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Effect of a sex stereotype on cortical activity during a self-paced exercise: A motor-related cortical potential approach

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ABSTRACT

Recent research has shown that inducing a negative stereotype toward women does not always decrease the subsequent motor performance of women, but can increase it, especially during endurance tasks. The mechanisms involved are nonetheless still poorly understood. The main aim of the present study was to investigate the effect of a negative stereotype toward women on men's and women's performance during an endurance task, and to analyze the neuropsychological mechanisms involved through motor-related cortical potentials and motivation toward men/women. Thirty-four participants were assigned to a negative stereotype toward women condition and a nullified-stereotype condition and performed 80 self-paced intermittent isometric elbow contractions at a moderate perceived intensity. Results showed that women performed better when assigned to the negative stereotype toward women condition, they were more motivated to outperform men, and their MRCP amplitudes were higher in this same condition over the prefrontal cortex (i.e., FP1 and FP2). Concerning men, they also performed better when the negative stereotype toward women was induced. However, no effect emerged on motivation toward women and MRCP amplitudes. This study showed that inducing a negative stereotype during an endurance task led to a performance increase in women, which is contrary to the stereotype threat theory, strengthening the idea of a task-dependency effect when inducing a negative stereotype. This performance improvement observed in women may be caused by increased motivation to outperform men and a planning of the upcoming movement. Concerning men, more research is needed to clarify the mechanisms involved in such performance improvement.

1. Introduction

According to the stereotype threat theory (Steele, 1997), when a negative stereotype toward one group is induced, a decrease in performance is usually observed. In the physical domain, most studies evaluating its effect focused on the sex stereotype that women have poor athletic ability, as it is very salient in the sport domain (e.g., Clément-Guillotin, Chalabaev, & Fontayne, 2012). They mainly observed that when a negative stereotype toward women was induced, a performance decrease emerged for women (for a meta-analysis, see Gentile, Boca, & Giammusso, 2018). This performance impairment was explained by the explicit monitoring hypothesis and consequently by the type of tasks (Beilock & Carr, 2001). Indeed, studies mainly used technical tasks such as golf-putting (e.g., Stone & McWhinnie, 2008), soccer-dribbling (Cardozo, Cibeira, Rigo, & Chiviacowsky, 2021; Chalabaev, Sarrazin, Stone, & Cury, 2008; Heidrich & Chiviacowsky, 2015; Hermann & Vollmeyer, 2016), soccer-kicking (Cardozo et al., 2020; Grabow & Kühl, 2019; Mousavi, Gray, Beik, & Deshayes, 2021), tennis serving (Hively & El-Alayli, 2014), basketball shooting (Hively & El-Alayli, 2014; Laurin, 2013), or stride jumping (Laurin, 2017). The execution in this type of tasks (i.e., requiring coordination) relies on proceduralized skills that run relatively automatically, mainly in experts because they have automatized task execution. When a negative stereotype is induced, participants increase their monitoring on the task, and are likely to isolate and focus on specific components of task execution. In turn, the probability of making errors increases, resulting

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in a performance decrease (Beilock & Carr, 2001).

For twenty years, most studies have replicated this deleterious effect on women's physical performance, even if few did not report any effect (e.g., Chalabaev et al., 2013; Chalabaev, Stone, Sarrazin, & Croizet, 2008). However, five recent studies found that the induction of a negative stereotype toward women could also increase women performances during non-technical tasks (Deshayes, Clément-Guillotin, & Zory, 2019; Deshayes, Zory, Chalabaev, Seitchik, & Clément-Guillotin, 2019; Deshayes, Zory, Chalabaev, Seitchik, & Clément-Guillotin, 2020; Huber, Brown, & Sternad, 2016; Huber, Seitchik, Brown, Sternad, & Harkins, 2015, Study 3). For example, it has been shown that at the same perceived intensity, women developed more power output after the induction of a negative stereotype toward women, compared to when a nullified-stereotype was induced during a cycling task (Deshayes, Clément-Guillotin, & Zory, 2019). The authors suggested that the effect of the induction of a negative stereotype would be task-dependent (i.e., technical vs. non-technical). To corroborate this hypothesis, in the present study we used a non-technical task consisting of a repetition of isometric elbow contractions.

Even if the interest in stereotype threat in the physical domain has increased over the past decade, there is still a fundamental unanswered question: "How does the negative stereotype operate?". Most studies in the physical domain only investigated the effect of the induction of a negative stereotype on performance (e.g., Hively & El-Alayli, 2014; Stone & McWhinnie, 2008) or analyzed the effect of a negative stereotype on psychological variables through self-reported measures with inconsistent results (e.g., Hermann & Vollmeyer, 2016). Therefore, and as realized in the cognitive domain (see for example the integrated process model; Schmader, Johns, & Forbes, 2008), it is thus necessary to combine direct measures (i.e., questionnaires) and more indirect measures (e.g., neurophysiological) to accurately assess how the induction of a negative stereotype influences physical performance.

Many studies have suggested that inducing a negative stereotype increases participants' motivation to counter it, leading to enhanced involvement in the task to prove that the stereotype is wrong (see the mere effort account, Jamieson & Harkins, 2007; the integrated process model, Schmader et al., 2008; see also Deshayes, Clément-Guillotin, & Zory, 2019). However, the role of this increased motivation to counter the negative stereotype has not been clearly established and was for example never assessed using self-reported measures. If women are motivated to prove that the negative stereotype is wrong, as the stereotype mainly referred to the superiority of men, it may be suggested that women want to outperform men in a stereotype threat situation. According to the achievement goals theory (Elliot & Church, 1997), individuals in achievement contexts can pursue different goals. For example, if individuals desire to perform better than others, as it is suggested in the present research, they are likely to endorse performance-approach goals. Consequently, self-reported motivation was assessed in the current study, using performance-approach goals.

Additionally, some research in the cognitive domain showed that the induction of a negative stereotype influences cortical activity (Inzlicht & Kang, 2010; Krendl, Richeson, Kelly, & Heatherton, 2008; Wraga, Helt, Jacobs, & Sullivan, 2007). For example, Krendl, Richeson, Kelley, and Heatherton (2008) found that when a negative stereotype was induced during a mathematical task, participants strongly recruited a region associated with social and emotional processing: the anterior cingulate cortex (ACC), located in the prefrontal cortex. In contrast, this region was not recruited when no stereotype was induced. To our knowledge, no studies in the physical domain have investigated the effect of a negative stereotype on cortical activity, and especially on the prefrontal cortex.

Chalabaev et al. (2013) showed that during a maximal strength task the induction of a negative stereotype toward women influenced women's rate of force development (RFD). The RFD is closely associated with the planning stage of force production. Hence, they suggested that the induction of the negative stereotype results in a modification in the preparatory processes occurring before task execution. Recently, Laurin, Renard-Moulard, and Cometti (2020) replicated Chalabaev et al.'s (2013) results and provided evidence that the induction of a negative sex stereotype impairs movement preparatory processes in the pre-contraction stage. However, no study has directly investigated the effects of a sex stereotype induction on these preparatory processes in the brain activity during a physical task.

One good way to study the preparatory process in the brain activity is the investigation of the motor-related cortical potentials (MRCPs), using electroencephalography. MRCPs represent the electroencephalographic activity preceding self-initiated movement and are involved in the planning and the initiation of the future movement (for a review, see Shibasaki & Hallett, 2006). Two regions appeared to be relevant in the present research: the motor cortex and the prefrontal cortex. The motor cortex is particularly involved in the planning and the execution of the movement (for a review, see Ghez, 1991). Previous studies mostly observed the generation of MRCPs over the motor cortex and particularly over the supplementary motor area and the contralateral central area (for a review, see Shibasaki & Hallett, 2006). The prefrontal cortex is also implicated in movement preparation (e.g., Guo, Sun, & Zhang, 2017; Jahanshahi, Dirnberger, Liasis, Towell, & Boyd, 2001; Kim, Kim, & Chung, 2017; Ryun et al., 2014; Sochurkova, Rektor, Jurak, & Stancak, 2006), especially when the task requires trial-by-trial decision-making (e.g., when to do an action and how to do it), as used in the present research. In addition, investigating cortical activity over the prefrontal cortex also appears relevant because as reported, past research have shown that this area may be highly impacted when a negative stereotype is induced (Inzlicht & Kang, 2010; Krendl et al., 2008; Wraga et al., 2007).

In addition to impacting performance of the targeted group (e.g., women), it has been shown that the non-targeted group (e.g., men) could increase their performance (i.e., stereotype lift; Walton & Cohen, 2003). For example, Chalabaev, Stone, et al. (2008) found that men increased their performance during a balance task when a negative stereotype toward women was induced. This effect was replicated during a strength task (Chalabaev et al., 2013), a stride jumping task (Laurin, 2017), a basket-ball shooting task (Laurin, 2013), a ball-bouncing task (Huber et al., 2016) and endurance tasks (Deshayes, Clément-Guillotin, & Zory, 2019; Deshayes, Zory, Seitchik, Chalabaev, & Clément-Guillotin, 2019; 2020). Nonetheless, few studies in the physical domain have investigated the potential mechanisms involved in such performance increase (Chalabaev, Stone, et al., 2008). Consequently, we also have investigated the neuropsychological mechanisms involved in this performance improvement in men after the induction of a negative stereotype toward women.

Accordingly, the aim of the present research was to investigate the effect of the induction of a negative stereotype toward women on men's and women's performance during a non-technical task, with an investigation of the neuropsychological mechanisms involved, measured by MRCPs and motivation through performance-approach goals. Concerning women, based on the type of the task, we predicted that they would perform better when assigned to the negative stereotype toward them as compared to when assigned to the nullified-stereotype condition. This performance increase would be associated to an increased motivation to outperform men, as well as an increase in MRCPs amplitude in the prefrontal cortex. Also, as there is a relationship between the amplitude of MRCPs and the strength produced over the motor cortex (e.g., Siemionow, Yue, Ranganathan, Liu, & Sahgal, 2000), we also expected that the amplitude of MRCPs would be higher in the supplementary motor area and in the contralateral central in the negative stereotype condition as compared to the nullified-stereotype condition. For men, in line with the stereotype lift phenomenon, we predicted that they would perform better when assigned to the negative stereotype toward women as compared to when assigned to the nullified-stereotype condition. However, no hypotheses were made concerning the potential neuropsychological mechanisms involved in men.

2. Method

2.1. Participants

Thirty-four students (17 women and 17 men; *M*age = 21.2, *SD*age = 2.9) took part in this study. On the basis of a recent meta-analysis evaluating the effect size of the induction of a negative stereotype toward women on physical performance (Gentile et al., 2018), a moderate effect size was expected ($F = 0.25$). With a fixed α -level (0.05) and a high statistical power of 0.80, the required sample size was at least 28 participants. They were recruited on a voluntary basis by announcements made during classes and provided informed consent. Approval of the study protocol was obtained from the ethics committee of the university. To observe an effect of the induction of a negative stereotype, it was recommended to recruit participants identified with the domain evaluated who would thus consider the relevant task to be important for them (Roberson & Kulik, 2007; Steele, 1997). Therefore, as the task focused on physical capacities, we ensured that participants considered athletic ability important to them, prior to the experiment. To do that, participants completed two 7-point items ("it is important for me to have good physical abilities" and "it is important for me to be good during physical activities"), with responses ranging from 1 (strongly disagree) to 7 (strongly agree). This scale has been used in past studies in order to measure domain identification in the physical domain (e.g., Deshayes, Clément-Guillotin, & Zory, 2019). The internal reliability of the domain identification scale was satisfactory ($\rho = 0.90$). All the recruited participants had a mean score higher than 4 ($M = 6.10$, $SD = 1.05$) and were consequently added in this study.

2.2. Experimental design

The large majority of stereotype threat studies have used a between-subject design in which participants were randomly assigned to one of the conditions (e.g., Chalabaev et al., 2013; Heidrich & Chiviacowsky, 2015; Hively & El-Alayli, 2014). In the present research, a within-subject design was used as it has greater statistical power (Charness, Gneezy, & Khun, 2012) and enables better observation of individual differences, as participants are assigned to all conditions. For few years, this type of design has gained popularity when the effects of stereotypes on physical domain were investigated (Chalabaev, Palluel, & Ruchaud, 2020; Deshayes, Clément-Guillotin, & Zory, 2019; Deshayes, Zory, Seitchik, Chalabaev, & Clément-Guillotin, 2020; Gray, d'Arripe-Longueville, Deshayes, & Colson, 2021; Gray, Deshayes, Colson, d'Arripe-Longueville, & Clément-Guillotin, 2022; Laurin et al., 2020). Specifically, the present study included three laboratory sessions, each separated by seven days, and performed at the same time of the day. The first visit was a familiarization session during which participants were familiarized with the perception of effort scale (Borg, 1998) and the isometric task. During the second visit and the third visit, participants were assigned to a negative stereotype toward women condition and to a nullified-stereotype condition, in a randomized order and performed 80 intermittent isometric elbow contractions at RPE 5 (i.e., "somewhat hard" effort). This intermittent task based on the perceived effort was chosen for two main reasons. Firstly, to obtain measurable MRCPs, it requires a large number of trials (e.g., Liu et al., 2005). Secondly, to optimize the generation of MRCPs in the prefrontal cortex, the task needs a decision making for "what to do" and "when to do" (e.g., Jahanshahi et al., 2001). Consequently, instead of fixing a required strength (e.g., 50% of participants' maximal strength), we fixed a perceived intensity, letting participants decide how much effort to provide. Participants were requested to avoid physical activity for 24h before each session to avoid any pre-fatigue, to ensure that participants started each session in the same physical state.

2.2.1. Familiarization session

Participants came to the laboratory 1 week prior to the first experimental session and were familiarized with the material, and especially with the RPE scale. This session lasted approximately 90 min. Firstly, standardized instructions on use of the RPE scale were read and explained to participants. Then, participants performed two MVCs. The objectives of these contractions were both: to represent the anchor 10 on the scale and to be used by participants as a reference to adapt future contractions. Then, participants performed 5 isometric contractions for 5 s each at selected RPE values and according to the following order: RPE 3 (i.e., "moderate effort"), RPE 5 (i.e., "strong effort"), RPE 7 (i.e., "very strong effort"), three times. Participants adjusted themselves their strength to correspond to the selected RPE value. Between each RPE value, participants had 2 min to recovery. During this resting time, feedback was made to the participants: the experimenter and the participant discussed the last series of contractions and especially the participant's perception and the strength produced in order to improve the accuracy of the next series and correctly match the strength and the perception of effort. Finally, participants performed two tests of 10 contractions at RPE 5 for 5 s each, with 5 min of recovery between the two tests. These two tests were used for confirming that participants were well familiarized with the procedure. To validate this, the coefficient of variation (CV) had to be lower than 5% during these two trials. The CV has been suggested as one of the most appropriate methods to assess reliability (Atkinson & Nevill, 1998). This threshold demonstrated the ability of participants to consistently replicate similar performance outcomes when placed in the same conditions. If this coefficient was higher than 5%, participants had to perform 10-5sec more contractions at RPE-5, until it was less than 5% ($M = 2.44$; $SD = 1.72$). For each contraction, the mean of the 4 last seconds was calculated and all contractions were averaged to obtain one performance value for each series. This methodology to familiarize participants with the RPE scale has been previously used in a recent study in order to investigate the effects of a sex stereotype on women's physical performance (Deshayes, Clément-Guillotin, & Zory, 2019).

2.2.2. Experimental sessions

One week after the familiarization session, when arriving to the laboratory, participants were seated on the custom-made chair and were instrumented with the EEG and the strength materials. The EEG and the protocol setup were explained to the participants in details by the experimenter, as well as the RPE scale. Then, participants undertook a warm-up consisting in 8–10 submaximal contractions and finally performed two MVCs. Next, participants were assigned either to a negative stereotype toward women condition, or to a nullified-stereotype condition. In the negative stereotype toward women condition, all participants were told: "We are going to investigate differences between men and women. For this reason, we will measure physical and physiological settings. Previous research has demonstrated sex differences. Indeed, women have been shown to underperform on this task relative to men", whereas in the nullified-stereotype condition, they were told: "We are going to investigate differences between men and women. For this reason, we will measure cognitive and psychological settings. Previous research has demonstrated that this test has not been shown to produce any sex differences". This induction was adapted from previous research (e.g., Chalabaev et al., 2013, Chalabaev, Sarrazin, Stone, & Cury, 2008) and was previously used in a recent research using a within-subject design (Deshayes, Clément-Guillotin, & Zory, 2019). The protocol was then initiated (Figure 1). Participants were instructed to perform 80 self-paced intermittent isometric elbow contractions at RPE 5. The experimenter clearly explained to participants that they did not have to produce the same strength during the 80 contractions but that they had to produce each contraction at the same perceived intensity (i.e., "strong effort"). If necessary, they could adjust their strength produced (i.e., increase or decrease) to stay at the same perceived intensity during the 80 contractions. Immediately after the task, 2 MVCs were performed. Finally, participants filled out the questionnaire. Participants came back one week later and again performed the same self-paced exercise but

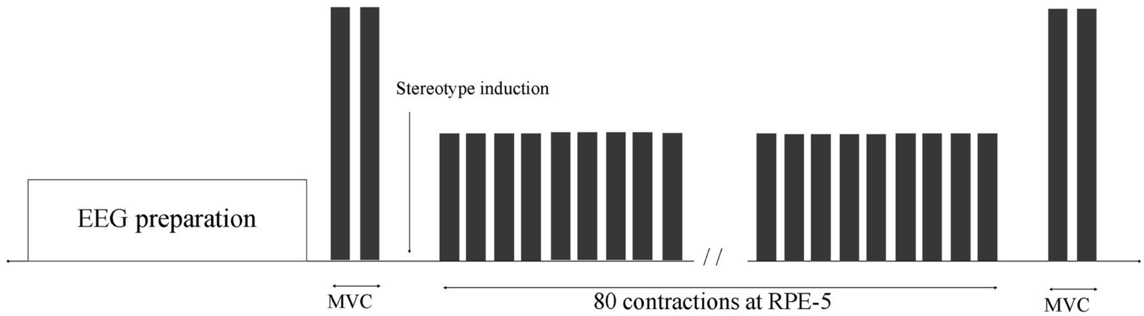

Fig. 1. Schematic illustration of the experimental protocol.

were presented with the alternate condition (i.e., the negative stereotype toward women condition or the nullified-stereotype condition).

2.3. Experimental setup

Participants sat upright in a custom-built chair with both hips and knees at 90° of flexion. The elbow angle was at 90° and the forearm and the wrist in a neutral position. A non-compliant strap attached to the participants' left wrist was connected to a calibrated load cell (TSD 121C, MP100 Holliston, MA, USA), to determine voluntary arm strength. Participants were firmly secured to the chair using non-compliant belts across the waist in order to minimize any extraneous body movements during the physical tasks.

2.3.1. Perception of effort

The entire protocol was based on the Borg's CR10 scale (Borg, 1998). This scale is composed of 11 ranks ranging from 0 corresponding to "no effort" to 10 corresponding to "maximal effort". During the three sessions, participants had to perform contractions at different levels (i.e., RPE 3, 5 and 7 in the familiarization session; RPE 5 in the experimental conditions). That is why, during the familiarization session and at the beginning of the experimental sessions, the scale was explained in detail to participants. The experimenter ensured that all participants understood the scale before starting the familiarization and the experimental sessions.

2.3.2. Instructions during the task

During the intermittent protocol, there was no interaction between the experimenter and the participant until the end of the protocol. Consequently, all of the instructions (i.e., beginning of the contraction or end of it) were placed on a monitor. It was placed at eye-level 100 cm in front of the participant. During the entire protocol, participants looked at the screen and followed these instructions: "contract when you want" (lasted 1.5 s), "maintain" (lasted 3.5 s), and then "relax" (lasted 5 s). This sequence was repeated 80 times (i.e., for the 80 contractions). This repetition of sequences was created using the E-prime software. For each repetition, when "contract when you want" appeared on the screen, a trigger was released and automatically reported on the EEG and strength recording. The onset of the contraction was then found using Matlab software. Throughout the entire protocol, participants did not receive visual feedback of their strength production.

2.3.3. EEG recordings

Continuous electroencephalographic activity was recorded using an EEG system (ANT-Neuro, Berlin, Germany) with 64 active sensors and mounted according to the 10-10 international system, which was referenced to Cz, with a sampling rate of 2000 Hz. Ocular artifact was assessed by electro-oculogram (EOG) recordings from an electrode placed at the right outer canthi. Participants were asked to maintain a stable body position and avoid eye blinks, teeth clenching, and upper limb and head movements during the contraction. Possible sources of distraction and noise were minimized. Electrode impedance was maintained below 40 kΩ. Offline analysis was performed using the Brainstorm analyzer software (version 3.4). Raw EEG data were re-referenced to average cortical activity and filtered with a 0.1–40 Hz bandpass and visually inspected to identify and discard epochs contaminated with artifacts prior to the signal averaging.

2.3.4. Questionnaires

Motivation was assessed by an adaptation of the Performance-Approach goals subscale from the French version of the Achievement Goals Questionnaire for Sports and Exercise (Riou et al., 2012). For this study, we have replaced the word "others" by the term "men" or "women". Thus, all participants were asked to answer these six items: "I am striving to be superior to men", "My goal is to outperform men", "My goal is to perform better than men"; "I am striving to be superior to women", "My goal is to outperform women", "My goal is to perform better than women"; using a 7-response scale ranging from 1 (*not at all*) to 7 (*extremely*). The three first items reflected "motivation toward men" and the last three items referred to "motivation toward women". A good internal consistency was found for both motivation scales toward men and toward women ($\alpha = 0.94$ and $\alpha = 0.89$, respectively).

The effectiveness of the stereotype threat manipulation was also evaluated at the end of each experimental session, in line with previous research (e.g., Huber et al., 2016; Mousavi et al., 2021). The questionnaire asked to what extent are gender differences in performance on this task (1 = no gender differences and 11 = gender differences), and who perform better on this task? (1 = males performed better, 6 = males and females perform the same, 11 = females performed better). Each question was analyzed separately, as performed in previous studies (Huber et al., 2016; Mousavi et al., 2021).

2.4. Data analysis

Data were analyzed using a mixed model approach. Unlike traditional analyses of variance, mixed models have some advantages (Boisgontier & Cheval, 2016). For example, they consider the sampling variability of both participants and experimental conditions, reducing therefore the risk of Type 1 error; or prevent information loss due to the averaging of observations, with the consideration of all single trials (Boisgontier & Cheval, 2016; Boisgontier et al., 2017). This statistical approach, more and more used and recommended, has especially been recently used to evaluate the effects of negative stereotype on physical performance (Chalabaev et al., 2020; Deshayes, Zory, Radel, & Clément-Guillotin, 2022).

2.4.1. Exercise performance

In this study, exercise performance referred to the strength produced by participants. Rather than averaging the 80 intermittent contractions, which results in a loss of information (Speelman & McGann, 2013), all contractions were analyzed using a mixed model approach. For each contraction, the mean strength developed was used for statistical analyses. The distribution of strength was positively skewed. To accommodate this skewed distribution of strength, a general linear mixed model (GLMM) was used by modelling strength data with a gamma function and a log link that is typically adapted for positive data that have asymmetry in the largest values (Myers & Montgomery, 1997). A random intercept effect structured by participants was included to control for the non-independence of the data. The fixed factors of the GLMM were the Sex (women vs. men), the Condition (negative stereotype toward women condition vs. nullified-stereotype condition), the Order of the condition (Visit 2 vs. Visit 3), the pre-MVC developed, and the interaction between Sex and Condition. To account for the nested structure of the data (each measurement sample nested within a measure and each measure nested within a same individual), we included a random effect structured by participant and a random effect structured by measure by participant.

2.4.2. Maximal voluntary contractions

The distribution of MVCs assessed before and after the intermittent task was positively skewed. As for performance, a GLMM was used. A random intercept effect structured by participants was included to control for the non-independence of the data. The fixed factors of the GLMM were the Sex (women vs. men), the Condition (negative stereotype toward women condition vs. nullified-stereotype condition), the Order of the condition (Visit 2 vs. Visit 3), the Time of measurement (pre-task vs. post-task) and the interaction between these different factors. To account for the nested structure of the data (each measurement sample nested within a measure and each measure nested within a same individual), we included a random effect structured by participant and a random effect structured by measure by participant.

2.4.3. MRCPs

The MRCPs were separately segmented and averaged into non-overlapping 2500 ms epochs that were measured 2000 ms before and 500 ms after the onset of contraction. For each condition, the grand average was calculated. The baseline was derived from the mean amplitude over the initial 500 ms epochs. To further reduce high-frequency noise, the time grand-averaged MRCPs were low-pass filtered at 5 Hz (e.g., Spring, Place, Borrani, Kayser, & Barral, 2016). On the basis of previous studies (e.g., Guo et al., 2017) two components of MRCP pre-contraction slow waves were calculated. Firstly, Bereitschaftspotentials or Readiness Potentials (i.e., BP) were derived by calculating the mean amplitude from 1500 ms to 100 ms before the onset of contraction, which can reflect the movement preparation/planning. Secondly, motor potentials (i.e., MP) were also calculated by the mean amplitude from 0 to 150 ms, which is indicative of the early execution of movement. Those components were calculated for three regions of interest: the supplementary motor area (i.e., mean activity of the Cz electrode), the contralateral central area (i.e., mean activity of the C2 electrode) and the prefrontal cortex (i.e., mean activity of the FP1 and FP2 electrodes). These electrodes were chosen for several reasons. Concerning the prefrontal cortex, previous studies have observed that inducing a negative stereotype toward women influenced the activity of the prefrontal cortex (Inzlicht & Kang, 2010; Krendl et al., 2008; Wraga et al., 2007). Also, as evoked, some research revealed that this region is implicated in the generation of MRCPs (e.g., Jahanshahi et al., 2001; Kim et al., 2017). Moreover, a study by Berchicci, Menotti, Macaluso, and Di Russo (2013) revealed that the prefrontal cortex, and especially the FP1 electrode, is modulated by the RPE. As the task used in the present research assessed the RPE/intensity relationship (i.e., developing a strength at a fixed perceived intensity), it is reasonable to expect a modification of MRCPs amplitude over the prefrontal cortex at FP1/2 sites. Concerning the supplementary motor area and the contralateral central area, previous studies noted that they are associated with the strength produced (e.g., Siemionow et al., 2000) and that they may be modulated when the RPE/intensity relationship is modified (e.g., Berchicci et al., 2013; de Morree, Klein, & Marcora, 2014). Consequently, it also appeared rational to assess MRCPs over these regions.

For each electrode and for BP and MP, the distribution was normal and a linear mixed model (LMM) was used. A random intercept effect structured by participant was included to control for the non-independence of the data. The fixed factors of the LMM were the Sex (women vs. men), the Condition (negative stereotype toward women condition vs. nullified-stereotype condition), the Order of the condition (Visit 2 vs. Visit 3), and the interaction between Sex and Condition. To include for the nested structure of the data (each measurement sample nested within a measure and each measure nested within a same individual), we included a random effect structured by participant and a random effect structured by measure by participant.

2.4.4. Performance-approach goals

The distribution was normal and consequently, a LMM was used. A random intercept effect structured by participant was included to control for the non-independence of the data. The fixed factors of the LMM were the Sex (women vs. men), the Condition (negative stereotype vs. positive stereotype vs. control), the Order of the condition (Visit 2 vs. Visit 3), performance-approach goals reported during the familiarization session and the interaction between Sex and Condition. To calculate an effect size for each dependent variable, Cohen's *ds* were calculated to represent the effect size using the difference of the exact means and standard-deviations.

3. Results

3.1. Manipulation check

Concerning the first item (i.e., to what extent are gender differences in performance on this task?), analyses showed a significant main effect of Condition ($F\,(1, 60) = 116, 96$, $p < 0.001$, $d = 1.51$) as well as a Sex × Condition interaction effect ($F\ (1,\ 60) = 9{,}7$, $p = 0.03$). Specifically, when participants were assigned to the negative stereotype toward women condition, men and women reported that gender differences existed in this task to a greater extent ($M = 8.38$, $SD = 2.62$) than when assigned to the nullified-stereotype condition ($M = 2.58$, $SD = 2.05$). There was no significant main effect of Sex ($p > 0.05$).

For the second item (i.e., who perform better on this task?), analyses revealed a Condition main effect ($F\,(1, 60) = 68{,}54$, $p < 0.001$, $d = 1.19$). Participants reported that men performed better on the task than women when they were assigned to the negative stereotype toward women condition ($M = 2.88$, $SD = 2.10$), as compared to when assigned to the nullified-stereotype condition ($M = 5.79$, $SD = 0.60$). Neither the main effect of Sex, nor the interaction was significant ($p > 0.05$). These results suggest that the stereotype manipulation used was effective to induce the negative stereotype.

3.2. Exercise performance

The GLMM indicated no significant main effect of Sex ($F\,(1, 5273) = 0.95$, $p = 0.33$), but a Condition main effect ($F\,(1, 5273) = 235.69$, $p < 0.001$, $d = 0.22$). Specifically, participants developed more strength when they were assigned to the negative stereotype toward women condition ($M = 5.69$; $SD = 2.40$) than when they were assigned to the nullified-stereotype condition ($M = 5.45$; $SD = 2.40$; See Figure 2). Finally, no Sex x Condition effect emerged ($F\,(1, 5273) = 0.54$, $p = 0.46$; see Table 1).

3.3. Maximal voluntary contractions

Analyses showed a significant effect of Sex with men producing more strength ($M = 30.81$; $SD = 5.60$) than women ($M = 18.94$; $SD = 3.39$), ($F\,(8, 127) = 62.33$, $p < 0.001$, $d = 2.56$). The GLMM also indicated a Time of measurement effect with participants developing more strength

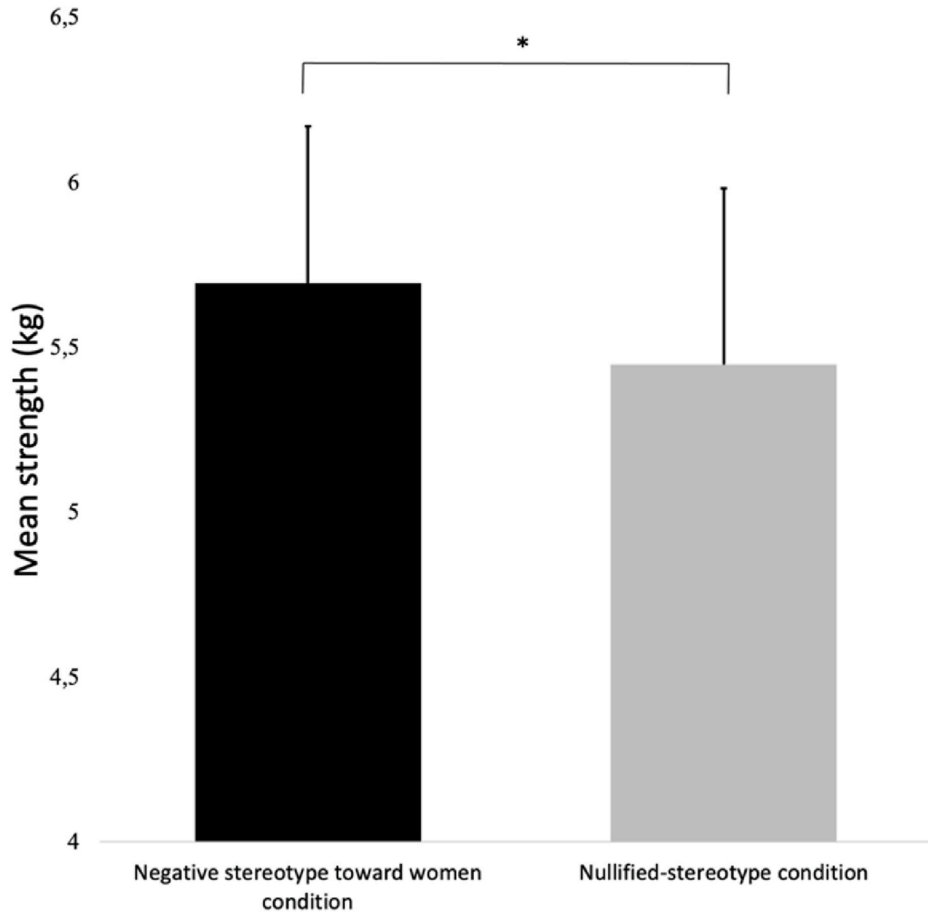

Fig. 2. Mean strength developed according to the different conditions.

Table 1
Means (± standard deviations) for the different dependent variables.

Sex & Variables	Conditions: Familiarization	Negative stereotype toward women	Nullified-stereotype
Men			
ΔMVC (%)	–	8.96 ± 7.02	9.92 ± 8.21
Mean strength (kg)	–	7.25 ± 1.20*	7.02 ± 1.29
Motivation toward women	2.61 ± 1.54	2.63 ± 1.59	2.51 ± 1.56
Motivation toward men	4.06 ± 2.31	4.12 ± 2.19	4.25 ± 2.14
Women			
ΔMVC (%)	–	8.33 ± 7.60	10.02 ± 7.22
Mean strength (kg)	–	4.17 ± 0.67*	3.97 ± 0.66
Motivation toward women	3.35 ± 1.54	3.02 ± 1.63	2.78 ± 1.49
Motivation toward men	2.78 ± 1.73	3.16 ± 1.76*	2.80 ± 1.65

Notes. MVC = maximal voluntary contraction
* Indicates a difference in the mean strength and motivation between the negative stereotype toward women condition and the nullified-stereotype condition ($p < 0.05$).

before the intermittent task ($M = 26.08$; $SD = 7.79$) than after the intermittent task ($M = 23.67$; $SD = 7.40$; $F(1, 127) = 75.04$, $p < 0.001$, $d = 1.46$), suggesting that the task was fatiguing. Importantly, analyses revealed no Condition main effect ($F(1, 127) = 1.0$, $p = 0.32$) and no interaction effects ($p > 0.05$), revealing that there was no significant difference in fatigue between participants according to the different conditions (See Table 1).

3.4. MRCPs

Figures 3 and 4 show respectively the representative grand averaged MRCP waveforms and histograms in women and men at the prefrontal cortex (FP1 and FP2), the supplementary motor area (Cz) and the contralateral central area (C2).

3.4.1. Fp1

Concerning BP, the LMM indicated no significant main effect of Sex, $F(1, 51) = 1.23$, $p = 0.27$, $d = 0.42$, and Condition, $F(1, 51) = 1.64$, $p = 0.21$, $d = 0.35$. However, a significant Sex × Condition interaction effect emerged ($F(1, 51) = 4.18$, $p = 0.05$), suggesting that the amplitude of BP was higher for women when they were assigned to the negative stereotype condition ($M = 0.23$; $SD = 0.71$) as compared to when they were assigned to the nullified-stereotype condition ($M = -0.16$; $SD = 0.61$), $F(1, 51) = 5.50$, $p = 0.02$, $d = 0.60$. For men, no significant difference emerged between the negative stereotype toward women condition ($M = 0.20$; $SD = 0.51$) and the nullified-stereotype condition ($M = 0.27$; $SD = 0.42$), $F(1, 51) = 0.26$, $p = 0.61$, $d = 0.13$. Concerning MP, analyses showed no significant main effect of Sex, Condition and Sex × Condition interaction ($p > 0.05$; See Table 2).

3.4.2. Fp2

Concerning BP, analyses showed no main effect of Sex ($F(1, 50) = 0.77$, $p = 0.39$, $d = 0.35$) but a marginal Condition main effect ($F(1, 50) = 3.92$, $p = 0.054$, $d = 0.46$) as well as a marginal Sex × Condition interaction effect ($F(1, 50) = 3.89$, $p = 0.054$). As for Fp1, the amplitude of BP was marginally higher for women when they were assigned to the

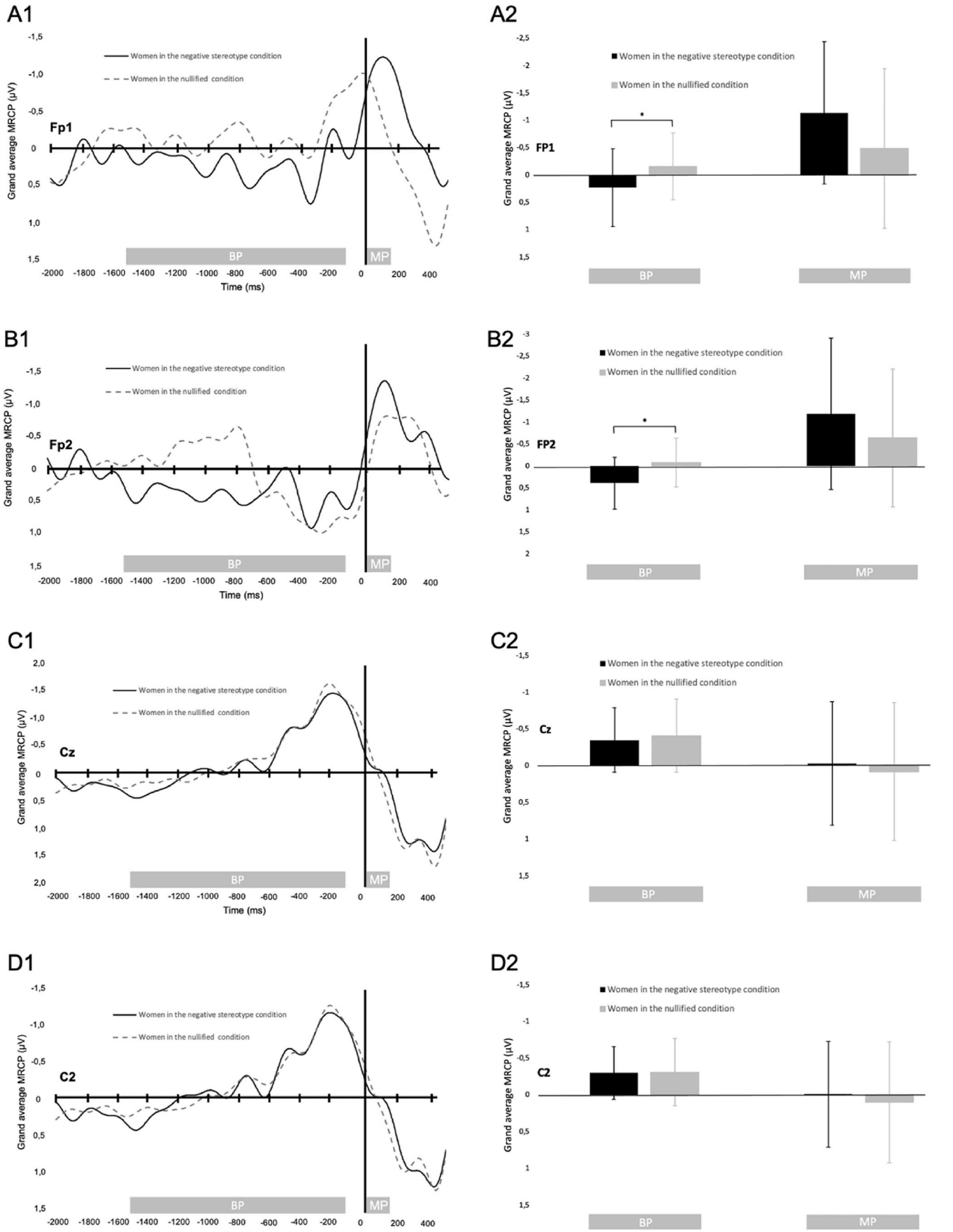

Fig. 3. Grand Average MRCP waveforms and histograms in women at the prefrontal cortex (FP1: A1, A2; FP2: B1, B2), the supplementary motor area (Cz: C1, C2) and the contralateral central area (C2: D1, D2).

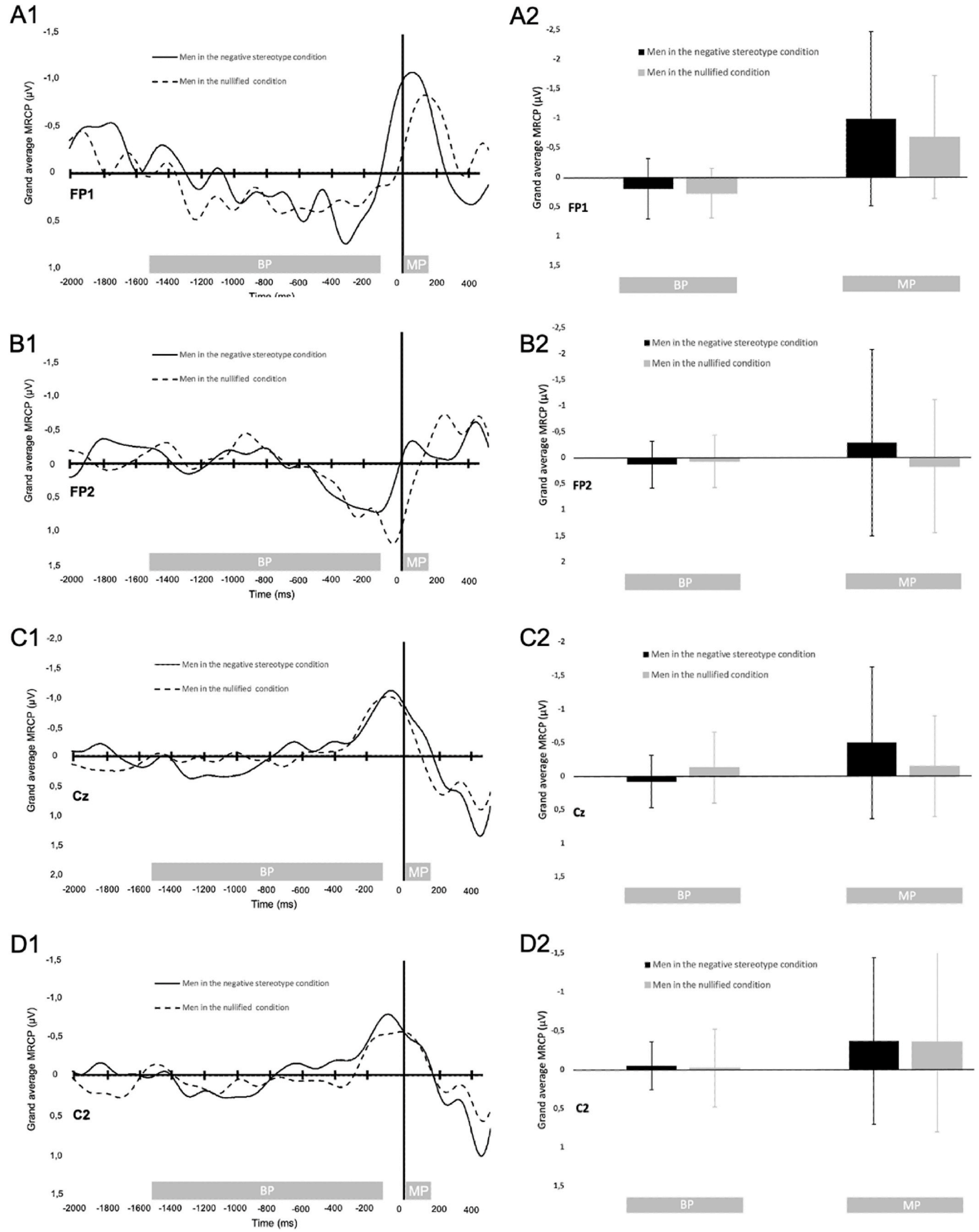

Fig. 4. Grand Average MRCP waveforms and histograms in men at the prefrontal cortex (FP1: A1, A2; FP2: B1, B2), the supplementary motor area (Cz: C1, C2) and the contralateral central area (C2: D1, D2).

Table 2
Means (± standard deviations) for the MRCPs according to the different conditions.

Conditions			
Sex & Variables	Familiarization	Negative stereotype toward women	Nullified-stereotype
Men			
Fp1			
BP	–	0.20 ± 0.51	0.27 ± 0.42
MP	–	−0.99 ± 1.48	−0.68 ± 1.04
Fp2			
BP	–	0.13 ± 0.45	0.07 ± 0.50
MP	–	−0.29 ± 1.79	0.16 ± 1.28
Cz			
BP	–	0.08 ± 0.39	−0.13 ± 0.53
MP	–	−0.50 ± 1.13	−0.15 ± 0.75
C2			
BP	–	−0.05 ± 0.31	0.002 ± 0.50
MP	–	−0.37 ± 1.07	−0.36 ± 1.16
Women			
Fp1			
BP	–	0.23 ± 0.71*	−0.16 ± 0.61
MP	–	−1.14 ± 1.30	−0.49 ± 1.46
Fp2			
BP	–	0.39 ± 0.59*	−0.08 ± 0.55
MP	–	−1.19 ± 1.72	−0.64 ± 1.57
Cz			
BP	–	−0.35 ± 0.44	−0.41 ± 0.50
MP	–	−0.03 ± 0.84	0.08 ± 0.94
C2			
BP	–	−0.30 ± 0.36	−0.31 ± 0.46
MP	–	−0.0008 ± 0.72	0.1 ± 0.82

Notes. Data are expressed in μV
* Indicates a difference in the BP amplitude between the negative stereotype toward women condition and the nullified-stereotype condition ($p < 0.05$).

negative stereotype condition ($M = 0.39$; $SD = 0.59$) compared to when they were assigned to the nullified-stereotype condition ($M = -0.08$; $SD = 0.55$), $F(1, 50) = 8.07$, $p = 0.006$, $d = 0.76$). While for men, no significant difference emerged between the negative stereotype toward women condition ($M = 0.13$; $SD = 0.45$) and the nullified-stereotype condition ($M = 0.07$; $SD = 0.50$), $F(1, 50) < 0.01$, $p = 0.98$, $d = 0.12$. For MP, analyses showed no significant main effect of Sex, Condition and Sex × Condition interaction ($p > 0.05$; See Table 2).

3.4.3. Cz

For BP and MP, the LMM indicated no significant main effect of Sex, Condition and Sex × Condition interaction effect ($p > 0.05$; See Table 2).

3.4.4. C2

For BP, the LMM indicated only a Sex main effect ($F(1, 51) = 4.47$, $p = 0.04$, $d = 0.78$) revealing that the amplitude of BP was higher for women ($M = -0.30$; $SD = 0.39$) than for men ($M = -0.22$; $SD = 0.33$). There was no significant main effect of Condition ($F(1, 51) = 0.29$, $p = 0.59$, $d = 0.07$) and Sex × Condition interaction ($F(1, 51) = 0.21$, $p = 0.64$). Concerning MP, analyses revealed no significant main effect of Sex, Condition and Sex × Condition interaction effect ($p > 0.05$).

3.5. Performance-approach goals

Concerning "motivation toward men", the main analyses indicated no significant main effect of Sex, $F(1, 60) = 0.11$, $p = 0.75$, $d = 0.61$, and Condition, $F(1, 60) = 1.36$, $p = 0.25$, $d = 0.42$. A significant effect of Sex × Condition interaction was found ($F(1, 60) = 6.47$, $p = 0.01$), suggesting that women were more motivated to outperform men when the negative stereotype toward women was induced ($M = 3.02$, $SD = 1.63$) as compared to when the nullified-stereotyped was induced ($M = 2.78$, $SD = 1.49$), $F(1, 60) = 6.73$, $p = 0.01$, $d = 0.59$. However, for men, no difference emerged between the negative stereotype toward women condition ($M = 4.12$, $SD = 2.19$) and the nullified-stereotype condition ($M = 4.25$, $SD = 2.14$), $F(1, 60) = 0.97$, $p = 0.33$, $d = 0.24$. Concerning "motivation toward women", analysis showed no significant of Sex ($F(1, 60) = 0.72$, $p = 0.40$, $d = 0.04$), Condition ($F(1, 60) = 1.26$, $p = 0.27$, $d = 0.17$), and Sex x Condition ($F(1, 60) = 0.25$, $p = 0.62$; see Table 1).

3.6. Mediational analysis

Previous analyses showed that the induction of a negative stereotype toward women influenced men's and women's performance (i.e., strength produced) as well as women's BP amplitude at FP1 and FP2 and women's motivation toward men. We consequently examined whether the increase in BP amplitude and motivation toward men may have caused the performance increase observed through a mediational analysis (Figure 5). To examine this, we compared BP_{FP1}, BP_{FP2}, and motivation toward men in the two conditions using contrast coding. Specifically, we assigned codes of 1 and -1 to the nullified-stereotype condition, and the negative stereotype toward women condition, respectively. Several regression analyses were performed following the procedure advocated by Hayes (2013). The manipulation condition did not significantly predict BP_{FP1} ($b = 3.92$, $p = 0.13$, $r^2 = 0.09$), BP_{FP2} ($b = 3.12$, $p = 0.16$, $r^2 = 0.07$), and motivation toward men ($b = 0.38$, $p = 0.57$, $r^2 = 0.01$), revealing no mediational analysis.

4. Discussion

The current study investigated the effect of the induction of a negative stereotype toward women on women's and men's performance during a repetition of 80 isometric elbow contractions at a fixed perceived intensity, and the neuropsychological mechanisms involved. As predicted, results showed that women's performance was increased after the induction of the negative stereotype toward them, accompanied by an increase in self-reported motivation to perform better than men and an increase in BP amplitude over the prefrontal cortex. However, no significant difference emerged concerning the amplitude of MRCPs over the supplementary motor area and the contralateral central area. Concerning men, analyses revealed that they also increased their performance when they were assigned to the negative stereotype toward women condition. However, no effect emerged on self-reported motivation toward men and women and MRCPs amplitude in the three areas of interest.

4.1. Effect of the negative stereotype toward women on women's performance, cortical activity and performance-approach goals

Since 1999, most studies evaluating the effect of an induction of a negative stereotype observed a decrease in physical performance for the targeted group, as compared to when no stereotype was induced, during technical tasks. This performance decrease was explained by the explicit

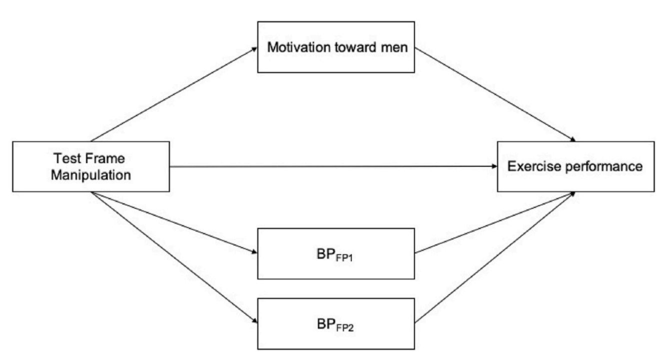

Fig. 5. Hypothetical mediation model of performance improvement by motivation toward men and BP amplitudes (at FP1 and FP2).

monitoring hypothesis (Beilock & Carr, 2001). In the present study, a self-paced isometric task was used, task that did not focus on technical skills and did not require coordination (i.e., only one component of task execution). Consequently, the explicit monitoring hypothesis cannot impact performance. The performance improvement observed in the present research corroborates past studies showing that during non-technical tasks, the induction of a negative stereotype may lead to a performance increase, contrary to stereotype threat predictions. These results strengthen the idea that the effect of the induction of a negative stereotype toward women is likely to be task-dependent (Deshayes, Clément-Guillotin, & Zory, 2019; Deshayes et al., 2020; Huber et al., 2016). However, it appears now necessary to validate this hypothesis by comparing the effect of stereotype inductions on physical performance during a technical task and a non-technical task.

In order to explain why women developed more strength in the negative stereotype condition, MRCPs and motivation (i.e., performance-approach goals) were assessed. In the literature, a higher strength produced has been shown to be generally accompanied by an increase in BP amplitude, especially over the supplementary motor area and the contralateral central area (e.g., Becker & Kristeva, 1980; Hink, Deecke, & Kornhuber, 1983; Kutas & Donchin, 1974; Nishihira, Araki, & Ishihara, 1989; Siemionow et al., 2000). Intriguingly, despite a higher strength produced in the negative stereotype condition as compared to the nullified-stereotype condition, no significant difference emerged for BP between these two conditions. Some previous studies have observed that when the strength difference is low, a difference in BP amplitude may not be observed (e.g., Hazemann, Metral, & Lille, 1989; Kristeva, Cheyne, Lang, Lindinger, & Deecke, 1990; Wilke & Lansing, 1973). For example, Kristeva et al. (1990) found no significant differences of the amplitude of BP between loads corresponding to 250 g and 400 g during finger flexion (i.e., this load difference was less than 2% of the maximal load). In our study, as the difference observed between the two conditions was approximately 4%, this may explain why no significant difference emerged in these areas.

In addition to the supplementary motor area and the contralateral central area, the prefrontal cortex has also been showed to be involved in the planification of the movement and the generation of BP (e.g., Jahanshahi et al., 2001; Kim et al., 2017; Ryun et al., 2014; Sochurkova et al., 2006). The present results showed, in women, a significant increase in BP amplitude when the negative stereotype toward women was induced, as compared to when the nullified-stereotype was induced. This result is in line with previous studies showing that when a negative stereotype toward women is induced, regions in the prefrontal cortex were highly activated, while they were not under control conditions (Inzlicht & Kang, 2010; Krendl et al., 2008; Wraga et al., 2007). This suggests that the preparation of the movement was more important in the prefrontal cortex when the negative stereotype was induced as compared to when the nullified-stereotype was induced.

Interestingly, the present research also revealed that when women were assigned to the negative stereotype toward women, they reported that they wanted to perform better than men to a greater extent than when they were assigned to the nullified-stereotype condition. This study is one of the first observing this increased motivation through self-reported measures. This confirms the hypothesis postulating that when a negative stereotype toward one group is induced, this group is more motivated to counter it (see the mere effort account, Jamieson & Harkins, 2007; the integrated process model, Schmader et al., 2008; Steele, 1997). More precisely, this result reveals that women wanted to outperform the group that was not targeted by the stereotype (i.e., men). This increased motivation may echo the results observed concerning BP. Indeed, it has been shown that an increase in participants' motivation is associated with an increase in BP amplitude (e.g., McAdam & Seales, 1969; Pornpattananangkul & Nusslock, 2015). Consequently, as the prefrontal cortex is reputed to be a decisional center, especially during physical tasks (e.g., Robertson & Marino, 2016), we may suggest that the induction of the negative stereotype has resulted in an increase in women's motivation, resulting in a conscious decision to develop more strength, characterized by an increase in BP amplitude over the prefrontal cortex, leading to the performance improvement observed.

However, research on "free will" could also reveal that the stereotype made its impact unconsciously. In their initial study, Libet, Gleason, Wright, and Pearl (1983) found that participants became consciously aware of the decision to make a movement 200 ms before its initiation. Surprisingly, they observed a cortical wave, corresponding to BP, starting approximately 550 ms before the movement, thus leaving about 350 ms between the initial rising of the BP and the conscious awareness of the decision to move. Libet et al. (1983) concluded that the brain unconsciously plans our movement but allows for a conscious "veto" to alter the outcome of our volition. For thirty years, many studies replicated this experiment (e.g., Soon, Brass, Heinze, & Haynes, 2008) or called it into question (Danquah, Farrell, & O'Boyle, 2008; Dominik et al., 2017). In 2022, this debate is still open, but as we observed a difference in BP in the present research, our results may suggest that the initial decision to produce more strength for the same perceived intensity is initially made unconsciously. It could be interesting, in further research, to ask participants if they perceived a difference in effort production during the different conditions. This information could be easily collected and could give more insights about how stereotypes operate.

Even if the results observed in women are in line with our hypothesis and recent past studies, two others factors may have caused the performance increase observed: domain identification and task difficulty. Firstly, based on the initial stereotype threat theory, only participants who considered the studied/stereotyped domain to be important for them can be affected by the negative stereotype (Roberson & Kulik, 2007; Steele, 1997). In the present research, recruited participants were strongly identified with the physical activity domain. Laurin (2017) and Nguyen and Ryan (2008) found that the level of identification could moderate the effect of stereotype threat, with moderately identified participants being more impacted than highly identified ones. Saunders (2016) showed that a high level of identification with math boosted threatened women's performance instead of dampening it. It is thus possible that a high level of identification, as identified in the present study, may boost rather than reduce threatened women's performance. In line with this, recent research observing a positive effect of the induction of a negative stereotype toward women also recruited highly identified participants (e.g., Deshayes, Clément-Guillotin, & Zory, 2019; Deshayes, Zory, et al., 2019). Future research should test this domain identification hypothesis more in depth, for example, with a comparison between moderately and highly identified participants.

Finally, concerning task difficulty, previous studies found that when the task is non-difficult, participants could be non-affected by the induction of a negative stereotype, or could even increase their performance (Ben-Zeev, Fein, & Inzlicht, 2005; Neuville & Croizet, 2007; O'Brien & Crandall, 2003). However, these studies were exclusively conducted in the cognitive domain. To the best of our knowledge, no study in the physical domain have officially tested the role of task difficulty in a stereotype threat situation in women. In the present research, participants had to produce an effort corresponding to 5 on a modified CR-10 scale which corresponds to a "strong effort". Assuming that the anchor 10 corresponds to the maximal strength produced, we suppose that the anchor 5 corresponds to approximately 50% of participants' maximal strength (even if the perception of effort is slightly less than the equivalent value on the CR-10 scale; Pincivero, Polen, & Byrd, 2010). However, on average, participants demonstrated only 22% of their maximal strength (and only 27% for the five first contractions). In addition, we acknowledge that we did not ask participants if they perceived the task as difficult. Consequently, it could be interesting to replicate this study, asking participants how they perceive the task, and/or increasing the intensity of the task to ensure that it is difficult for participants.

4.2. Effect of the negative stereotype toward women on men's performance, cortical activity and performance-approach goals

This study also investigated the influence of the induction of a negative stereotype toward women on men's performance. In line with the stereotype lift phenomenon (Walton & Cohen, 2003), we observed that men increased their performance when assigned to the negative stereotype toward women condition, as compared to when assigned to the nullified-stereotype condition. This positive effect on men's performance was previously observed in a large variety of tasks such as a balance task (Chalabaev, Stone, et al., 2008), a stride jumping task (Laurin, 2017), a maximal strength task (Chalabaev et al., 2013), a basketball shooting task (Laurin, 2013), a ball-bouncing task (Huber et al., 2016) or endurance tasks (Deshayes, Clément-Guillotin, & Zory, 2019; Deshayes, Zory, et al., 2019; 2020). As for women, the mechanisms involved have rarely been investigated.

Concerning performance-approach goals, men were not more motivated to outperform women when the negative stereotype toward women was induced. Chalabaev, Stone, et al. (2008) found that when a negative stereotype was induced toward women, men were more confident about their capacity to perform well on the task. We may suggest that men were not more motivated to perform better than women because they probably felt that they were better than them (i.e., increased self-confidence) due to the induction of the negative stereotype toward women.

Concerning the cortical mechanisms (i.e., MRCPs) involved in this performance improvement, as for women, no significant difference emerged between the two conditions for Cz and C2, probably due to the low difference in strength produced between the experimental conditions (i.e., the improvement observed for men and women were approximately the same). Concerning the prefrontal cortex, no significant difference emerged on FP1. On FP2, even if a marginal condition main effect emerged, the marginal Sex × Condition interaction effect revealed that only women had higher BP amplitude in the negative stereotype toward women condition as compared to the nullified-stereotype condition. This is confirmed by the effect size observed for women and men ($d = 0.76$ and $d = 0.12$ respectively). As there is a link between motivation and BP amplitude (e.g., McAdam & Seales, 1968; Pornpattananangkul & Nusslock, 2015) and as men were not more motivated to outperform women in the negative stereotype toward women condition, this may explain why no modification on BP amplitude was observed for men. Thus, these results suggest that the performance increase observed in men was not due to increased planning for the upcoming movement (i.e., contrary to women). This is nonetheless in line with Chalabaev et al.'s (2013) results, revealing that the increase in performance observed for men in their study was not due to a modification in the preparatory processes occurring before task execution. Consequently, more research is needed to define the neuropsychological mechanisms involved in such performance increase.

4.3. Limitations and perspectives

Despite the innovative results observed, some limitations of the current study should be taken into consideration. Firstly, no mediational effect was observed from the motivation and BP amplitude in the prefrontal cortex. This absence of mediation could be explained by the sample size. Indeed, based on Fritz and Mackinnon (2007) study, our sample size was probably too small to detect a mediational effect, despite being sufficient to investigate the effect of a negative stereotype on physical performance. It could be interesting to recruit more participants in future studies in order to increase the statistical power of the study, to detect smaller effects, and to test the potential mechanisms involved in this performance improvement in greater depth. Secondly, even though the EEG system had a lot of advantages, it presented limitations and especially a weak spatial resolution which limited our interpretation concerning the specific areas involved (i.e., which area in the prefrontal cortex was the most impacted). Hence, functional magnetic resonance imaging (fMRI) should be used to investigate this issue further. Thirdly, the present research focused on the performance-approach goals. However, it could have been interesting to also assess performance-avoidance goals as they may also be implicated in a stereotype threat situation (Chalabaev, Sarrazin, et al., 2008). Finally, in the present research, we measured the cortical activity over the prefrontal cortex. It would be interesting in future studies to assess, in the prefrontal cortex, executive functions and especially working memory and inhibition. Indeed, these variables have been identified as being implicated during a stereotype threat situation (e.g., Hutter, Davies, Sedikides, & Conner, 2019; Wang & Yang, 2020), especially in the physical domain (e.g., Chalabaev et al., 2020; Laurin et al., 2020). This would allow to define the potential moderating or mediating role of these variables, and thus explain in greater depth the role of the prefrontal cortex during a stereotype threat situation in the physical domain.

5. Conclusion

The current study explored the effect of a negative sex stereotype toward women on women's and men's performance during a self-paced exercise with an investigation of the neuropsychological mechanisms involved, through MRCPs and motivation (i.e., performance-approach goals). Concerning women, in addition to observing a positive effect of the induction of a negative stereotype, which contrasts dramatically with the stereotype threat theory (Steele, 1997), this study provides, for the first time in the physical domain, some evidence of how the negative stereotype operates. More specifically, under stereotyping, women are more motivated to outperform men. This study also reveals that the induction of a negative stereotype elicited in women adaptations in the prefrontal cortex and precisely in the planning for strength production. Finally, we strengthen the hypothesis suggesting that the effect of negative stereotypes would be task-dependent. Concerning men, the results are in line with the stereotype lift phenomenon, but more studies are needed to explain the cortical mechanisms involved in such performance improvement.

Declaration of competing interest

The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

Data availability

Data will be made available on request.

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