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Intersubjective action-effect binding: Eye contact modulates acquisition of bidirectional association between our and others' actions

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ABSTRACT

In everyday social life, we predict others' actions in response to our own actions. Subsequently, on the basis of these predictions, we control our actions to attain desired social outcomes and/or adjust our actions to accommodate the anticipated actions of the others. Representation of the bidirectional association between our and others' actions, that is, intersubjective action-effect binding, could make such intersubjective action control easier and smoother. The present study investigated not only whether or not intersubjective action-effect binding was acquired but also whether or not eye contact modulated it. Experiment 1 showed that after a repeated experience during which participants' finger movements triggered a target female individual's mouth gesture, observing the target's mouth gestures came to automatically trigger the participants' finger movements. Experiments 2 and 3 revealed that this effect was not observed when the target's gaze direction was averted (Experiment 2) or when the target's eyes were closed (Experiment 3) throughout the acquisition phase. These results indicate that intersubjective action-effect binding occurs and that an ostensive signal, that is, eye contact modulates it.

1. Introduction

How do we become intentional agents? Inspired by Lotze (1852), Harleß (1861), James (1890) indicated that we cannot perform an act voluntarily unless we can foresee its effects. Voluntary action is taken according to our anticipation of the movements' sensible effects. We can voluntarily act only by anticipating the effects of the movement. In James' words, "when a particular movement, having once occurred in a random, reflex, or involuntary way, has left an image of itself in the memory, then the movement can be desired again, proposed as an end, deliberately willed" (James, 1890, Vol. 2, p. 487). Later, James' idea was further elaborated by Elsner and Hommel (2001), who proposed a two-stage model of acquisition of voluntary action control. According to their model, in the first stage, randomly produced movements lead to specific, perceivable changes in the environment. After repeated co-occurrences between movements and their effects, the motor pattern of that action becomes associated with that effect in a bidirectional manner. In the second stage, once such a bidirectional action-effect association has been acquired, actions are automatically activated by anticipation of their effects. Thus, movements come to be intentionally executed by activating the perceptual codes that represent the desired goal (i.e., expected effect).

Once bidirectional association between movement and effect is acquired, it has several functions other than action control. James (1890) noted a report by Lotze (1852) that the thrust of a sword triggered slight movements of

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spectators' arms. Later theory has suggested that such automatic mimicry allows us to directly understand the meanings of actions by internally replicating them without any explicit reflective mediation (e.g., Rizzolatti, Fogassi, & Gallese, 2001). In addition, it also contributes to the self/other distinction. My observed leg movement (and/or the feeling of my leg moving) is perfectly contingent upon my motor commands (or predictions based on motor commands), but another person's is not (e.g., Bahrick & Watson, 1985; Daprati et al., 1997; Morgan & Rochat, 1997; Tsakiris, Haggard, Franck, Mainy, & Sirigu, 2005). Moreover, self-produced sensations or distal effects can be correctly predicted on the basis of motor commands. This predictable component is removed from incoming sensory signals, thereby attenuating the sensory effect of self-generated movement. Such a mechanism enables differentiation between self-produced and externally generated sensations, thereby producing a sense of self-agency (i.e., the sense that I am the one who causes the action) (Bays, Flanagan, & Wolpert, 2006; Blakemore, Frith, & Wolpert, 1999; Sato & Yasuda, 2005).

To test their model, Elsner and Hommel (2001) conducted several influential experiments. Their experiments consisted of two phases: an acquisition phase and a test phase. In the acquisition phase, participants experienced co-occurrences between left and right key presses and low- and high-pitched tones. In the subsequent test phase, participants were instructed to respond to the tones now used as imperative stimuli as quickly and correctly as possible according to a fixed stimulus–response mapping. Participants were randomly divided into two groups: the non-reversal and reversal groups. For the non-reversal group, the stimulus–response mapping in the test phase was consistent with the response-stimulus mapping acquired in the preceding acquisition phase. For the reversal group, the stimulus–response mapping was inconsistent with the response-stimulus mapping acquired in the preceding acquisition phase. The logic was as follows: if participants had acquired bidirectional associations between responses and tones, then presenting the tones should activate the associated responses. Therefore, response-compatible tones should allow for faster responses than response-incompatible tones. Their results supported this assumption. In the next experiment, they showed that acquired bidirectional action-effect associations also biased participants' freely made choices according to the learned associations. The acquisition of action-effect representations depends on both the temporal contiguity and the contingency between an action and an effect (contingency is the extent to which an action reliably predicts an effect), thus suggesting that action-effect representations are acquired by associative learning mechanisms (Elsner & Hommel, 2004). Action-effect binding can occur for voluntary nonactions and their effects (Kühn, Elsner, Prinz, & Brass, 2009). Moreover, action-effect associations can be acquired not only through active experience, but also through observing the actions of others (Paulus, van Dam, Hunnius, Lindemann, & Bekkering, 2011). A recent study showed that even 9-month-olds can acquire bidirectional action-effect associations through active experience (Verschoor, Weidema, Biro, & Hommel, 2010).

Although a number of studies have investigated action control in the physical world, it remains unclear whether or not bidirectional associations can be acquired even between one's own and another person's actions. Such intersubjective action-effect binding is important in the following respect: in daily life, we predict others' actions in response to our actions, and we select and control our actions to obtain desired responses from others on the basis of these predictions. Moreover, successful joint action in which co-actors cooperate to attain shared goals depends on the ability to integrate the predicted effects of one's own and others' actions (e.g., Sebanz, Bekkering, & Knoblich, 2006). In particular, when attainment of shared goals requires opposing or complementary actions between co-actors, we must adjust our actions to accommodate the anticipated actions of others. In that case, intersubjective action-effect binding would enable smooth cooperation between co-actors. In addition to intersubjective action control and action understanding, intersubjective action-effect binding would contribute to the development of the sense of social agency (i.e., the sense that I am the one who causes and/or controls the other's action) or "interpersonal self" (Neisser, 1988), just like action-effect binding does to the development of the sense of self-agency in the physical world. In this study, by using a similar paradigm to Elsner and Hommel (2001), we investigated whether or not intersubjective action-effect binding was acquired (Experiment 1) and whether or not eye contact modulated it (Experiments 2 and 3).

Each experiment consisted of two phases: an acquisition phase and a test phase. In the acquisition phase, participants learned that each button press triggered a mouth gesture of a target female individual. In the test phase, previous effect stimuli were used as primes. If participants have acquired bidirectional associations between their own actions and the target individual's actions, presenting the effect-prime (mouth gesture) should activate the associated responses (finger movement). Therefore, responses should be facilitated when primed (observed) and required responses are congruent and should be interfered when they are incongruent. Moreover, given that eye contact modulates various aspects of the cognitive processing and/or behavioral responses which take place concurrent to or immediately following it (e.g., Csibra & Gergely, 2009; Farroni, Mansfield, Lai, & Johnson, 2003; Macrae, Hood, Milne, Rowe, & Mason, 2002; Mason, Hood, & Macrae, 2004; Senju & Csibra, 2008; Senju & Johnson, 2009), eye contact should also modulate an intersubjective action-effect binding.

In Experiment 1, the target individual's gaze direction was always direct throughout the acquisition phase, whereas in Experiment 2, the target's gaze direction was always averted. In Experiment 3, the target individual's eyes were always closed. Even if evidence is obtained showing that presenting an effect-prime activates the associated responses, it is possible that participants have simply acquired bidirectional associations between their actions and the change in photographs. In that case, the observed effect might be simply caused by the well-established action-visual event integration and priming rather than intersubjective action-effect binding, in which