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Temporal perception in joint action: This is MY action

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ABSTRACT

Here we investigated the temporal perception of self- and other-generated actions during sequential joint actions. Participants judged the perceived time of two events, the first triggered by the participant and the second by another agent, during a cooperative or competitive interaction, or by an unspecified mechanical cause. Results showed that participants perceived self-generated events as shifted earlier in time (*anticipation* temporal judgment bias) and non-self-generated events as shifted later in time (*repulsion* temporal judgment bias). This latter effect was observed independently from the kind of cause (i.e., agentive or mechanical) or interaction (i.e., cooperative or competitive). We suggest that this might represent a mental process which allows discriminating events that cannot plausibly be linked to one's own action. When an event immediately follows a self-generated one, temporal judgment biases operate as self-serving biases in order to separate self-generated events from events of another physical causality.

1. Introduction

As Hume famously argued (1739/1888), causality cannot be perceived directly, but must be inferred from the temporal contiguity and contingency of the events. According to this view, time provides the perceptual input from which causal representations are derived: we expect the cause to be contiguous with the effect and we tend, therefore, to perceive an event precedent and contiguous with another to be the cause of that event. On this account, perception of time shapes our experience of causality. Intriguingly, however, the reverse relationship also exists: perception of causality can shape our experience of time. It has been showed, for instance, that strong causal beliefs affect temporal order perception such that if the event A is believed to have caused the event B, then A is perceived as having occurred before B, even when this leads to a reversal of the objective temporal order (Bechlivanidis & Lagnado, 2013, 2016). Moreover, when the events A and B are considered to be causally related, they also appear closer together in time, that is they become temporally bounded.

This effect of Temporal Binding (TB, hereinafter) has been described as the subjective compression of the time interval between actions and their effects (Frith, 2013; Haggard & Tsakiris, 2009). When people perform an action A (e.g., a key press),

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the perceived time of the action is shifted later in time and the perceived time of the event B (e.g., a tone) is shifted earlier in time, resulting in temporal binding of the two events.

It has been argued that TB is an essential feature of the comprehension of cause–effect relations (Buehner, 2012; Buehner & Humphreys, 2009; Cravo, Claessens, & Baldo, 2011), and a distinctive marker of voluntary actions which connotes the experience of agency (Frith, 2014; Haggard, Clark, & Kalogeras, 2002). In this vein, TB has been used as indirect measure of pre-reflective sense of agency (for a review see Moore & Obhi, 2012). Interestingly, however, TB occurs not only for self-generated actions, but also for actions performed by others. Wohlschläger, Haggard, Gesierich, and Prinz (2003), for example, compared the perceived onset time of self-generated actions, other-generated actions, and machine-generated actions. TB was observed both for self- and other-generated actions, but not for machine-generated actions, suggesting that TB might function as an *agent-serving bias*, binding an effect to the agent who caused it (Frith, 2013), whether self or other.

Similar effects have been documented in joint actions, when two or more individuals coordinate their actions in space and time to achieve a common goal. Strother, House, and Obhi (2010), for example, used a joint action task in which two participants jointly performed a task (a key press) that had a single effect-event (a tone). Participants showed a similar TB for both self-generated and other-generated actions. These findings have been taken to suggest that, during joint action, individuals build up a shared motor plan, which incorporates others' actions into their own motor system (Haering & Kiesel, 2012; Obhi & Hall, 2011; Wohlschläger et al., 2003). The study by Strother et al. (2010) was explicitly designed to be highly ambiguous about which of the two agents had caused an event. In everyday circumstances, however, a joint goal can often only be accomplished through a *sequence* of actions. Therefore, it remains unclear whether these findings generalize to social situations in which, rather than co-acting the same action, agents coordinate their actions sequentially in time.

To investigate this issue, here we employed a modified version of the time judgment paradigm used by Libet, Gleason, Wright, and Pearl (1983), in which participants initiated an action and experienced an effect (tone) immediately prior to a second person joining in and making a similar action to produce a second tone. Participants were asked to judge the timing of either the first (self-generated) tone or the second (other-generated) tone in two different settings: a cooperative setting and a competitive setting. Cooperation and competition have been shown to influence to degree to which another person's action is incorporated into one's own motor plan. For example, de Bruijn, Miedl, and Bekkering (2008) found that fast responders in a competitive game are able to block out response plans of competitors. On the contrary, cooperation has been shown to facilitate the creation of a shared motor plan (Liepelt, Wenke, Fischer, & Prinz, 2011; Sebanz, Knoblich, Prinz, & Wascher, 2006). We reasoned that if TB in joint action reflects co-representation, then it might similarly vary as a function of setting. Specifically, one would expect TB for the effects of the second person's action when the second person acts cooperatively, but not when he/she acts competitively. In this latter case, TB might vanish or even reverse into a 'repulsion' effect, with action and effect perceived further apart in time than they actually are (Haggard, Poonian, & Walsh, 2009).

2. Experiment 1

2.1. Participants

Twenty right-handed volunteers (15 females, 5 males; age range = 19–30 years) participated in the experiment. All had normal or corrected-to-normal vision and hearing and were naïve with respect to the purpose of the study. The experimental procedures were approved by the local Ethics Committee and were carried out in accordance with the principles of the revised Helsinki Declaration (World Medical Associations General Assembly, 2008).

2.2. Apparatus

Participants were administered a modified version of the time judgment paradigm used by Libet et al. (1983). Stimuli were presented on a 15 inches pc monitor (800 × 600 pixels; refresh rate 85 Hz) at a viewing distance of 70 cm. Participants were seated in a comfortable chair alongside a co-actor. At the beginning of each trial, an image of a clock marked at conventional '5-min' intervals (Libet et al., 1983) and a single hand, equal to the radius of the clock (approximately 10 cm long), appeared. The initial position of the hand was determined randomly. The hand remained stationary for 1000 ms, at which point began to rotate clockwise with a period of 2220 ms. The hand rotated continuously until the end of each trial.

E-Prime V1.0 was used to control stimuli presentation and data collection (Psychology Software Tools, Inc).

2.3. Procedure

Three persons took part to each experimental session. Unbeknown to participants, two of them were co-experimenters.

Each participant performed the time judgement task in three experimental conditions: 'Cooperation', 'Competition', and 'Sequence', run in separate blocks (40 trials each).

The participant and a co-experimenter worked in pair in front of the monitor and operated one response key each with their right index finger (Fig. 1a).

In the 'Cooperation' condition, the participant was instructed to perform a key press at a time of his/her choice (Fig. 1b) with the only restriction to wait an entire hand clock rotation. He/she was encouraged to avoid initiating key presses at