotheses and conditions. Interference scores were computed by subtracting average latency on the congruent block from average latency on the incongruent block. Lower scores indicate higher attentional self-regulation.

After six practice trials, participants performed a baseline measure of three blocks (incongruent, congruent, neutral), with stimuli being presented in the middle of the screen. Block order was counter-balanced across participants. After baseline assessment of performance, stereotype instructions were introduced on the computer. Participants were told of research establishing that males perform worse on attentional tasks than females. These instructions were designed to induce stereotype threat among males but not females, who acted as controls. Participants then completed two other series of three blocks, each series being presented either on the left or right side of the screen. The rest of the procedure and measures were similar to those used in Study 1. After each block, mood was assessed along with additional self-perceptions, allowing us to test whether these variables influenced our effects (e.g., Grimm et al., 2009). Specifically, we asked participants "How good do you think your performance was on this task? (1 = *very bad*; 7 = *very good*)," "How much did you like the task? (1 = *I did not like at all*; 7 = *I liked very much)*," and "How motivated were you to do well on the task? (1 = *very unmotivated*; to 7 = *very motivated*)."

Results

Detailed results are presented in the supplemental materials file (Table 3).

Stroop interference. Three outliers on Stroop interference were removed using the median absolute deviation method (Leys, Ley, Klein, Bernard, & Licata, 2013), leaving 44 participants (23 females) for further analyses. Because sex was confounded with stereotype induction, we first confirmed no initial differences in Stroop interference between males (*M*=6.74 s, *SE*=1.04) and females (*M*=8.66 s, *SE*=1.31), *t*(42)=-1.13, *p*=.264. We also checked that participants performed lowest in the incongruent block. A repeated measures ANOVA

showed a main effect of block type, $F(2, 86)=116.47$, $p<.001$, $\eta^2_p=.73$. As expected, responses were slower on incongruent trials ($M=19.99$, $SE=0.62$) than on congruent ($M=12.10$, $SE=0.36$) or neutral ones ($M=14.08$, $SE=0.48$), $F(1, 43)=188.82$, $p<.001$, $\eta^2_p=.82$.

Next, a 2 (sex) × 2 (laterality of stimulus location) × 2 (task order) mixed-factorial ANCOVA controlling for baseline interference showed a marginally significant interaction effect on Stroop interference, $F(1, 39)=3.17$, $p=.083$, $\eta^2_p=.08$. As in Studies 1-2, this interaction was not qualified by the sex × laterality × task order interaction, $F(1, 39)=0.02$, $p=.896$, $\eta^2_p=.00$ Specifically, among males, left-side stimuli location increased performance (Adj$M=7.34$, $SE=0.85$) compared to right-side stimuli location (Adj$M=9.29$, $SE=1.04$), $F(1, 39)=5.11$, $p=.032$, $\eta^2_p=.12$. Among females, the difference in performance between left-side (Adj$M=7.75$, $SE=0.81$) and right-side (Adj$M=7.56$, $SE=0.99$) locations was not significant, $F(1,39)=0.05$, $p=.818$, $\eta^2_p=.00$ (see Figure 3). There was no significant main effect of sex or laterality (Fs<1). To ensure that the interaction effect on Stroop interference was not due to a speed-accuracy trade-off, we computed an error interference score by subtracting the number of errors on congruent trials from the number of errors on incongruent trials (e.g., Ståhl et al., 2012). The mixed-factorial ANCOVA controlling for baseline error interference showed that the sex × laterality interaction was not significant ($F<1$).

Self-reports. A series of 2×2×2 mixed-factorial ANCOVAs controlling for baseline values showed no significant main or interactive effects of sex and laterality on mood, perceived performance, liking, or motivation, confirming that self-perceptions did not drive our effects.

Discussion

Study 3 replicated the results observed in Studies 1 and 2, while extending them to another cognitive task and a different stereotype. Again, motivational congruence was observed in the stereotype threat condition, performance being higher with left-side

(avoidance) sensorimotor experience than with right-side (approach) sensorimotor experience. Laterality of sensory input did not affect performance in the control group. Overall, these findings provide further support for the hypothesis that motivational congruence can be achieved by pairing a sensorimotor manipulation with a higher-level motivation manipulation (i.e. stereotype threat).

Study 4

Study 4 went a step further by investigating the processes of the sensorimotor–mental congruence effect. Past research indicates congruence effects on subjective feeling of fluency, defined as the conscious experience of ease, low effort, and high speed (e.g., Lee & Aaker, 2004; Regenberg, Häfner, & Semin, 2012). For example, participants found a message easier to process when it was congruent with their regulatory focus than when it was not (Lee & Aaker, 2004, Experiment 4A). Individuals could thus find easier to process information when the laterality of sensorimotor cues is congruent with their stereotype-induced avoidance motivation. Since fluency predicts performance on cognitive tasks, including problem-solving (e.g., Ackerman & Zalmanov, 2012) and cognitive flexibility (e.g., Cretenet & Dru, 2009, Study 5), fluency was hypothesized to mediate the sensorimotor–mental congruence effect on cognitive performance. In relation with this process, we also examined whether motivational congruence reduces task-unrelated thoughts, and leads to lower avoidance (and higher approach) motivation. Finally, we examined task confidence, which may be affected by motor congruence effects (Dru & Cretenet, 2011).

Study 4 also aimed at replicating the results observed in Studies 1-3 with a more standard manipulation of stereotype threat (i.e., women in math). We reasoned that the academic major stereotype used in Studies 1-2 might not be as salient as the math gender stereotype usually studied in stereotype threat research. In addition, instead of inducing positive stereotypes, we used a more standard control condition in which no stereotype was

activated, by explicitly stating that there were no gender differences on the test. Finally, a post stereotype manipulation block with no motivation induction was added, with math items presented in the middle of the screen. Showing that the left-side condition significantly differs under stereotype threat from both the right-side and middle conditions would provide further support for the congruence hypothesis. Indeed, comparing only left-side and right-side conditions as we did in Studies 1-3 is not sufficient to disentangle whether the difference is caused by an increase in performance in the left-side condition (i.e., congruence effect), or a decrease in the right-side condition (i.e., incongruence effect). This additional block also enabled us to test the classic stereotype threat effect, by examining whether the stereotype manipulation impacts subjective experience and math performance in the absence of laterality-induced motivation.

Method

Participants and design. Fifty-six right-handed females (M_{age}=26.4) were recruited by three research assistants through emails sent to their classmates (students in human movement sciences) and relatives. After giving their consent to take part in a cognitive study, participants were directed to an online survey website using the SurveyMonkey platform. The study comprised a 2 (stereotype threat / control) × 3 (right / middle / left stimulus location) mixed-factorial design, with stereotypes as the between-subject variable and stimulus location as the within-subject variable.

Procedure and measures. Study 4 was identical to Study 2 with a few exceptions detailed in the supplemental materials file. At the end of each 10-item block, the following subjective variables were measured. Approach and avoidance motivation were indexed by *challenge and threat appraisals,* which were assessed with the 4-item scale used in Chalabaev et al. (2012). This included the stem "During completion of the task, I felt…" and the following items: eager, confident, nervous, worried. Participants answered from 1 (strongly

disagree) to 7 (strongly agree). The first two items comprised the challenge appraisal and the last two items comprised the threat appraisal. The reliability of these two-item scales was tested at each time point using the Spearman-Brown coefficient (Eisinga, Grotenhuis, & Pelzer, 2013). Results indicated good reliability, coefficients ranging from .74 to .89 for the challenge appraisal scale, and from .72 to .81 for the threat appraisal scale. As in Chalabaev et al. (2012), we analyzed these appraisals separately and relatively to each other by computing the difference between challenge and threat appraisals (i.e., challenge-threat index). Next, *subjective task fluency* ("To what extent were the calculations easy to perform?"), adapted from Regenberg et al., 2012, *task confidence* ("To what extent were you confident in your answers?") (Dru & Cretenet, 2011), and *task-related thoughts* ("To what extent were your thoughts focused on the task?") (Mrazek, Chin, Schmader, Hartson, Smallwood, & Schooler, 2011) were measured on 7-point scales, along with liking and motivation, which were assessed similarly to Study 3.

The rest of the procedure and measures were similar to those used in Study 2.

Results

Data analysis. Given that the mediation hypothesis involved testing whether within-person changes in the subjective variables affected within-person changes in math performance, we conducted multilevel models (see supplemental materials file for detailed description of our analysis strategy). Sensorimotor–mental congruence effects were tested by regressing each outcome on a two-level random intercept model that included the main and interactive effects of the stereotype and laterality manipulations, along with the baseline measure and task order. The effect of laterality was examined with a set of orthogonal contrasts, following the principles proposed by Abelson and Prentice (1997). Contrast 1 (i.e., the contrast of interest) tested whether responses in the left-side stimulus location (+2) differed from responses in the middle-side (-1) and right-side (-1) conditions. Contrast 2

tested the residual variance by comparing the middle-side (+1) to the right-side (-1) stimulus location (left-side was coded 0). With regard to the stereotype manipulation, the stereotype threat condition was coded -1 and the control condition was coded +1. A sensorimotor–mental congruence effect was observed when the stereotype manipulation significantly interacted with contrast 1, but not contrast 2.

Preliminary analyses. Four outliers were removed using the median absolute deviation method (Leys et al., 2013), as well as two participants who were left-handed, leaving 50 participants for further analyses. We first compared baseline measures between stereotype threat and control conditions. Student's *t* tests indicated no significant differences in baseline performance (see Table 4 in the supplemental materials file).

Primary analyses. Detailed results are described in the supplemental materials file (Table 5).

Sensorimotor–mental congruence effect on math performance. Results showed a significant effect of stereotype threat ($b=0.04$, $SE=.02$, $p=.026$, $R^2=.10$) and a significant effect of laterality (contrast 1) ($b=0.01$, $SE=.01$, $p=.037$, $R^2=.05$) on math performance. In other words, accuracy was higher in the control condition than in the stereotype threat condition, and higher when items were presented in the left side of the screen than in the middle or right sides. However, no significant interactive effects emerged, indicating that the beneficial effect of a left-side induction was not specific to the stereotype threat condition.

Mediation analyses. The mediating role of the subjective variables was tested with the *a* and *b* joint significance test (Cohen & Cohen, 1983; Fritz, Taylor, & MacKinnon, 2012). It is the only test that does not suffer from the Type I error issue, and it is statistically as powerful as other commonly used tests, such as the percentile bootstrap and numerical integration tests (Judd, Yzerbyt, & Muller, 2014). The joint significance test consists in testing mediation by estimating *a* (effect of the predictor on the process) and *b* (effect of the

process on the outcome, controlling for the predictor), and testing them individually against zero. Given that the predictor (congruence) is an interaction term, we followed Muller, Judd, and Yzerbyt's (2005) recommendations for testing mediated moderation. The *a* path was tested by regressing each potential mediator on the stereotype × laterality interaction, controlling for the effects of stereotype, laterality, along with baseline measure of the mediator and task order. When the stereotype × laterality interaction was significant, we examined the *b* path by regressing performance on the mediator, controlling for the main and interactive effects of the stereotype and laterality manipulations, the subjective task fluency × stereotype interaction, along with baseline performance and task order. This last interaction allowed us to examine if the effect of fluency on performance differed in the stereotype threat and control conditions or not (Muller et al., 2005).

 Sensorimotor–mental congruence effects on subjective variables (a path). Concerning *subjective task fluency*, since participants may have derived their feeling of fluency from their performance rather than from the sensorimotor–mental congruence context, we controlled for accuracy in the analysis (Regenberg et al., 2012). In line with the sensorimotor–mental congruence hypothesis, results indicated a significant stereotype × laterality (contrast 1) interaction effect (b=-0.12, SE=.05, p=.017, R^2=.07), but no effect of accuracy (b=.72, SE=.71, p=.314, R^2=.01). More particularly, in the stereotype threat condition, participants experienced more ease in the left-side condition than in the middle-side and right-side conditions, (b=0.18, SE=.08, p=.019, R^2=.07). In contrast, in the control condition, subjective fluency in the left-side condition did not significantly differ from the middle-side and right-side conditions, (b=-0.05, SE=.06, p=.382, R^2=.01). No other main or interactive effects of the manipulations emerged.

 Concerning *threat appraisal,* results showed a nearly significant effect of laterality (contrast 1) (b=-0.08, SE=.04, p=.054, R^2=.03) that was qualified by a marginally significant

stereotype × laterality (contrast 1) interaction effect (b=0.08, SE=.04, p=.058, R^2=.03). These results could suggest a sensorimotor–mental congruence effect, however, a significant stereotype × laterality (contrast 2) interaction effect (b=-0.16, SE=.07, p=.024, R^2=.05) also emerged. This means that the contrast of interest (contrast 1) did not predict sufficient variance in threat appraisal, as the residual variance (contrast 2) was also significant. More particularly, in the stereotype threat condition, participants felt less threatened in the left-side condition than in the middle-side and right-side conditions (b=-0.16, SE=.06, p=.014, R^2=.06), but also marginally less threatened in the right-side condition than in the middle-side condition (b=0.19, SE=.11, p=.086, R^2=.03). In the control condition, threat appraisal in the left-side condition did not significantly differ from the middle-side and right-side conditions, (b=-0.00, SE=.05, p=.978, R^2=.00), and participants did not feel less threatened in the right-side condition than in the middle-side condition (b=-0.13, SE=.09, p=.138, R^2=.03). No other main or interactive effects of the manipulations emerged. In sum, these results only partially support the hypothesis that motivational congruence reduces threat appraisal.

Concerning *challenge appraisal,* no significant main or interactive effects of the experimental manipulations emerged. Results with regard to the *challenge-threat index* showed a significant laterality (contrast 1) effect (b=0.15, SE=.07, p=.024, R^2=.04), that was not qualified by an interaction with the stereotype condition (b=-0.06, SE=.07, p=.338, R^2=.00). In other words, participants felt more challenged than threatened in the left-side condition than in the middle-side and right-side conditions.

Next, results revealed a significant effect of the stereotype condition (b=0.32, SE=.13, p=.017, R^2=.11) on *task confidence*, that was not qualified by an interaction with laterality (contrast 1) (b=-0.06, SE=.04, p=.157, R^2=.02), nor with laterality (contrast 2) (b=-0.05, SE=.07, p=.453, R^2=.00). In other words, participants felt more confident in the control condition than in the stereotype threat condition, whatever the stimulus location was.

Concerning *task-related thoughts,* no significant main or interactive effects of the experimental manipulations emerged. Finally, as expected, no significant main or interactive effects of the manipulations emerged on *liking* and *motivation*, confirming that motivational congruence effects were not attributable to participants' motivation to comply with the experimental instructions or their liking for the task (e.g., Grimm et al., 2009).

In sum, there was a subjective experience of the sensorimotor–mental congruence effect, which increased subjective fluency. We next examined whether higher fluency led to higher performance.

Effect of subjective task fluency on math performance (b path). Results of this model indicated a significant effect of subjective fluency (b=0.02, SE=.01, p=.026, R^2=.03) on accuracy. In other words, the more participants experienced task fluency, the higher their performance, after controlling for the experimental manipulations, and this relationship did not significantly differ depending on the stereotype condition (b=0.01, SE=.01, p=.539, R^2=.00). Finally, the effects of stereotype condition (b=0.06, SE=.04, p=.161, R^2=.02), laterality (contrast 1) (b=0.01, SE=.01, p=.091, R^2=.05), laterality (contrast 2) (b=-0.01, SE=.01, p=.236, R^2=.01), the stereotype × laterality (contrast 1) (b=-0.00, SE=.01, p=.883, R^2=.00), the stereotype × laterality (contrast 2) (b=0.01, SE=.01, p=.303, R^2=.00), and baseline accuracy (b=0.10, SE=.11, p=.388, R^2=.00) did not reach significance, while the effect of task order was significant (b=0.05, SE=.02, p=.018, R^2=.02).

In sum, the results showed a stereotype × laterality interaction effect on subjective task fluency (i.e., *a* path), which affected in turn math performance (i.e., *b* path), indicating an indirect effect of sensorimotor–mental congruence on performance through subjective task fluency (see Figure 4).

Stereotype threat effects on math performance and subjective variables.

Finally, we checked whether a classic stereotype threat effect occurred by testing the simple main effect of stereotype threat within the middle stimulus location condition. Results showed a significant stereotype threat effect on math accuracy (b=0.05, SE=.010, p=.023, R^2=.09), participants performing significantly lower in the stereotype threat condition than in the control condition. A significant stereotype threat effect was also observed on threat appraisal (b=-0.38, SE=.16, p=.021, R^2=.08) and task confidence (b=0.33, SE=.15, p=.035, R^2=.08), participants feeling more threatened and less confident in the stereotype threat condition than in the control condition. Finally, a marginally significant effect of stereotype threat on the challenge-threat index was observed (b=0.41, SE=.24, p=.083, R^2=.05), participants feeling marginally more challenged than threatened in the control condition than in the stereotype threat condition. These findings are in line with the stereotype threat literature. No other significant differences emerged.

Discussion

Study 4 indicates that sensorimotor–mental congruence occurs at a high level of processing, by revealing that this effect is associated with the conscious feeling of fluency. This effect occurred after controlling for accuracy, suggesting that participants did not infer their feeling of fluency from their performance, but rather from the sensorimotor–mental congruence context.

We did not replicate the effect on objective cognitive performance observed in Studies 1-3, possibly because of the online format used in Study 4, which may render the testing situation less motivating and engaging than the lab environment. The high dropout rate among participants is supportive of such an explanation. Nevertheless, when looking at the simple effects of the stereotype manipulation within the middle stimulus location condition, results were in line with the stereotype threat literature, by showing that threatened participants felt more threatened, less confident, and performed lower than control

participants. More importantly, results showed an *indirect* effect of sensorimotor–mental congruence on math performance, through subjective task fluency. Given that stereotype threat-related thoughts tap into the same cognitive resource as the resolution of modular arithmetic problems (Beilock et al., 2007; Rydell et al., 2014), this finding suggests that motivational congruence helped to restore this resource. However, these results need to be interpreted with care. First, although the congruence effect on fluency was observed after controlling for accuracy, it does not rule out the possibility that ease of calculation reflects performance expectations, because the latter do not map perfectly onto actual performance. Moreover, our fluency measure refers to calculation, which is not specific and not influenced by stereotype threat (Quinn & Spencer, 2001). The observation that performance is better when fluency is high could be due to increased processing resources, but also to more efficient ones (i.e., better processing algorithms).

General Discussion

Four experiments consistently indicated that stereotype threat can be alleviated by a novel intervention that does not require effortful reappraisal processes. Drawing on embodied cognition premises, we showed that simple sensorimotor inductions can put individuals in an optimal state to deal with stereotype threat. This non-verbal strategy, although surprising and counter-intuitive, may be easily implemented in testing situations. Beyond this practical appeal, our results have important theoretical implications.

Stereotype threat theory relies on a traditional view of mind-body relationships, suggesting that the subjective experience of stereotype threat leads to bodily and behavioral changes (Mendes & Jamieson, 2012). Research on stereotype threat reduction has embraced this conception by focusing on changing the mental experience of stereotype threat (e.g., Alter et al., 2010; John-Henderson et al., 2015; Martens et al., 2006). In contrast, we followed Mendes and Jamieson's (2012) encouragement to reverse this conception and examine

whether modifying sensorimotor states may alter cognitive performance under stereotype threat. We did so by bringing together stereotype threat and embodied cognition research around the phenomenon of motivational congruence. In four independent experiments demonstrating motivational congruence effects, we revealed that mental representations (stereotypes) and sensorimotor experience may interact to affect higher-order cognitive performance. Observing such interaction suggests that there is some crosstalk between mental concepts and sensorimotor cues. In other words, congruence effects may occur when motivations are induced through different channels. In line with Niedenthal et al. (2005), these results challenge the traditional view that embodied cognition theories have little to say about higher cognitive functions.

An alternative explanation of our results rests on the resource recruitment hypothesis proposed by Ståhl et al. (2012). Our avoidance sensorimotor cues might have been beneficial to performance because they initiated immediate recruitment of additional cognitive control resources. This recruitment is adaptive to tackle instant threats, and may have restored updating and inhibition functions, increasing in turn performance. However, we believe this hypothesis is unlikely to account for our results. Indeed, additional resource recruitment is supposed to precede cognitive depletion, which is evidenced by an increase in performance on the task that immediately follows the stereotype manipulation, and a decrease in performance on a follow-up task (Ståhl et al., 2012). This is not what we found, as avoidance cues under threat led to similar performance boosts on the task that immediately followed the stereotype manipulation, as well as on the follow-up task. It is possible that the first post-manipulation task was not long enough to observe subsequent cognitive depletion. However, in Studies 1-2, completion of the post-manipulation task lasted approximately the same time as in Ståhl et al.'s (2012) study (i.e., 4 min): 3 min 30 s in Study 1 and 3 min in Study 2, followed by completion of self-reports. Therefore, our results provide support to the motivational

congruence hypothesis rather than to the resource recruitment hypothesis. Future research should determine when the immediate recruitment hypothesis holds and when it does not.

To conclude, while work on stereotype fit has focused on task framing to alleviate stereotype threat (Barber & Mather, 2012; Chalabaev et al., 2012; Grimm et al., 2009), the present research extends this phenomenon to sensorimotor inductions. This raises the question of the definition of stereotype fit, which is purported to arise when the means of goal pursuit matches the stereotype-induced prevention goal adopted by the individual. Our results suggest that it might not be the match between a manner of task engagement and a goal that generates fit, but instead compatibility between motivational triggers, which may include reward structure of the task but also sensorimotor experience.

Acknowledgments

References

Abelson, R. P., & Prentice, D. A. (1997). Contrast tests of interaction hypothesis.

Psychological Methods, 2, 315-328. doi:10.1037/1082-989X.2.4.315

Ackerman, R., & Zalmanov, H. (2012). The persistence of the fluency–confidence association

in problem solving. *Psychonomic Bulletin & Review, 19*, 1187-1192.

doi:10.3758/s13423-012-0305-z

Alibali, M. W., & Nathan, M. J. (2012). Embodiment in mathematics teaching and learning:

Evidence from learners' and teachers' gestures. *Journal of the Learning Sciences*, *21*,

247-286. doi:10.1080/10508406.2011.611446

Alter, A. L., Aronson, J., Darley, J. M., Rodriguez, C., & Ruble, D. N. (2010). Rising to the

threat: Reducing stereotype threat by reframing the threat as a challenge. *Journal of

Experimental Social Psychology*, *46*, 166-171. doi:10.1016/j.jesp.2009.09.014

Barber, S. J., & Mather, M. (2013). Stereotype threat can both enhance and impair older

adults' memory. *Psychological Science*, *24*, 2522-2529.

doi:10.1177/0956797613497023

Barber, S. J., Mather, M., & Gatz, M. (2015). How stereotype threat affects healthy older

adults' performance on clinical assessments of cognitive decline: The key role of

regulatory fit. *The Journals of Gerontology Series B: Psychological Sciences and

Social Sciences, 70*, 891-900. doi:10.1093/geronb/gbv009

Bassel, C., & Schiff, B. B. (2001). Effects of unilateral facial contractions on approach and

withdrawal responses. *Neuropsychologia*, *39*, 282-287.

Beilock, S. L., Rydell, R. J., & McConnell, A. R. (2007). Stereotype threat and working

memory: Mechanisms, alleviation, and spillover. *Journal of Experimental Psychology:

General*, *136*, 256-276. doi:10.1037/0096-3445.136.2.256

Bem, D. J. (1967). Self-perception: An alternative interpretation of cognitive dissonance

      phenomena. *Psychological Review, 74*, 183-200. doi:10.1037/h0024835

John-Henderson, N. A., Rheinschmidt, M. L., & Mendoza-Denton, R. (2015). Cytokine

      responses and math performance: The role of stereotype threat and anxiety

      reappraisals. *Journal of Experimental Social Psychology, 56*, 203-206.

      doi:10.1016/j.jesp.2014.10.002

Brodish, A. B., & Devine, P. G. (2009). The role of performance–avoidance goals and worry

      in mediating the relationship between stereotype threat and performance. *Journal of

      Experimental Social Psychology*, *45*, 180-185. doi:10.1016/j.jesp.2008.08.005

Cacioppo, J. T., Priester, J. R., & Berntson, G. G. (1993). Rudimentary determinants of

      attitudes: Arm flexion and extension have differential effects on attitudes. *Journal of

      Personality and Social Psychology, 65*, 5-17. doi:10.1037//0022-3514.65.1.5

Carr, P., & Steele, C. (2010). Stereotype threat affects financial decision making.

      Psychological Science, 21, 1411-1416. doi:10.1177/0956797610384146

Chalabaev, A., Major, B., Sarrazin, P., & Cury, F. (2012). When avoiding failure improves

      performance: Stereotype threat and the impact of performance goals. *Motivation and

      Emotion*, *36*, 130-142. doi:10.1007/s11031-011-9241-x

Chalabaev, A., Sarrazin, P., Stone, J., & Cury, F. (2008). Do achievement goals mediate

      stereotype threat?: An investigation on females' soccer performance. *Journal of Sport

      & Exercise Psychology*, *30*, 143-158.

Cohen, J., & Cohen, P. (1983). *Applied multiple regression/correlation analyses for the

      behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum. doi:10.2307/2064799

Cretenet, J., & Dru, V. (2004). The influence of unilateral and bilateral arm flexion versus

      extension on judgments: An exploratory case of motor congruence. *Emotion*, *4*, 282-

      294. doi:10.1037/1528-3542.4.3.282

Cretenet, J., & Dru, V. (2009). Influence of peripheral and motivational cues on rigid–flexible

    functioning: Perceptual, behavioral, and cognitive aspects. *Journal of Experimental*

    Psychology: General, *138*, 201-217. doi:10.1037/a0015379

Croizet, J. C., Després, G., Gauzins, M. E., Huguet, P., Leyens, J. P., & Méot, A. (2004).

    Stereotype threat undermines intellectual performance by triggering a disruptive

    mental load. *Personality and Social Psychology Bulletin*, *30*, 721-731.

    doi:10.1177/0146167204263961

Davidson, R. J. (1992). Emotion and affective style hemispheric substrates. *Psychological*

    Science, 3, 1, 39-43. doi:10.1111/j.1467-9280.1992.tb00254.x

Dru, V., & Cretenet, J. (2011). Performing lateralized approach and avoidance behaviors:

    Effects on perceptual, affective and confidence judgments. *Journal of the*

    International Neuropsychological Society, *17*, 289-294.

    doi:10.1017/S1355617710001657

Eisinga, R., Te Grotenhuis, M., & Pelzer, B. (2013). The reliability of a two-item scale:

    Pearson, Cronbach, or Spearman-Brown? *International Journal of Public Health, 58*,

    637-642. doi:10.1007/s00038-012-0416-3

Emerson, K. T. U., & Murphy, M. C. (2015). A company I can trust? Organizational lay

    theories moderate stereotype threat for women. *Personality and Social Psychology*

    Bulletin. doi:10.1177/0146167214564969

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in*

    Psychological Science, 11, 19-23. doi:10.1111/1467-8721.00160

Faul, F., Erdfelder, E., Lang, A. –G., & Buchner, A. (2007). G*Power3: A flexible statistical

    power analysis program for the social, behavioral, and biomedical sciences. *Behavior*

    Research Methods, 39, 175-191. doi:10.3758/BF03193146

Freitas, A. L., & Higgins, E. T. (2002). Enjoying goal-directed action: The role of regulatory fit. *Psychological Science, 13*, 1-6. doi:10.1111/1467-9280.00401

Friedman, R. S., & Förster, J. (2000). The effects of approach and avoidance motor actions on the elements of creative insight. *Journal of Personality and Social Psychology, 79*, 477-492. doi:10.1037//0022-3514.79.4.477

Fritz, M. S., Taylor, A. B., & MacKinnon, D. P. (2012). Explanation of two anomalous results in statistical mediation analysis. *Multivariate Behavioral Research, 47*, 61-87. doi:10.1080/00273171.2012.640596

Grimm, L. R., Markman, A. B., Maddox, W. T., & Baldwin, G. C. (2009). Stereotype threat reinterpreted as a regulatory mismatch. *Journal of Personality and Social Psychology, 96*, 288-304. doi:10.1037/a0013463

Harmon-Jones, E. (2006). Unilateral right-hand contractions cause contralateral alpha power suppression and approach motivational affective experience. *Psychophysiology, 43*, 598-603. doi:10.1111/j.1469-8986.2006.00465.x

Harmon-Jones, E., Price, T. F., & Harmon-Jones, C. (2015). Supine body posture decreases rationalizations: Testing the action-based model of dissonance. *Journal of Experimental Social Psychology, 56*, 228-234. doi:10.1016/j.jesp.2014.10.007

Higgins, E. T. (2000). Making a good decision: value from fit. *American Psychologist, 55*, 1217-1230. doi:10.1037/0003-066X.55.11.1217

Inzlicht, M., McKay, L., & Aronson, J. (2006). Stigma as ego depletion: How being the target of prejudice affects self-control. *Psychological Science, 17*, 262-269. doi:10.1111/j.1467-9280.2006.01695.x

Jostmann, N. B., Lakens, D., & Schubert, T. W. (2009). Weight as an embodiment of importance. *Psychological Science, 20*, 1169-1174. doi:10.1111/j.1467-9280.2009.02426.x

Judd, C. M., Yzerbyt, V. Y., & Muller, D. (2014). Mediation and moderation. *Handbook of Research Methods in Social and Personality Psychology, 2*, 653-676. doi:10.1017/cbo9780511996481.030

Keller, J., & Bless, H. (2006). Regulatory fit and cognitive performance: The interactive effect of chronic and situational self-regulatory mechanisms on cognitive test performance. *European Journal of Social Psychology, 36*, 393-405. doi:10.1002/ejsp.307

Lee, A. Y., & Aaker, J. L. (2004). Bringing the frame into focus: The influence of regulatory fit on processing fluency and persuasion. *Journal of Personality and Social Psychology, 86*, 205-218. doi:10.1037/0022-3514.86.2.205

Leys, C., Ley, C., Klein, O., Bernard, P., & Licata, L. (2013). Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. *Journal of Experimental Social Psychology*, *49*, 764-766. doi:10.1016/j.jesp.2013.03.013

MacLeod, C. M., & MacDonald, P. A. (2000). Interdimensional interference in the Stroop effect: uncovering the cognitive and neural anatomy of attention. *Trends in Cognitive Sciences, 4*, 383-391. doi:10.1016/S1364-6613(00)01530-8

Marble, J. G., & Proctor, R. W. (2000). Mixing location-relevant and location-irrelevant choice-reaction tasks: Influences of location mapping on the Simon effect. *Journal of Experimental Psychology: Human Perception and Performance*, *26*, 1515-1533. doi:10.1037//0096-1523.26.5.1515

Martens, A., Johns, M., Greenberg, J., & Schimel, J. (2006). Combating stereotype threat: The effect of self-affirmation on women's intellectual performance. *Journal of Experimental Social Psychology*, *42*, 236-243. doi:10.1016/j.jesp.2005.04.010

Maxwell, J. S., & Davidson, R. J. (2007). Emotion as motion: Asymmetries in approach and

    avoidant actions. *Psychological Science*, *18*, 1113-1119. doi:10.1111/j.1467-

    9280.2007.02033.x

Mendes, W. B., & Jamieson, J. (2012). Embodied stereotype threat: Exploring brain and body

    mechanisms underlying performance impairments. In M. Inzlicht & T. Schmader

    (Eds.), *Stereotype threat: Theory, process, and application* (pp.51-68). New York:

    Oxford University Press.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T.

    (2000). The unity and diversity of executive functions and their contributions to

    complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49-

    100. doi:10.1006/cogp.1999.0734

Mrazek, M. D., Chin, J. M., Schmader, T., Hartson, K. A., Smallwood, J., & Schooler, J. W.

    (2011). Threatened to distraction: Mind-wandering as a consequence of stereotype

    threat. *Journal of Experimental Social Psychology*, *47*, 1243-1248.

    doi:10.1016/j.jesp.2011.05.011

Muller, D., Judd, C., & Yzerbyt, V. (2005). When moderation is mediated and mediation is

    moderated. *Journal of Personality and Social Psychology, 89*, 852-863.

    doi:10.1037/0022-3514.89.6.852

Mullet, E., Cretenet, J., & Dru, V. (2014). Motor influences on judgment: Motor and

    cognitive integration. *British Journal of Psychology*, *105*, 69-91.

    doi:10.1111/bjop.12022

Nash, K., McGregor, I., & Inzlicht, M. (2010). Line bisection as a neural marker of approach

    motivation. *Psychophysiology*, *47*, 979-983. doi:10.1111/j.1469-8986.2010.00999.x

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Review*, *9*, 184-211. doi:10.1207/s15327957pspr0903_1

Pavlova, M. A., Weber, S., Simoes, E., & Sokolov, A. N. (2014). Gender stereotype susceptibility. *PLoS ONE, 9*, e114802. doi:10.1371/journal.pone.0114802

Peterson, C. K., Schackman, A. J., & Harmon-Jones, E. (2008). The role of asymmetrical frontal activity in aggression. *Psychophysiology*, *45*, 86-92. doi:10.1111/j.1469-8986.2007.00597.x

Phaf, R. H., & Rotteveel, M. (2009). Looking at the bright side: The affective monitoring of direction. *Emotion*, *9*, 729-733. doi:10.1037/a0016308

Porac, C., & Cohen, S. (1981). Lateral preferences and human behavior. New York: Springer-Verlag.

Quinn, D. M., & Spencer, S. J. (2001). The interference of stereotype threat with women's generation of mathematical problem-solving strategies. *Journal of Social Issues, 57*, 55-71. doi:10.1111/0022-4537.00201

Regenberg, N., Häfner, M., & Semin, G. R. (2012). The Groove Move: Action affordances produce fluency and positive Affect. *Experimental Psychology, 59*, 30-37. doi: 10.1027/1618-3169/a000122

Root, J. C., Wong, P. S., & Kinsbourne, M. (2006). Left hemisphere specialization for response to positive emotional expressions: A divided output methodology. *Emotion*, *6*, 473-483. doi:10.1037/1528-3542.6.3.473

Rydell, R. J., Van Loo, K. J., & Boucher, K. L. (2014). Stereotype threat and executive functions: Which functions mediate different threat-related outcomes? *Personality and Social Psychology Bulletin, 40*, 377-390. doi:10.1177/0146167213513475

Schiff, B. B., & Lamon, M. (1989). Inducing emotion by unilateral contraction of facial muscles: A new look at hemispheric specialization and the experience of emotion. *Neuropsychologia, 21*, 923-935. doi:10.1016/0028-3932(89)90068-7

Schiff, B. B., & Lamon, M. (1994). Inducing emotion by unilateral contraction of hand muscles. *Cortex*, *30*, 247-254. doi:10.1016/s0010-9452(13)80196-7

Schmader, T., Johns, M., & Forbes, C. (2008). An integrated process model of stereotype threat effects on performance. *Psychological Review*, *115*, 336-356. doi:10.1037/0033-295X.115.2.336

Schubert, T. W. (2005). Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology, 89*(1), 1-21. doi:10.1037/0022-3514.89.1.1

Seibt, B., & Förster, J. (2004). Stereotype threat and performance: how self-stereotypes influence processing by inducing regulatory foci. *Journal of Personality and Social Psychology*, *87*, 38-56. doi:10.1037/0022-3514.87.1.38

Slepian, M. L., & Ambady, N. (2012). Fluid movement and creativity. *Journal of Experimental Psychology: General, 141*, 625-629. doi:10.1037/a0027395

Ståhl, T., Van Laar, C., & Ellemers, N. (2012). The role of prevention focus under stereotype threat: Initial cognitive mobilization is followed by depletion. *Journal of Personality and Social Psychology*, *102*, 1239-1251. doi:10.1037/a0027678

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *American Psychologist*, *52*, 613-629. doi:10.1037//0003-066X.52.6.613

Footnote

1. Fifty-four students in human movement sciences rated their agreement that these stereotypes exist on 7-point scales (1 = completely disagree; 7 = completely agree). Mean responses were greater than the scale's mid-point, indicating that these stereotypes were known (negative stereotype: M = 4.94 [4.48, 5.41], t(53) = 6.21; positive stereotype: M = 4.30 [3.84, 4.76], t(53) = 3.46).

Figure 1. Adjusted mean number of correct responses and 95% confidence intervals as a function of stereotype threat and laterality of hand contraction (Study 1).
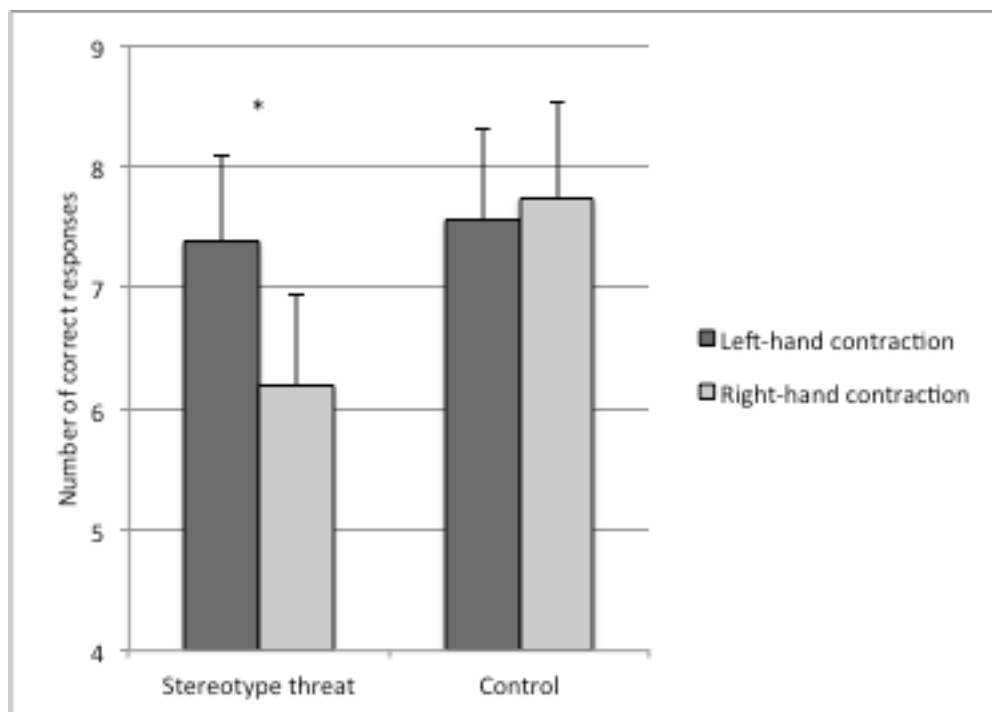
Figure 2. Adjusted mean number of correct responses and 95% confidence intervals as a function of stereotype threat and laterality of stimulus location (Study 2).
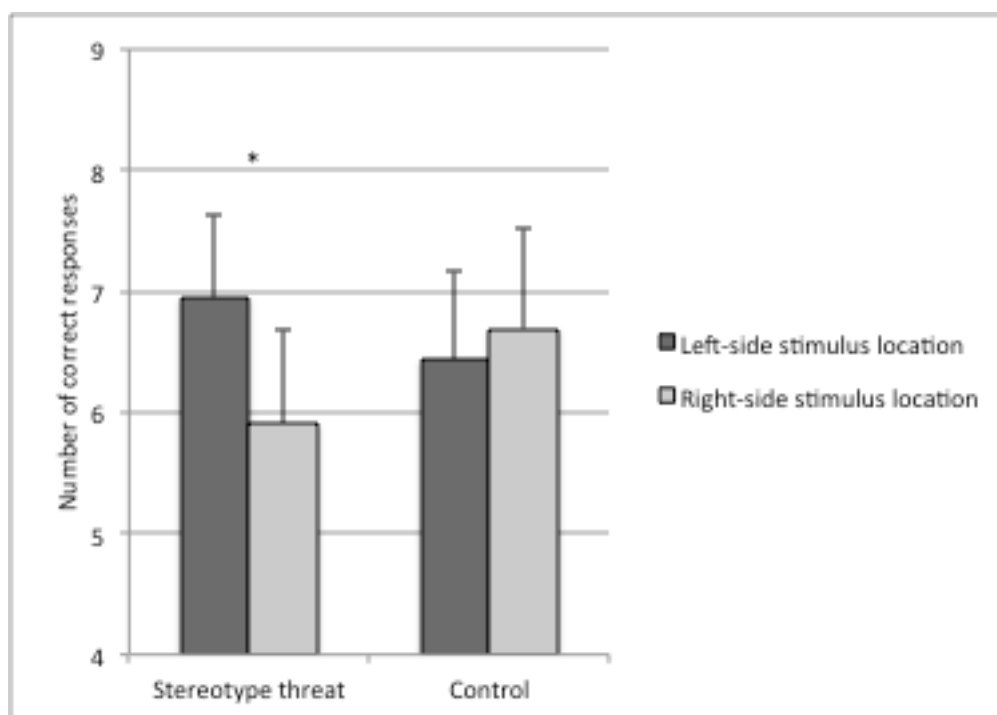
Figure 3. Adjusted Stroop interference and 95% confidence intervals as a function of sex and laterality of stimulus location (Study 3).
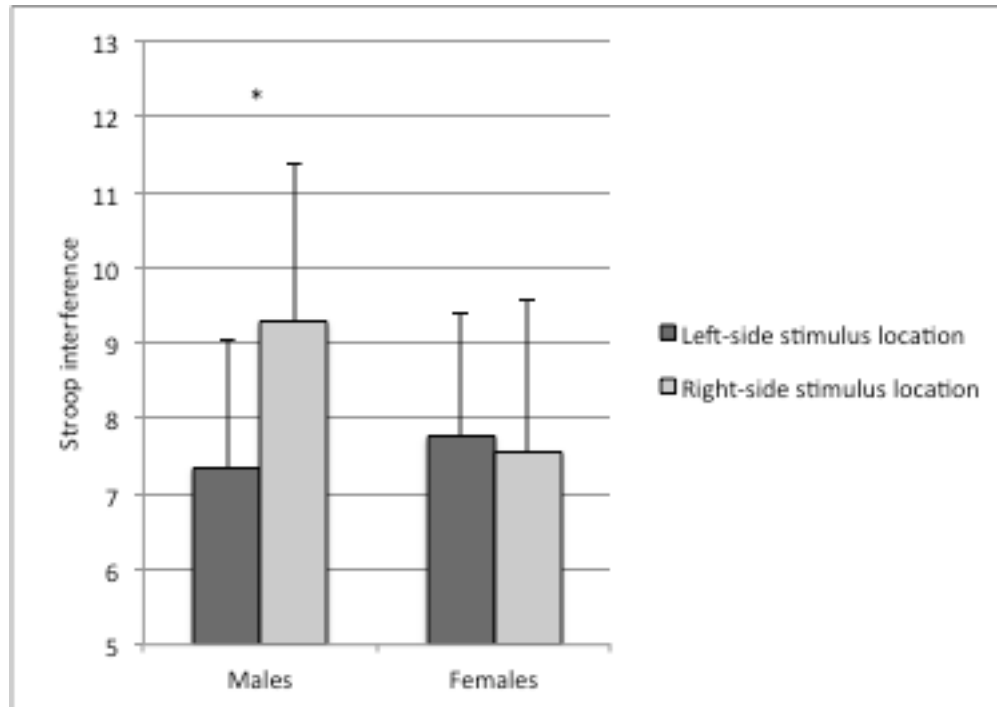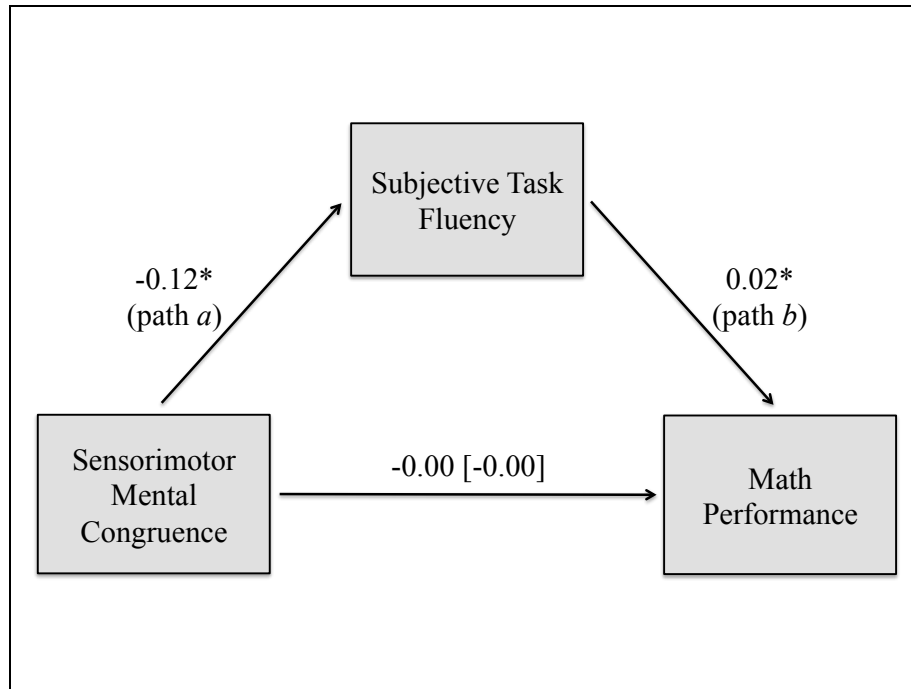
Figure 4. Mediation of the sensorimotor–mental congruence effect on math performance by subjective task fluency (Study 4).

Notes. Coefficients represent unstandardized estimates obtained from multilevel modeling. The coefficient between sensorimotor–mental congruence and subjective task fluency is the stereotype × laterality interaction effect on fluency (i.e., path *a*), after controlling for the effects of the experimental manipulations, baseline fluency, task order, and accuracy. The coefficient between subjective task fluency and math performance (i.e., path *b*) is controlled for the effects of the experimental manipulations and their interaction, the stereotype × fluency interaction, baseline accuracy, and task order (Muller et al., 2005). This equation also allowed estimating the coefficient between sensorimotor–mental congruence and math performance. Finally, the coefficient into brackets is the stereotype × laterality interaction effect of math performance, controlling for the effects of stereotype, laterality, baseline accuracy, and task order.

$* p < .05$.