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Interference in simultaneously perceiving and producing facial expressions—Evidence from electromyography

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ABSTRACT

The goal of the current studies was to examine perception–action interactions in a socially relevant domain. Social interactions are based on a mutual understanding of the emotions and actions of others. We assume that the perception of emotional actions also stimulates a parallel action preparation in the perceiver, underlining the common coding theory. We report two experiments aimed to examine whether the perception of socially relevant facial actions (e.g., happy vs. angry facial expressions) interact with the execution of such actions. More specifically, we use a stimulus–response compatibility paradigm, in which subjects responded to the gender of a face by either smiling or frowning while ignoring the fact that the presented face is also randomly either smiling or frowning. We measured reaction time (RT) as onset latency on the two large muscle groups used for smiling (zygomaticus major) and frowning (corrugator supercilii) using electromyography. Experiment 1 showed that on compatible trials, in which perceived facial expression and actually produced facial expression matched, RTs were shorter than on incompatible trials. Experiment 2 used pre-instructed (i.e., blocked) responses and replicated the compatibility effect, suggesting that the effect is functionally located not in response selection but in response initiation or execution. We discuss these results in relation to cognitive mechanisms of common coding of perception and action and to the human mirror neuron system.

The study of the influence of action observation on cognition and behavior has a venerable tradition in several research fields. For instance, in social psychology it has been shown that observers can easily reproduce actions performed by a model (e.g., Bandura, 1977). More recent studies on imitation learning ascribe action observation a crucial role in human behavior in general (Brass & Heyes, 2005). Likewise, the field of cognitive psychology has demonstrated that observing other person's actions has a profound influence on action coding in the observer (see Hommel, Müsseler, Aschersleben, & Prinz, 2001, for a review).

For example, in a study by Brass, Bekkering, Wohlschläger, and Prinz (2000), a hand was presented on the screen, and numbers were superimposed on the fingers. Subjects had to lift their index or middle finger in response to the presentation of a number 1 or 2, but the fingers on the screen also moved. The major finding was that reaction times (RTs) were shorter when the to-be-moved finger was the same as the finger that moved on the screen, even though finger movement on the screen was nominally irrelevant to the task. Hence, the task-irrelevant stimulus resulted in a tendency to imitate the observed action.

This interference effect can be considered an instance of the so-called "Simon" effect, in which an irrelevant spatial stimulus feature corresponds or does not correspond to the location of the required response and is thus part of a larger family of S–R compatibility effects (see, e.g., Proctor & Vu, 2006, for a review). Brass et al. (2000) extended the S–R compatibility paradigm to include real human movements that allow for the study of socially relevant behavior. Similar effects have been observed in a variety of other studies (see Brass & Heyes, 2005, for a review).

The study of action imitation also gained strong interest in the neurosciences. Rizzolatti and Craighero (2004) review evidence showing that cells in the premotor cortex of the monkey respond selectively both when the monkey performs an action and when he observes another monkey's action (so-called "mirror neurons", see e.g., Binkofski & Buccino, 2006; Rizzolatti & Craighero, 2004, for reviews). It has been proposed that such a mirror neuron system also exists in the human brain (Binkofski et al., 2000; Buccino et al., 2001; Iacoboni et al., 1999; for reviews see Binkofski & Buccino, 2006; Iacoboni, 2009; Rizzolatti & Craighero, 2004). The human mirror neuron system is assumed to be involved in the understanding of other humans' actions and associated with empathy and

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processing of others' emotions (e.g., Gallese, Keysers, & Rizzolatti 2004; Jacob & Jeannerod, 2005; Schulte-Rüther, Markowitsch, Fink, & Piefke, 2007; Sommerville & Decety, 2006) and is thus relevant for social cognition in general (Gallese et al., 2004; Iacoboni & Dapretto, 2006, for a review).

The present study aimed at studying the role of observing another person's action with respect to its social and emotional valence and to see how it affects the observer's action. To this end, we had subjects produce facial expressions (frowning vs. smiling), using electromyography (EMG) to measure the movement onset of facial muscle activity, while they observed the facial expression of a stimulus person. This paradigm fits nicely with the affective Simon paradigm as introduced by De Houwer, Hermans, & Eelen (1998), who showed that compatibility effects occur when using affective stimuli of which the affective value had to be ignored.

Studies reveal that when people are exposed to facial expressions they spontaneously react to these expressions with similar facial expressions (Dimberg, Thunberg, & Elmehed, 2000; Lundqvist, 1995; Wild, Erb, & Bartels, 2001). Darwin (1872) already argued that emotional expressions have a biological basis (Ekman, 1973; Izard, 1977; Tomkins, 1962) and that we are inclined to generate distinct facial muscle reactions as a response to both social stimuli (Dimberg, 1990, 1997) and non-social stimuli (Dimberg, 1986). Dimberg, Thunberg, and Grunedal (2002) proposed that these responses are based on automatic processes (for a review, see, e.g., Bargh & Chartrand, 1999), suggesting that the evaluation of emotional stimuli occurs spontaneously and effortlessly, without necessary involvement of conscious processes (Esteves, Dimberg, & Öhman, 1994; Whalen et al., 1998). Thus, it should be rather difficult to voluntarily interrupt or completely restrain the 'automatic' reaction once evoked and therefore the automatic response should consequently interfere with consciously controlled activities.

The current study combined this automatic processing of facial expression with the production of facial expressions. Participants were instructed to respond to pictures of male and female faces by either smiling or frowning. The pictures themselves, however, also showed either smiling or frowning faces, resulting in compatible and incompatible trials. On a compatible trial, we expected an automatically induced response facilitation of the correct response, whereas on an incompatible trial, the correct response should take longer due to interference of the automatically activated incorrect response. We used electromyography (EMG) to test this, applying facial surface electrode-pairs on the zygomaticus major, the main muscle group used when smiling, and the corrugator supercilii, the main muscle group used when frowning (as defined by Fridlund & Cacioppo, 1986).

A recent study by Lee, Dolan, and Critchley (2008) examined a similar effect. Participants viewed movie clips of happy or angry expressions in different intensities and were instructed to respond to an auditory stimulus with either a smile or a frown. They found faster responses on compatible trials than on incompatible trials. In contrast to Lee et al. (2008), we used static photographs in the current study to have maximum control of the timing of relevant information. Moreover, in Lee et al.'s (2008) study, the imperative stimulus was auditory and presented *after* the video had been displayed, whereas we used the gender of the presented face as the imperative stimulus. This way, the task-relevant information and the task-irrelevant information were displayed at exactly the same time and in the same modality.

The current study was also designed to look more closely at the different mechanisms of cognitive control and timing. To this end, we performed two additional analyses. The first focused on reaction time distributions to examine how the compatibility effect evolves over time (i.e., whether it decreases or increases with longer reaction times). In a regular Simon task, it is generally found that the compatibility effect becomes smaller with slower reaction times due to decay of the automatically activated but task-irrelevant response code (e.g., Hommel, 1994). The second analysis focused on sequential effects, as there is evidence that the compatibility effect changes depending on the previous trial. For example, Stürmer, Leuthold, Soetens, Schröter, and Sommer (2002) found that the effect is smaller after an incompatible trial, suggesting suppression of the automatic response after an incompatible trial.

In Experiment 1, we used a two-choice task setting, in which compatibility effects can arise during response selection as a function of response conflict. This response conflict arises due to an automatically induced incorrect response during an incompatible trial (see Proctor & Vu, 2006). For example, the image shows a smile but the required reaction would be to frown. The automatically induced, but wrong, response would be to smile, since the task required the participant to frown. This 'activation' of two different responses should lead to a response conflict. In Experiment 2, we required participants to perform a simple response task. More specifically, they were pre-instructed as to which facial expression they had to perform prior to each experimental block. Any compatibility effects that arise would, most likely, be due to interference within later response processing stages, such as initiation or execution, since the response is already pre-instructed.

1. Experiment 1

1.1. Methods

1.1.1. Participants

We recruited and tested 20 students from RWTH Aachen University. The study was approved by the local Ethics Committee and each participant gave written informed consent. All participants had normal or corrected-to-normal vision and were naïve as to the purpose of the study. Participants received either credit points or a small fee for participating. Three participants were excluded from the data analysis due to technical errors and artifacts and one participant was excluded from the analysis because of more than 25% errors. The final sample contained 16 students of which 7 were male and 9 were female (with age $M = 23.6$, $SD = 4.2$).

1.1.2. Stimuli and apparatus

Twenty-four professional actors from local theatre schools were asked to help in creating an emotional expression database. The actors were instructed and trained on the 6 basic emotions and subsequently videotaped. Videos were analyzed using the FACS coding system to assure that the appropriate muscles were used. In addition, the videos were rated by 69 students on affect, clarity, and realism of the emotions and emotional expressions. We only used videos of those actors with high ratings (90% or higher) on all categories. We extracted static images of the emotional expressions at their peak to use in the current experiment. For the experiment we used eight stimuli, showing two male and two female actors, each both either with a happy or angry facial expression (see Fig. 1). The stimuli were presented full screen on a 19 inch monitor (35 cm × 25 cm) at a distance of approximately 70 cm from the participants. The experiment was written in MATLAB 2008a, using the psychtoolbox 3 (Brainard, 1997; Pelli, 1997).

1.1.3. Procedure

Participants were instructed to produce a happy or angry facial expression as fast as possible in response to either a male or a female face. The mapping of gender of the stimulus person (female vs. male) and the required facial response (smile vs. frown) was counterbalanced across participants. Moreover, we also counterbalanced for gender effects, meaning half of the female and male participants were instructed to smile at female images, whereas the other half was instructed to smile at male images.[1]

The experiment itself began with a white fixation cross in the center of the screen. After 500 ms, a brief auditory warning signal was presented indicating the start of a trial. After another 500 ms, an image appeared on the screen depicting either a female or a male face with either a 'happy' or an 'angry' facial expression. The image was visible for 1000 ms, after which the fixation cross reappeared. The participant had another 2500 ms after stimulus offset to respond and to relax their facial muscles again. Finally, they had to indicate the end of the trial by a key press to initiate, after 500 ms, the next trial. We presented 4 experimental blocks, each containing 40 randomized trials with an equal amount of happy/angry expressions

[1] *Note*: We tested for gender effects but no significant effects were found, therefore we excluded further analyses of this type.