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Error-related negativity varies with the activation of gender stereotypes

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ABSTRACT

The error-related negativity (ERN) was suggested to reflect the response-performance monitoring process. The purpose of this study is to investigate how the activation of gender stereotypes influences the ERN. Twenty-eight male participants were asked to complete a tool or kitchenware identification task. The prime stimulus is a picture of a male or female face and the target stimulus is either a kitchen utensil or a hand tool. The ERN amplitude on male-kitchenware trials is significantly larger than that on female-kitchenware trials, which reveals the low-level, automatic activation of gender stereotypes. The ERN that was elicited in this task has two sources—operation errors and the conflict between the gender stereotype activation and the non-prejudice beliefs. And the gender stereotype activation may be the key factor leading to this difference of ERN. In other words, the stereotype activation in this experimental paradigm may be indexed by the ERN.

A gender stereotype can be described as culturally specific, publicly shared characteristics that are associated with one particular gender [15]. In Chinese traditional culture, the stereotypes of gender are rather pervasive: the role of female is always associated with housekeeping, while that of male is more associated with social production. Although individuals may attempt to prevent gender stereotypes from affecting their behavior by engaging in controlled processes, the intentions to control gender bias are not always successful. Even for the self-avowed egalitarians, the prejudices of gender have often slipped through in their behavior despite their non-prejudiced intentions. Previous studies revealed that stereotyping is an automatic, implicit, cognitive process, and it can be automatically activated by gender features [22]. The stimulus of gender features can automatically start an activated gender stereotype [3]. When the activated stereotypic information conflicts with one's non-prejudiced beliefs, the following neural processes will result.

In cognitive neuroscience, there are two separate neural systems that work in concert to arrive at an intended behavior in the face of conflicting behavioral tendencies. The first one is a conflict-detection system, which monitors ongoing responses and is sensitive to competition between different response tendencies [4,19]. This system is constantly active, requiring few cognitive resources, and has been shown to operate below conscious awareness. When a conflict is detected by this system, it alerts the second, resource-dependent regulatory system designed to implement the intended response while inhibiting the unintended response [9].

The error-related negativity (ERN) wave, a component of the event-related potential (ERP), reflects the response-performance monitoring process [23]. The onset of the ERN coincides with response initiation, as determined by the onset of the electromyogram (EMG) associated with the responding hand, and peaks roughly 80 ms thereafter. Its spatial distribution lies over the frontal–central regions of the scalp [14], and is symmetrical to the midline [23]. The anterior cingulate cortex, which is specifically involved in the brain's error processing system, seems to be the generator site of the ERN [13].

In past studies, it was demonstrated that the ERN can be elicited by conflicts and errors. Response conflict monitoring theory of ERN suggests that the amplitude of ERN reflects the degree of response conflict. In higher-conflict incongruent trials, larger ERN amplitudes are produced [23]. From reinforcement learning theory, the ERN is sensitive to the degree of error, as larger errors correspond with larger negativity [14,18]. The ERN is elicited whenever it detects a mismatch between the produced response and the correct, or the intended, response [8], such as the wrong hand, the wrong finger, or both the wrong hand and the wrong finger [5]. Recently, some studies correlate the ERN with some modulating factors. Confronted with the same error, the ERN peaks both earlier and larger in the context of pleasant backgrounds than neutral or unpleasant backgrounds [16]. The impulsivity of participant is correlated with the ERN amplitude, which suggests that

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the high-impulsive participants have smaller ERN amplitudes on punishment trials than the low-impulsive participants [12]. Social culture, such as racial stereotypes, can also induce lager ERNs [9]. Few studies however, have focused on how the gender stereotypes affect the ERN.

In this study, the participants were asked to identify the target stimulus which was a tool or a piece of kitchenware, and the prime stimulus was a male or female face. We speculated that the prime stimulus would activate the gender stereotypes which would influence the judgment of the target stimulus. The ERN would be recorded on these trials that the participants' identification of the target stimulus was wrong, and larger ERNs would be observed on the trials of gender stereotype-incongruent.

Twenty-eight right-handed male undergraduates aged between 20 and 35 years (mean = 27.5) were employed in this study. All had normal or corrected-to-normal visual acuity. They did not have any history of neurological or mental diseases. All the participants claimed holding predominantly non-prejudiced attitudes of gender.[1]

The stimuli consisted of 144 prime-target pairs. The primes in these pairs included 12 digital photographs of 6 Asian male and 6 Asian female faces, and the targets included 12 digital photographs of 6 kitchen utensils (fork, knife, spatula, rolling pin, ladle, chopsticks) and 6 hand tools (drill, ratchet, wrench, pliers, brush, shovel). These photographs were digitized at 228 × 172 pixels.

Stimuli were presented sequentially in the center of a computer screen, with a visual angle of 2.58° × 2.4°. Each trial began with a pattern mask (1 s), followed by the prime (200 ms), and then the target (200 ms). The next trial starts after the participant responded or after 1500 ms had elapsed since the onset of the target. The prime-target pairs were divided into four conditions: male-kitchenware, female-kitchenware, male-tool, and female-tool. The stimulus pairs of male-tool and female-kitchenware are called stereotype-congruent pairs and those of male-kitchenware and female-tool are called stereotype-incongruent pairs. The stimulus pairs were randomly presented in sequence and had the same probability. Stimuli and recording triggers were presented using STIM 2 software (Neurosoft Labs, Inc., Sterling, USA).

After participants provided informed consent, they were fitted with an electrode cap for electroencephalographic (EEG) recording. Then, the participants were instructed to classify the target picture as a piece of kitchenware or a tool as quickly as possible, and were told that an erroneous "kitchenware" response on a female-tool trial or an erroneous "tool" response on a male-kitchenware trial was indicative of gender bias.

Electroencephalogram was continuously recorded (band pass 0.05–100 Hz, sampling rate 500 Hz) with Neuroscan Synamp2 Amplifier (Scan 4.3.1, Neurosoft Labs, Inc., Sterling, USA), using an electrode cap with 64 Ag/AgCl electrodes mounted according to the extended international 10–20 system and referenced to linked mastoids. Vertical and horizontal electrooculograms were recorded with two pairs of electrodes, one placed above and below the right eye, and the other 10 mm from the lateral canthi. Electrode impedance was maintained below 5 kΩ throughout the experiment. Following electrode application, participants sat in a comfortable sofa located in a shielded room and were asked to fix a point in the center of the computer display. Next, the experimenter gave participants instructions to classify the second picture as a kitchenware or a tool by pressing the corresponding key with their right or left index finger. Responses were to be made within 500 ms of the target presentation. If the responses exceeded this time limit, the participants would receive a red warning symbol "×" to make them respond more quickly. After 30 practice trials, 576 stimulus trials were presented.

Table 1
Means (S.D.s) of RTs on correct responses and error rates in different conditions

Experimental condition	RT for correct response (ms)	Response error rate
Male-T	344.88 (72.93)	0.3084 (0.1365)
Male-K	363.03 (77.66)	0.4361 (0.1688)
Female-T	379.72 (72.22)	0.4353 (0.1593)
Female-K	345.92 (76.01)	0.3373 (0.1590)

Male-K, male-kitchenware trials; female-K, female-kitchenware trials; male-T, male-tool trials; female-T, female-tool trials.

An 800 ms epoch of EEG signal, centered on key press, was selected for each artifact-free trial with the first 400 ms of the epoch as a baseline. Electrooculogram artifacts were corrected using the method proposed by Semlitsch et al. [21]. Trails contaminated by amplifier clipping, bursts of electromyographic activity, or peak-to-peak deflection exceeding ±80 μV were excluded from averaging. The remaining trails were baseline corrected. ERPs for correct and incorrect trails were averaged within their respective trial types and the averaged ERPs were digitally filtered with a low pass filter at 30 Hz (24 dB/Octave). The ERNs were scored, in this study, when the peak negative deflection occurred between 50 ms before key press and 150 ms after key press at the frontocentral site.

In each analysis, only participants with valid response on all measures were adopted. To ensure reliable and stable ERP component with relative higher signal-to-noise ratio extracting from digitized EEG signal, it was necessary to exclude the participants with insufficient sample of valid trials. Fabiani et al. [10] suggested that more than 20 valid trials for a condition are needed to obtain the stable ERP. In this study, we excluded the participants with fewer than 20 artifact-free error trials in any of the four conditions (7 participants). Thus, the primary analyses were conducted on the data from the rest (21 participants).

The data of means (Ms) and corresponding standard deviations (S.D.s) of reaction times (RTs) on correct responses and of response error rates in different conditions are given in Table 1. To examine whether the reaction times on stereotype-congruent trials are faster than on stereotype-incongruent trials, we conducted a 2 (gender: male vs. female) × 2 (object: tool vs. kitchenware) within-subjects analysis of variance (ANOVA) for RTs on correct responses. This analysis produced a main effect for gender of face, $F(1,20) = 9.135$, $p = 0.007$; responses to male faces ($M = 353.956$, S.D. = 74.974) were faster than responses to female faces ($M = 362.819$, S.D. = 75.198). However, there was not a main effect for objects, $F(1,20) = 2.778$, $p = 0.111$. The interaction between gender and object was significant, $F(1,20) = 21.252$, $p = 0.000$. Simple effect analyses showed that participants were quicker to identify kitchenware following female faces ($M = 345.920$, S.D. = 76.008) than following male faces ($M = 363.033$, S.D. = 77.659), $F(1,20) = 10.766$, $p = 0.004$, and were slower to identify tools following female faces ($M = 379.718$, S.D. = 72.217) compared with male faces ($M = 344.879$, S.D. = 72.934), $F(1,20) = 22.688$, $p = 0.000$. These results demonstrated an automatic association between the male face and tools and between the female face and kitchenware. Additionally, the slower responses to the pairings of male-kitchenware and female-tool suggested that participants adopted a more controlled response strategy on these trials in an effort to avoid gender bias.

In addition, to examine the effect of stereotypic associations on the response error rates, we conducted a 2 (gender) × 2 (object) within-subjects ANOVA for error rates. There was no main effect for gender, $F(1,20) = 1.433$, $p = 0.245$, nor object, $F(1,20) = 0.234$,

[1] All these participants were asked to fulfill a questionnaire that was created by authors following the idea of Burt's sex role stereotyping scales [7].