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Who's calling the shots? Intentional content and feelings of control

Natalie Sebanz *, Ulrich Lackner

Psychology Department, Rutgers University, Newark, NJ 07102, USA

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Abstract

Based on Pacherie's dynamic theory of intentions, this study investigated how the way an intention is formed and sustained affects action performance and the experience of control during acting. In Experiment 1, task-irrelevant verbal commands were given while participants responded to stimuli in a two-choice reaction time (RT) task. The commands referred to an action goal congruent or incongruent with the actor's current intention, or ordered the initiation or abortion of the action. In Experiment 2, the same commands were given as participants freely chose between two actions. The distractors affected performance in the reactive task only. In both experiments, feelings of control were based on movement parameters as well as perceived (mis)matches between distractors and intended actions. These findings suggest that the way an intention is implemented affects how well it can be shielded against external perturbations and how much one feels in control.

Keywords: Agency; Feeling of control; Experience of acting; Intention; Goal shielding; Common coding

1. Introduction

An important part of human consciousness is the experience that our intentions cause our actions and that we control the way we perform actions. It has been claimed that the experience of agency critically contributes to a sense of self in terms of experiential immediacy (see, e.g., Tsakiris & Haggard, 2005) and forms part of a ''minimal self'' (Gallagher, 2000). A phenomenological analysis allows one to distinguish between at least two different aspects that both contribute to the experience of agency: the *experience of mental causation* and the *experience of acting*. Whereas the former involves the experience of one's own causal effectiveness when initiating a particular action, the latter refers to the experience one has while performing an action until a certain goal is achieved.

Although the experience of agency is a pervasive feature of our daily mental lives, surrounding all of our goal-oriented actions (Haggard, 2006), only some of its aspects have been investigated by empirical research so far. Previous research has improved our understanding of when and why we experience perceived effects as caused by our own actions and intentions (for recent overviews, see Haggard, 2006; Jeannerod, 2006; Wegner,

* Corresponding author. Fax: +1 973 353 1171.
E-mail address: sebanz@psychology.rutgers.edu (N. Sebanz).

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2002) and how intentionality affects the perceived timing of actions and their consequences (e.g., Haggard, Clark, & Kalogeras, 2002). So far, however, little is known about how the effort it takes to perform an action and the difficulty associated with achieving a particular goal affect the experience of acting (Bayne & Levy, 2006).

In the present study, we focused on the feeling of control during action performance as a particular aspect of the experience of acting. Generally, control over an action is reduced when one finds oneself unable to execute movements the way one normally would in order to achieve a desired goal. Control can be reduced due to physical perturbations (e.g., imagine carrying a heavy tray full of drinks while a dog is snapping at your feet), but it can also be reduced as a result of perturbations of a mental sort. Such perturbations are likely to occur in social context, where one sometimes needs to carry out actions in the face of conflicting commands. For example, imagine driving a car and preparing to stop at a red traffic light while a backseat driver is telling you to speed up. Presumably, in this situation, it is more difficult to initiate and sustain the action of braking, compared to a situation in which the person in the back is telling one to do what one intends to do. The aim of the present study was to investigate to what extent actions can successfully be shielded against external perturbations in the form of verbal commands, and to explore how the experience of control over an action is affected by discrepancies between intended actions and external commands. Specifically, we aimed to investigate whether changes in the experience of control following perturbations are modulated by the kind of intention that initiates and sustains the action. We use Pacherie's (2006) work on intentionality as a framework because it provides a link between philosophical theories of intentionality and the empirical investigation of the experience of agency.

2. Different forms of intention

Proponents of the causal theory of action have linked the distinct phenomenology of action to intentions. Whereas in early versions of the theory, intentions were regarded as relevant features of actions in terms of causality (Davidson, 1963, 1980; Goldman, 1970), later proponents have stressed the contribution of intentions to the phenomenal distinctiveness of acting, the "what is it like" aspect (Bach, 1978; Pacherie, 2000, 2006; Searle, 1983; Wakefield & Dreyfus, 1991; see also Ansfield & Wegner, 1996). One of the most influential accounts in action theory is Searle's dual theory of action (1983). In his seminal work he introduced a distinction between prior intentions and intentions in action. The two kinds of intention differ in their representational contents as well as in their relative temporal position during the unfolding of an action. Whereas prior intentions are formed before the action, represent the whole action as a unit, and end with the onset of the corresponding body movements, intentions in action initiate and guide body movements and play a continuing causal role during the execution of an action.

Progress in empirical research has shown the limits of the Searlean theory. A differentiation of intentions in terms of their relative temporal position and their representational content does not suffice to do justice to the variety and complexity of action-related mental processes. To account for the various ways in which intentions guide and sustain action, Pacherie (2006) recently offered an expanded framework of intentions that differentiates between three categories or levels of intentions: future-directed, present-directed, and motor (henceforth F-intentions, P-intentions, and M-intentions). F-intentions are conceptual and descriptive in content and specify types of action rather than tokens. They are usually detached from the agent's current situation, such as when one forms an intention to buy milk the next morning. Whereas Pacherie's F-intentions are very similar to Searle's prior intentions, P- and M-intentions specify more precisely how an intention is sustained throughout the course of acting.

P-intentions serve to implement action plans "inherited" from F-intentions. They anchor the descriptive contents of the action plan both in time, such as when one decides to go to the supermarket to buy milk "now", and in the situation, such as when one puts on shoes that fit the weather, crosses the road to go to a particular shop etc. In addition, P-intentions are involved in the rational control of action, supporting control processes responsible for keeping track of the way in which an action is accomplished and for minimizing undesirable side effects of actions. As P-intentions are tied to ongoing actions, they are subject to cognitive and action-related temporal constraints. Rational control can only be exerted in so far as aspects of the situation and the ongoing action fall within the time scale of conscious perception and rational thought. Thus, more fine-grained guidance and control of actions cannot be realized by P-intentions.

However, for precise and smooth performance, actions need to be guided and controlled at a sensorimotor level. According to Pacherie's framework, M-intentions are involved in the selection of appropriate motor programs as well as the guidance and monitoring of action performance achieved through internal models (Frith, Blakemore, & Wolpert, 2000; Davidson & Wolpert, 2003; Wolpert & Kawato, 1998). Inverse models specify the movements to be performed in order to achieve an intended goal. For example, when buying a bottle of milk, we must use the right grip size and the right force to lift the bottle from the shelf. Forward models predict the sensory consequences of movements, so that discrepancies between predicted and actual sensory consequences can be used to adjust actions. For example, if the bottle of milk is slippery, or lighter or heavier than expected, we must instantly adjust the ongoing movements for grasping and lifting. These fast processes of online action control operate at a time scale that allows only for limited conscious access to motor representations (Fourneret & Jeannerod, 1998; Blakemore, Wolpert, & Frith, 2002).

3. P-intentions, M-intentions, and the experience of acting

The differentiation between different forms of intention provides a framework for understanding which kind of information contributes to the experience of acting. As I reach for the bottle of milk in the supermarket, what affects my feeling of doing so? According to Pacherie, P-intentions and M-intentions are directly relevant to the experience of acting because they occur along with the actions they guide and control. In contrast, F-intentions, which are not bound to specific actions in a particular situation, are assumed to play no direct role in the experience of acting. More specifically, P-intentions are thought to contribute to the experience of *what* we are doing, whereas M-intentions are critical for the experience *that* we are acting as well as *how* we are performing an action.[1] We suggest that the experience of control over an action can be affected both when external perturbations lead to difficulties at the level of P- and M-intentions.

3.1. P-intentions

The higher-level guidance and control functions of P-intentions involve awareness of action goals. External perturbations that occur while one is trying to achieve a particular goal are usually detectable. For example, an external perturbation could lead to an error in action selection, such as when an announcement from the supermarket's loudspeaker is blaring "chocolate pudding" and we find ourselves reaching for pudding instead of milk. Studies on error monitoring have shown that after an erroneous action is selected internal monitoring mechanisms signal that one has committed an error (Falkenstein, 2005; Falkenstein et al., 2001; van Schie, Mars, Coles, & Bekkering, 2004; Yordanova, Falkenstein, Hohnsbein, & Kolev, 2004). Such error signals could be used for action control at the level of P-intentions. As one realizes that the performed action did not lead to the intended goal, the original content of the P-intention can be preserved. Nevertheless, the experience of control may be affected, because a mismatch between what one intended to do and what one actually did is perceived. A mismatch could be interpreted as an indication that additional monitoring and control processes need to be recruited because one's control over the action was limited.

3.2. M-intentions

We are usually not aware of the way in which we perform actions. Especially highly automatized actions can be performed without much or any conscious control by P-intentions (e.g., see Hommel, 2006). As pointed out by Pacherie (2006) the experience *that* one is acting does not depend on conscious access to the contents of M-intentions. However, to experience *how* one is acting, sensorimotor signals must be consciously detected and interpreted. Previous studies have shown that while individuals often unconsciously adjust their movements to changes in visuomotor couplings (Bridgeman, Lewis, Heit, & Nagle, 1979; Goodale, Pélisson, &

[1] This does not necessarily imply that P-intentions represent goals while M-intentions represent means. Rather, it seems possible that goals and means are represented at both levels but at different levels of specificity.

Prablanc, 1986; Pisella et al., 2000), larger discrepancies between predicted and actual sensory consequences of movements can be consciously detected (e.g., Fourneret & Jeannerod, 1998; Jeannerod, 2006; Knoblich & Kircher, 2004). This can be explained by the assumption that one makes a prediction about the sensory consequences of each motor command, which is then compared to the actual sensory consequence of one's movements (Davidson & Wolpert, 2003; Wolpert & Kawato, 1998). An error signal generated from such a comparison might underlie the unconscious adjustment of one's movements to sensory feedback as well as the conscious detection of changes in visuomotor couplings (Knoblich & Kircher, 2004). Discrepancies between predicted and actual sensory consequences might affect how much one feels in control over an action, as further explained below.

4. The current study

Action control at the level of P-intentions involves an evaluation of one's actions with respect to the chances of achieving a particular action goal. The extent to which we experience control over an action seems to play an important role in this evaluation. If the performance of an action does not proceed as planned, we need to make adjustments to maximize the chances of success. The aim of the present study was to explore which kinds of information contribute to the experience of control.

In principle, there are two possibilities: The experience of control could be based solely on reasoning processes that evaluate how appropriate an ongoing or recently completed action is with respect to achieving the intended goal. For example, as we grasp for the chocolate pudding instead of the milk, the experience of control may be reduced as we notice the discrepancy between the action and our goal (note that the content of the intention would be preserved). Thus, the experience of control would rely on perceived (mis)matches between actions and goals. However, a second possibility is that the experience of control is also modulated by sensorimotor signals that become accessible when predicted and observed sensory consequences of movements diverge. Not only whether we achieve an action goal or not, but *how* we achieve it may determine the extent to which we feel in control.

To address this issue, we asked participants to perform simple actions and introduced external perturbations during their actions. The perturbations were chosen so that they would interfere with performance of the action at the motor level to different extents. By asking participants to report after each action how much they had felt in control during performance, we investigated to what extent sensorimotor cues contribute to the experience of control. In addition, we varied the dynamics and content of P-intentions by asking participants to react to stimuli or choose between actions at their own will. We predicted that perturbations would have a stronger effect on action performance when the anchoring of the P-intention in the current situation is guided by an external signal rather than when it is established by the actor him- or herself. This prediction rests on the assumption that one can better shield an intention against external perturbations when one (a) has had time to decide on a particular action, and (b) can control when to implement this action, compared to a situation where one merely reacts to certain environmental conditions that require certain actions.

5. Experiment 1

In this part of the study, participants performed a reaction task. They were asked to respond to two different visual stimuli (a circle and a star) with a left and a right button press, respectively (see Fig. 1). On half of the trials, a perturbation in the form of a voice giving a command was introduced as participants moved their hand to the corresponding response location as fast as possible. We varied the onset time of the voice (300, 200, or 0 ms before the stimulus appeared) and the content of the verbal distractor. Five different distractors (German words) were used. Two distractors referred to specific action goals in the situation (''circle'', ''star''), and two referred to action performance in a more general way (''go'', ''stop''). Finally, a German nonword (''baug'') was presented as a neutral distractor.

The specific distractors were either congruent or incongruent with respect to the actor's current goal. For example, when the actor's task was to respond to a star by pressing the button labelled with a star, the voice was heard saying either ''star'' (congruent) or ''circle'' (incongruent). The distractors referring to the initiation or abortion of the action (henceforth referred to as ''nonspecific distractors'') were also either congruent with

Fig. 1. Experimental set-up. In Experiment 1, participants moved as quickly as possible from a starting position on the keyboard to the response button labelled with a star or the response button labelled with a circle in response to pictures of a circle and a star, respectively.

the action ("go") or incongruent ("stop"). Reaction times (RTs) and feelings of control (FoCs) were recorded for each action.

5.1. Predictions: Action performance

Assuming that the semantic content of spoken words is automatically processed (e.g., Roelofs, 2005), we predicted that the distractors would affect RTs. If actions are coded in terms of their goals (for an overview, see Hommel, 2006), specific distractors should have larger effects on RTs than nonspecific distractors, because there is an overlap between the semantic content of the specific distractors and the intended action goals. In particular, responses should be facilitated when the distractor refers to the action goal (specific congruent) and should be impaired when the distractor refers to the alternative goal that is not to be pursued (specific incongruent). We predicted smaller effects of nonspecific distractors on RTs, because the distractors do not refer to action goals. Nevertheless, the affirming ("go") vs. deterring ("stop") message of the nonspecific distractors might affect RTs to some extent. The neutral distractor ("baug") should have the least effect on RTs.

5.2. Predictions: Experienced control

After each trial, participants rated on a continuous scale ranging from "No control" to "Full control" how much they had felt in control over the action during performance. We will refer to these judgments as feelings of control (FoCs). If the experience of control over an action is based on sensorimotor cues, then FoC judgments should be sensitive to RT. In particular, FoCs should be rated as lower when RTs are slowed. Since we expected a slowing of RTs in particular in response to specific incongruent distractors, we also expected that FoCs would be lowest on trials involving specific incongruent distractors. Furthermore, a negative correlation between RTs and FoCs would also indicate that judgments about action control are modulated by sensorimotor cues that are part of M-intentions.

However, it could also be that FoCs are based on perceived (mis)matches between actions and goals at the level of P-intentions. In the present paradigm, there is no clear mismatch between action and goal unless a participant commits an error. However, the incongruent distractors can be perceived as action-guiding forces that reduce the chances of goal achievement. Accordingly, the perceived mismatch between distractors and goals on incongruent trials could lead to reduced feelings of control. In this case, FoCs ratings should be determined by the relation between action and distractor and should be independent of motor performance. Such a pattern of results would suggest that the experience of control is not based on accessible contents of M-intentions, but reflects a (subjective) evaluation of how well a P-intention can be implemented in the present situation.

5.3. Method

5.3.1. Participants

16 participants (4 male, 12 female) aged between 19 and 32 years (mean age 25) were recruited through advertisements at the University of Munich and in local newspapers. Fourteen participants were right-handed, 2 were left-handed. All participants were native German speakers. All had normal or corrected-to-normal vision and normal hearing. All received payment for their participation.

5.3.2. Procedure and materials

Participants were asked to respond to a picture of a circle or a star presented centrally on a screen as fast as possible with a left or right button press. Participants initiated each trial by pressing the space bar on a computer keyboard. This triggered the presentation of a fixation cross that remained on the screen for 300 ms. After fixation, the stimulus was presented for 700 ms. There was a response window of 1300 ms starting from stimulus onset. Separate response buttons were placed in front of the participant to the left and to the right, at a distance of approximately 60 cm from the space bar (see Fig. 1). They were labeled with the corresponding pictures (e.g., when the task was to respond to a star with a left response and to a circle with a right response, a picture of a star was attached to the left button and a picture of a circle was attached to the right button). Participants performed all actions (pressing space bar and pressing response buttons) with their dominant hand. They received auditory feedback after each response (a particular tone for correct and incorrect responses, respectively).

On half of the trials a voice recording (50% male voice, 50% female voice) was presented in addition to the visual stimulus. The voice was presented 0, 100, or 300 ms after the space-bar had been pressed to initiate the trial (thus, 300, 200, or 0 ms before stimulus onset). We will refer to these stimulus onset asynchronies (SOAs) as "SOA-0" (0 ms after space bar press), "SOA-100" (100 ms after space bar press), and "SOA-300" (300 ms after space bar press). Five different German mono-syllabic words could be heard: "los" (go), "stopp" (stop), "Kreis" (circle), "Stern" (star), "baug" (non-word in German). After each trial, participants were asked to rate the feeling of control they had experienced while executing the action. They rated on a continuous scale ranging from "No control" to "Full control" by clicking on the scale with the computer mouse. Participants completed 240 trials. Silent trials and trials with each of the five distractor words were equally frequent (40 trials each), and the different types of trials were presented in random order.

The soundfiles were recorded with SoundEdit™ 16 through the internal microphone of an Apple Powerbook. A male and a female speaker were asked to utter the distractors in a loud, commanding voice. The distractors were recorded in stereo at an 8Bit rate, and were edited to have the same duration. The soundfiles were presented over external loudspeakers positioned behind the response buttons (see Fig. 1). Stimulus presentation and data collection were controlled by an Apple Power PC. The experiment was run using Psyscope. As input devices a standard Apple – keyboard, a mouse and a Psyscope Button Box (Cohen, MacWhinney, Flatt, & Provost, 1993) were used.

5.4. Results

5.4.1. Reaction times

All responses occurring in the response window of 1300 ms were analyzed. Errors and outliers (2.8% of the trials) were excluded from statistical analyses. Errors were not further analyzed due to their small number. As can be seen in Fig. 2a, RTs were affected only by the specific distractors. A 2×2 within-subjects analysis of variance (ANOVA) with the factors Distractor Type (specific vs. nonspecific) and Congruency (congruent vs. incongruent) was conducted to assess the observed differences in RTs. There was no significant main effect of Distractor Type, $F(1,15) = 1.51$, $p = .24$. The main effect of Congruency was almost significant, $F(1,15) = 4.03$, $p = .06$. The interaction between Distractor Type and Congruency was significant, $F(1,15) = 4.59$, $p < .05$. Newman–Keuls post hoc tests showed a significant difference between congruent and incongruent trials for specific distractors ($p < .05$), but not for nonspecific distractors.

In a next step, we compared the specific and nonspecific distractors to the baseline conditions (neutral and no distractor, see Fig. 2b). RTs on silent trials did not differ from RTs on neutral trials ($p > .05$). Two-sided

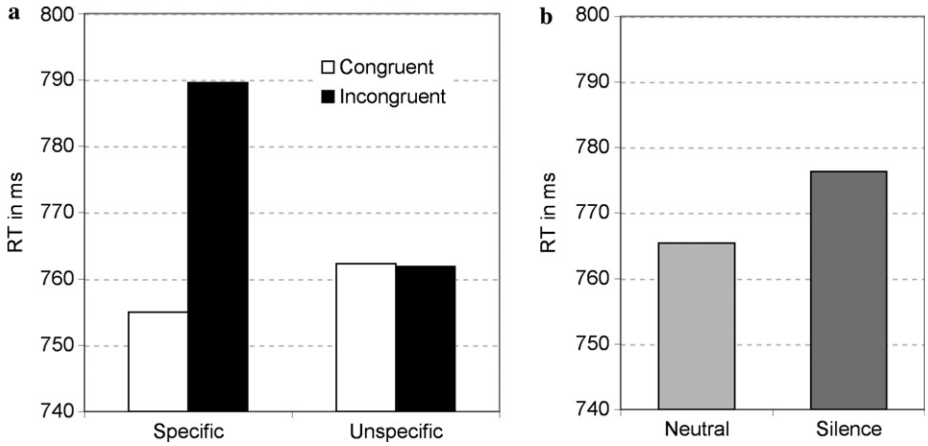

Fig. 2. Reaction time (RT) Results of Experiment 1. (a) Mean RT on congruent and incongruent trials with specific or nonspecific distractors. (b) Mean RT in the two baseline conditions (neutral and no distractor).

t-tests revealed that the RTs for nonspecific distractors also did not differ from RTs for the neutral distractor (all $p > .05$, see Fig. 2a and b). There was a marginally significant difference between the neutral condition and the specific incongruent condition, $t(1,15) = 1.8$, $p = .09$, whereas the difference between neutral and specific congruent was not significant, $t(1,15) = 0.95$, $p = .36$. This pattern of results indicates that specific incongruent distractors slowed responses compared to the neutral baseline. When silent trials were tested against trials with specific and nonspecific distractors, the only significant difference was between specific congruent trials and silent trials, $t(1,15) = 2.82$, $p < .05$. This indicates that relative to not hearing a voice, hearing a congruent, specific command facilitated responses.

5.4.2. SOA

A $2 \times 3 \times 2$ within-subjects ANOVA with the factors Distractor Type (specific vs. nonspecific), SOA (SOA-0, SOA-100, SOA-300) and Congruency (congruent vs. incongruent) showed that the only significant effect involving SOA was the interaction between Distractor Type and SOA, $F(2,30) = 5.51$, $p < .01$. At SOA-300, responses on trials with nonspecific distractors were faster than responses on trials with specific distractors (Newman–Keuls post hoc test, $p < .05$). For the other two SOAs, this effect was not significant. No other significant interactions were observed.

To determine whether SOA modulated the effect of specific distractors on RTs, we performed a 2×3 within-subjects ANOVA with the factors Congruency (congruent vs. incongruent) and SOA (SOA-0, SOA-100, and SOA-300). The main effect of Congruency was significant, $F(1,15) = 11$, $p < .01$. The main effect of SOA was not significant, $F(2,30) = 0.15$, $p = .86$. The interaction between Congruency and SOA was not significant, but showed a tendency, $F(2,30) = 2.91$, $p = .07$. A post hoc test (Newman–Keuls) showed that the congruency effect was only significant for SOA-0 ($p < .01$). The same ANOVA for nonspecific distractors showed a significant main effect for SOA, $F(2,30) = 3.36$, $p < .05$. RTs on trials with SOA-300 were faster than RTs on trials with SOA-100 and SOA-0. No other effects reached significance.

5.4.3. Ratings

The same trials as in the RT analysis were included in the analysis of ratings. A 2×2 within-subjects ANOVA with the factors Distractor Type (specific vs. nonspecific) and Congruency (congruent vs. incongruent) was conducted on FoCs to assess the observed differences in the ratings (see Fig. 3). The main effect of Distractor Type was not significant, $F(1,15) = 1.76$, $p = .20$. There was a significant main effect of Congruency, $F(1,15) = 8.74$, $p < .01$. The interaction between Distractor Type and Congruency was also significant, $F(1,15) = 5.11$, $p < .05$. A Newman–Keuls post hoc test showed a significant difference between congruent and incongruent trials both for specific and nonspecific distractors (all $p < .01$). However, the effect of specific distractors on FoCs was larger.

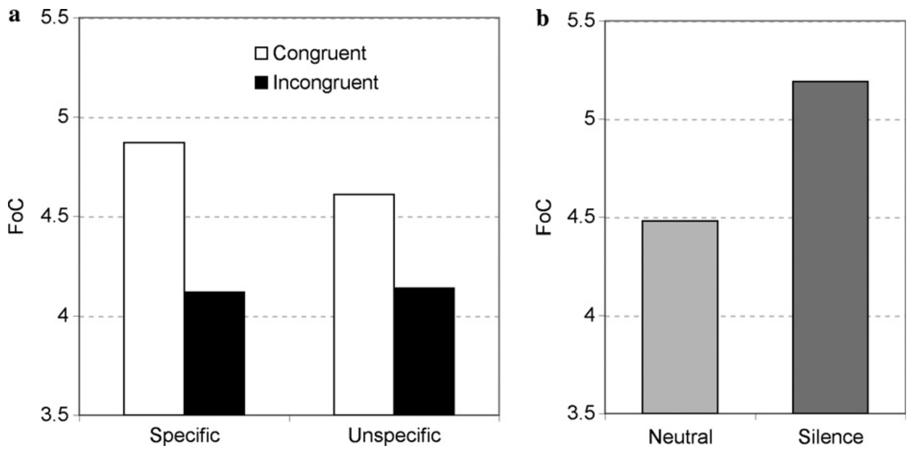

Fig. 3. Feelings of Control (FoCs) in Experiment 1. (a) Judgments of FoCs after congruent and incongruent trials with specific or nonspecific distractors. (b) Judgments after trials with a neutral or no distractor.

Again, two-sided *t*-tests were conducted to compare FoCs for specific and nonspecific distractors to the two baselines (neutral and silent, see Fig. 3b). FoCs were significantly higher on trials without a distractor compared to all other trials (all $p < .05$). Ratings on neutral trials were significantly different from specific congruent trials ($t\,(1,15) = 2.81$, $p < .05$), specific incongruent trials ($t\,(1,15) = 2.33$, $p < .05$), and nonspecific incongruent trials ($t\,(1,15) = 2.31$, $p < .05$). The difference between neutral and nonspecific congruent was not significant, $t\,(1,15) = 1.57$, $p = .13$.

5.4.4. SOA

To analyse effects of SOA, a $2 \times 3 \times 2$ within-subjects ANOVA with the factors Distractor Type (specific vs. nonspecific), SOA (SOA-0, SOA-100, and SOA-300) and Congruency (congruent vs. incongruent) was conducted. There was a significant main effect of Congruency (see above) and of SOA, $F\,(2,30) = 17.23$, $p < .001$. FoCs were highest for SOA-300 and lowest for SOA-0. In addition to the interaction between Distractor Type and Congruency (see above), there was a significant interaction between Congruency and SOA, $F\,(2,30) = 4.16$, $p < .05$. The reduction of FoC with increasing SOA was more pronounced for incongruent distractors. No further significant effects were observed.

To determine whether SOA modulated the effect of specific distractors on FoCs, we performed a 2×3 within-subjects ANOVA with the factors Congruency (congruent vs. incongruent) and SOA (SOA-0, SOA-100, and SOA-300). The main effect of Congruency was significant, $F\,(1,15) = 10.93$, $p < .01$. FoCs were higher on trials with congruent distractors. The main effect of SOA was also significant, $F\,(2,30) = 10.46$, $p < .001$. While FoCs were at the same level for SOA-300 and SOA-100, they were reduced for SOA-0. The interaction between Congruency and SOA was significant, $F\,(2,30) = 4.14$, $p < .05$. The congruency effect (higher FoC on congruent trials compared to incongruent trials) was significant for all SOAs (Newman–Keuls all $p < .01$), but was largest for SOA-0. Note that this corresponds with the larger compatibility effect in RTs for SOA-0.

5.5. Correlations between RTs and FoCs

The results showed that RTs were only affected by specific distractors. In particular, responses were slowed when the distractor referred to an alternative action goal that participants did not intend to achieve. A similar pattern was found for FoCs: less control was experienced when the distractor referred to the alternative action goal than when it referred to the actor's current goal. While this could be interpreted as evidence that the FoCs reflected actual motor performance, the pattern of FoCs on trials with nonspecific distractors suggests otherwise. Despite the fact that there was no RT difference between congruent and incongruent nonspecific distractors, FoCs differed between these two conditions. More control was experienced when the participants heard "go" than when they heard "stop." However, the difference between FoCs on congruent and incongruent trials was larger for specific than for nonspecific distractors, suggesting that both perceived (mis)matches between distractors and goals and sensorimotor cues could have contributed to the experience of control. To gain a better understanding of the relative contributions of these different kinds of information, we performed multiple regression analyses.

5.6. Multiple regression

For each participant, a multiple regression analysis was run, with FoC as the dependent variable and RT and trial types (silent, specific congruent, specific incongruent, nonspecific congruent, and nonspecific incongruent) as predictors.[2] Trial types were coded as dummy variables that could take the value 0 or 1. For instance, in specific congruent trials the value for the specific congruent dummy variable was set to 1 and all other dummy variables (silent, specific incongruent, etc.) were set to 0. For eleven of the 16 participants, a significant negative correlation between RT and FoC was observed (partial correlation, mean coefficient = −.46). The higher the RT, the lower the FoC. This suggests that for the majority of participants, the way the action was performed influenced the experience of control. Across all participants, the mean correlation between RT and FoC was −.34. This was significantly different from zero, $t(1, 15) = 5.50$, $p < .001$. Nine of the sixteen participants also showed a significant positive correlation between silent trials and FoC (partial correlation, mean coefficient = .31). In the absence of a verbal command, more control tended to be experienced. For some participants, smaller correlations were also found for the other trial types (see Table 1). FoC tended to be higher on congruent trials and lower on incongruent trials. In particular, nonspecific incongruent distractors ("stop") reduced the FoC.

5.7. Discussion

5.7.1. Performance

In Experiment 1, task-irrelevant verbal commands referring to an actor's current goal affected performance. Responses to a stimulus were faster when a voice referred to the corresponding action goal during execution of the action, and were slowed when the voice referred to an alternative action goal not to be effected. In contrast, distractors in the form of a command to initiate or stop the action did not affect performance. The slower RTs on specific incongruent trials compared to neutral trials suggest that hearing a voice referring to the alternative action goal created interference.

This pattern of results can be explained within the framework of the common coding theory (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Knoblich & Prinz, 2005; Prinz, 1997), which postulates that perceived and planned actions share a common representational domain. Interference effects are typically found when a (relevant or irrelevant) feature of the stimulus refers to an action alternative that is not to be performed (cf. Alluisi & Warm, 1990; Proctor & Reeve, 1990). For example, in the Simon task (Simon & Rudell, 1967; Simon & Craft, 1970), responses with a left button press are slower when the stimulus is presented on the right side than when it is presented on the left side (independent of modality). It is thought that the irrelevant stimulus feature interferes with action planning due to dimensional overlap between the irrelevant stimulus dimension and the response (Kornblum, Hasbroucq, & Osman, 1990; Kornblum & Lee, 1995).

The distractors in our experiments referred to one of two possible action goals. If one assumes that the semantic content of the distractors was automatically processed, it follows that a representation of the action corresponding to the action goal specified by the distractor was activated. For instance, when participants heard the word "star," a representation of the action of pressing the star-button should have been activated. On incongruent trials, the action activated by the distractor did not correspond to the action to be performed. Thus, it seems likely that the slowing of RTs reflects the time needed to overcome an action selection conflict (cf. Hommel, 1996). One might argue that participants may have encoded the actions in terms of left and right rather than "star" and "circle." However, many studies have shown that actions tend to be coded in terms of

[2] Neutral trials were left out of the analyses because the goal here was to investigate effects of the presence and absence of meaningful distractors.

Table 1
Partial correlation coefficients for the multiple regression analyses on FoCs in Experiment 1

Participant	RT	No Distr.	Spec. Con	Spec. Inc	Nons. Con	Nons. Inc
1	−.49*	.23*	.15*	−.04	.14*	.09
2	−.12	.22*	.10	−.04	−.03	−.06
3	−.39*	.03	.03	.01	.03	−.01
4	−.06	.26*	.12	−.39*	−.01	−.27*
5	−.02	.59*	.33*	−.26*	.21*	−.32*
6	−.22*	.17*	−.05	−.04	−.13	.04
7	−.58*	.12	.10	.05	.03	−.18*
8	−.59*	.01	−.10	−.12	—	−.17*
9	−.37*	.42*	.26*	−.07	.27*	−.15*
10	−.22*	—	—	—	—	—
11	−.58*	.13	.10	.07	.04	−.02
12	−.47*	.14*	−.03	−.20*	−.05	−.09
13	—	.29*	.10	−.19*	.02	−.27*
14	−.60*	−.04	−.02	−.12	.06	—
15	−.42*	−.02	−.09	−.12	−.01	−.11
16	−.03	.37*	.03	.23*	−.17*	−.19*
Mean	−.34*	.19*	.07*	−.08*	.02	−.11*

RT = reaction time; No Distr. = Trials without distractor; Spec. Cong = Specific congruent distractors; Spec. Inc = Specific incongruent distractors; Nons. Con = Nonspecific congruent distractors; Nons. Inc = Nonspecific incongruent distractors. Asterisks indicate significant correlations ($p < .05$).

effects rather than means (Hommel, 2006; Hommel et al., 2001). In addition, the response keys were labeled with the corresponding symbols. We think it is likely that when participants heard, for example, "star", this activated the corresponding action of pressing the "star"-button.

In contrast, nonspecific distractors did not affect performance because they did not refer to particular action goals. It seems that participants were able to "shield" their intentions (Goschke, 2003; Goschke & Kuhl, 1993) against the commands to initiate or stop the action they were about to perform. This interpretation is supported by the fact that the RT level for nonspecific distractors was the same as that for neutral distractors, where participants heard a non-word. Interestingly, RTs on trials without distractors did not differ from RTs on neutral and nonspecific distractor trials. This confirms that distractors that did not refer to an action goal were successfully ignored.

The effect of specific distractors on RT was modulated by the SOA between stimulus and distractor. Interference was greatest when the distractor was presented 300 ms before the stimulus. This fits with the assumption that hearing a voice referring to one of the two possible actions created a tendency to perform this action, which led to an action selection conflict. It seems that it was harder to ignore the distractor when it was presented before the relevant stimulus. A different pattern was found for nonspecific distractors. The faster RTs for SOA-300 compared to the other SOAs suggest that participants were able to ignore the nonspecific distractors to some degree when they were presented simultaneously with the stimulus. While nonspecific distractors presented before the stimulus (SOA-100 and SOA-0) may have been automatically processed without interfering with action planning, perhaps the nonspecific distractors presented simultaneously with the stimulus were processed less deeply as participants focused fully on the stimulus.

5.7.2. Experienced control

FoCs were highest on trials without distractors. This suggests that participants experienced any kind of verbal command as disturbing, regardless of the semantic content of the distractor. This was also reflected in the multiple regression analyses, where more than half of the participants (9 out of 16) showed a significant positive correlation between silent trials and FoCs. Given that RTs on silent trials were not significantly faster than RTs on neutral and nonspecific distractor trials, this indicates that FoCs were influenced by the perceived (mis)match between the verbal command and one's intention. Further evidence for this assumption is provided by the findings that FoCs were reduced on nonspecific incongruent trials compared to nonspecific congruent trials, despite the fact that there were no RT differences. This suggests that the experience of control reflects evaluation processes regarding the chances of achieving a particular action goal. A voice telling one to do the opposite of what one has intended to do is perceived as disturbing, hence engaging control processes at the level of P-intentions.

However, several findings suggest that the experience of control was also based on sensorimotor cues. First, the difference in FoCs between congruent and incongruent trials was larger for specific than for nonspecific distractors. This cannot be explained by the assumption that any mis-match between verbal command and intention reduces the FoC. Second, for specific distractor trials, FoCs tended to be reduced especially for SOA-0, where the largest RT effects were observed. Finally, the multiple regression analyses clearly showed that RT was the best predictor for reported FoC. More than two thirds of the participants showed a significant negative correlation between RT and FoC.

Taken together, the findings suggest that the experience of control over an action in the face of distracting verbal commands is determined not only by the experienced discrepancy between what one is told to do and one's intention, but also reflects sensitivity to performance-related aspects of the action. Participants were quite sensitive to *how* they performed actions and probably relied on sensorimotor cues when judging the control they had over an action. It seems likely that participants were able to use discrepancies between predicted and actual sensory consequences even without consciously detecting these discrepancies (cf. Blakemore, Wolpert, & Frith, 1998, 1999). As predictions made by forward models include both spatial and temporal parameters, participants could have used both discrepancies between the expected and actual timing of the movements, discrepancies between the predicted and the actual movement path, or a combination of such parameters. Future studies are needed to investigate which kinds of sensorimotor cues modulate the experience of control, and to what extent awareness of one's performance is critical for the experience of control. To come back to Pacherie's framework, the findings of Experiment 1 suggest that the experience of control is shaped by the contents of both P-intentions and M-intentions.

6. Experiment 2

Intentional action involves anchoring the descriptive contents of action plans that are part of future-directed intentions in the here and now (Pacherie, 2006). When actions are contingent upon external events, such as when specific stimuli require specific responses, this anchoring process is triggered externally rather than internally. However, in many situations, people decide when and how they want to implement action plans rather than relying on external signals. How an F-intention becomes anchored in a given situation may affect the following course of action. In particular, external perturbations might have less impact on action performance when the anchoring of the P-intention in the current situation is self-paced rather than when it is guided by an external signal, such as in Experiment 1.

To address this question, we asked participants in Experiment 2 to choose between two actions and initiate an action whenever they felt ready to do so while keeping all other aspects of the experiment the same. If intentions can be shielded more effectively against external perturbations when a conscious intention precedes the action, distractors should have less influence on RTs compared to Experiment 1. Different predictions can be made with regard to the experience of control. First, FoCs might be higher overall because participants experience a stronger intention to perform particular actions. Second, there may be less of an effect of incongruent distractors on FoCs, either because action performance is less affected or because the mismatch between incongruent distractors and action goals is less salient when the intention to perform a particular action is stronger. To the extent that FoCs do show congruency effects in the absence of RT effects, FoCs would reflect perceived (mis)matches between distractors and action goals.

6.1. Method

6.1.1. Participants

The same participants as in Experiment 1 took part in this experiment. The order in which participants performed Experiment 1 and 2 was counter-balanced across participants.

6.1.2. Procedure and materials

Participants were asked to produce a visual stimulus of their own choice (circle or star) by pressing the left or right button. In addition, they were told to produce each picture about equally often. In order to ensure that they made a conscious decision, they were asked to verbalize which stimulus they intended to produce and press the space bar after verbalization to signal their readiness to act. As in Experiment 1, pressing the space bar triggered the presentation of a fixation cross that remained on the screen for 300 ms. Participants were instructed to act as soon as the fixation cross disappeared. RTs were measured with respect to release of the space bar press. The response window of 1300 ms started with the offset of the fixation cross. As in Experiment 1, on half of the trials the space bar press triggered a verbal distractor, varying in onset 300 to 0 ms before the fixation cross disappeared. All other aspects were the same as in Experiment 1.

6.2. Results

All responses occurring in the response window of 1300 ms were analyzed. Errors and outliers (4.9% of the trials) were excluded from statistical analyses. Errors were not further analyzed.

6.2.1. Reaction times

Fig. 4a shows the mean RTs for the different trial types. A 2×2 within-subjects ANOVA with the factors Distractor Type (specific vs. nonspecific) and Congruency (congruent vs. incongruent) showed a significant main effect of Distractor Type, $F(1,15) = 6.16$, $p < .05$, confirming that RTs were slower on specific distractor trials. Neither the main effect of Congruency, $F(1,15) = .15$, $p = .71$, nor the interaction between Distractor Type and Congruency was significant, $F(1,15) = .02$, $p = .88$.

Two-tailed *t*-tests were run to compare the specific and nonspecific distractors to the neutral condition (see Fig. 4b). The only significant difference was between nonspecific incongruent distractors and neutral distractors, $t(1,15) = 2.4$, $p < .05$. Further *t*-tests showed that the mean RT for trials without a distractor was slower than mean RT for all other types of trials (all $p < .01$).

6.2.2. SOA

A $2 \times 3 \times 2$ within-subjects ANOVA with the factors Distractor Type (specific vs. nonspecific), SOA (SOA-0, SOA-100, and SOA-300) and Congruency (congruent vs. incongruent) showed a significant main effect of SOA, $F(2,30) = 17.94$, $p < .001$. RTs were slowest for SOA-300, where the distractor appeared at the time the

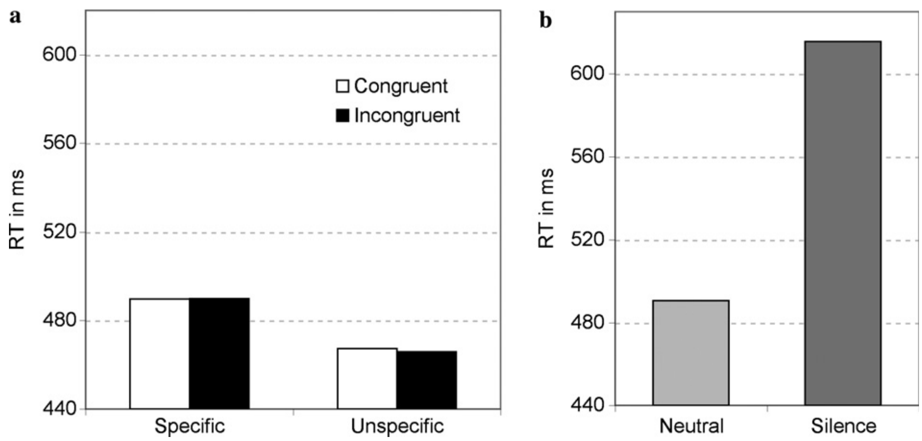

Fig. 4. Reaction time (RT) Results of Experiment 2. (a) Mean RT on congruent and incongruent trials with specific or nonspecific distractors. (b) Mean RT in the two baseline conditions (neutral and no distractor).

action was initiated, and were fastest for SOA-0, where the distractor appeared 300 ms before the action was initiated. No other significant effects of SOA were observed.

6.2.3. Ratings

The same trials as in the RT analysis were included in the analysis of ratings. A 2×2 within-subjects ANOVA with the factors Distractor Type (specific vs. nonspecific) and Congruency (congruent vs. incongruent) was conducted on FoCs to assess the observed differences in the ratings (see Fig. 5). There was a significant main effect of Distractor Type, $F(1,15) = 7.62$, $p < .05$. The main effect of Congruency was also significant, $F(1,15) = 6.36$, $p < .05$. The interaction between the two factors was not significant, $F(1,15) = .48$, $p = .5$. Two-tailed t-tests showed a nonsignificant difference between neutral and specific congruent trials, $t(1,15) = 2.18$, $p = .07$, and a significant difference between neutral and nonspecific incongruent trials, $t(1,15) = 3.1$, $p < .05$. FoCs were significantly higher on trials without distractor compared to nonspecific congruent and incongruent trials, and specific incongruent trials (all $p < .05$).

A two-tailed t-test showed that overall, FoC was higher in Experiment 2 ($M = 4.96$, $SD = 0.86$) than in Experiment 1 ($M = 4.57$, $SD = 1.01$), $t(1,15) = 3.16$, $p < .01$. Separate t-tests comparing FoC in Experiment 1 and 2 for each trial type showed significantly higher FoCs in Experiment 2 for all trial types except the baselines ($p < .05$). For trials with a neutral distractor or no distractor, there was a tendency in the same direction ($p = .08$ for neutral, $p = .14$ for no distractor).

6.2.4. SOA

A $2 \times 3 \times 2$ within-subjects ANOVA with the factors Distractor Type (specific vs. nonspecific), SOA (SOA-0, SOA-100, and SOA-300) and Congruency (congruent vs. incongruent) showed no significant effects of SOA.

6.3. Multiple regression

As in Experiment 1, a multiple regression analysis was run for each participant, with FoC as the dependent variable and RT and trial types (silent, specific congruent, specific incongruent, nonspecific congruent, and nonspecific incongruent) as predictors. For seven of the sixteen participants, a significant negative correlation between RT and FoC was observed (partial correlation, mean coefficient = −.32). As in Experiment 1, the higher the RT, the lower was the FoC. Across all participants, the mean correlation between RT and FoC was −.16. This was significantly different from zero, $p < .01$. Eleven of the sixteen participants showed a significant positive correlation between trials without distractors and FoC (partial correlation, mean coefficient = .34). In the absence of a verbal command, more control tended to be experienced. For the remaining types of trials, see Table 2.

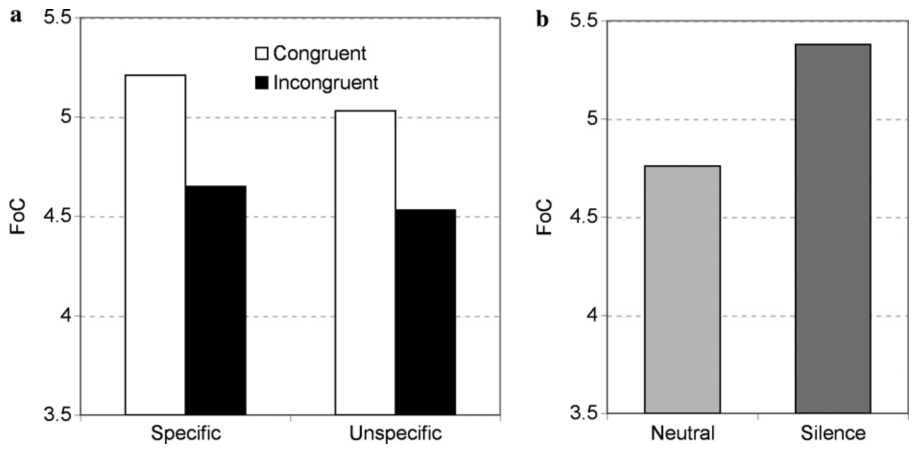

Fig. 5. Feelings of Control (FoCs) in Experiment 2. (a) Judgments of FoCs after congruent and incongruent trials with specific or nonspecific distractors. (b) Judgments after trials with a neutral or no distractor.

Table 2
Partial correlation coefficients for the multiple regression analyses on FoCs in Experiment 2

Participant	RT	No Distr.	Spec. Con	Spec. Inc	Nons. Con	Nons. Inc
1	−.38*	.17*	.03	−.14*	.06	−.20*
2	−.21*	.41*	.22*	−.11	.19*	−.07
3	.01	−.04	.03	−.05	−.04	−.01
4	−.38*	.52*	.28*	−.23*	.21*	−.17*
5	−.04	.51*	.38*	.06	.30*	—
6	.01	−.06	−.07	—	−.08	−.03
7	.01	.04	.05	.02	−.04	−.11
8	−.18	.31*	.19*	.12	.07	−.08
9	−.09	.46*	.36*	.10	.28*	−.01
10	−.24*	—	−.11	.01	−.03	−.18*
11	−.45*	.43*	.28*	.12	.17*	—
12	−.18*	.18*	.15*	−.18*	.04	−.08
13	−.12	.22*	.03	−.35*	−.12	−.38*
14	.08	.17*	−.04	.08	−.07	−.01
15	−.35*	.01	—	−.15*	−.01	−.17*
16	.07	.30*	−.17*	.15*	−.23*	−.09
Mean	−.16*	.24*	.10*	−.04	.04*	−.10*

RT = reaction time; No Distr. = Trials without distractor; Spec. Cong = Specific congruent distractors; Spec. Inc = Specific incongruent distractors; Nons. Con = Nonspecific congruent distractors; Nons. Inc = Nonspecific incongruent distractors. Asterisks indicate significant correlations ($p < .05$).

6.4. Discussion

6.4.1. Performance

We predicted that external perturbations would have less impact on action performance when the anchoring of the P-intention in the current situation is self-paced rather than guided by an external signal. This was confirmed in Experiment 2. There was no effect of congruency on RTs, suggesting that participants were able to shield their intentions more effectively against the distractors. Whereas in Experiment 1, participants' actions were slowed when they heard a voice referring to an action goal they did not intend to achieve, hearing an incongruent command did not affect performance in Experiment 2. However, independent of congruency, RTs were faster on trials with nonspecific distractors than on trials with specific distractors. Note, however, that relative to the neutral baseline, trails with specific distractors were not significantly slowed. Thus, whether a distractor referred to one of the two possible action goals (specific) or did not refer to the action at all (neutral) did not affect RTs. It remains unclear why responses on incongruent nonspecific distractor trials were faster than responses on neutral trials.

Responses for trials without distractors were surprisingly slow. A possible explanation is that whereas in Experiment 1, participants used stimulus onset as a signal to initiate the action, in Experiment 2, they may have used voice onset as a cue. On trials without distractor, the end of the fixation cross was the only cue to initiate the action. This is certainly less salient than voice onset. Consistent with this interpretation, we found that RTs were faster when the voice appeared 300 ms before the end of the fixation cross (SOA-0) and was slower when the voice appeared at the end of the fixation, just as the action was initiated (SOA-300). Given that SOA did not interact with any other factors, this effect is only of marginal interest and will not be discussed further.

6.4.2. Experienced control

The analysis of FoC judgments showed that participants experienced more control in Experiment 2 than in Experiment 1, independent of trial type. This suggests that more control over an action is experienced when the anchoring of a descriptive action plan in the current situation is self-guided rather than externally triggered. It seems likely that participants experienced a stronger intention to perform particular actions in Experiment 2 because they chose the kind of action to be performed as well as the time at which the action was initiated. This may have increased the experience of control during action performance.

Although congruency between distractors and action goals did not affect RTs, FoC judgments were affected by the nature of the distractors. Specifically, FoCs were higher when the voice referred to the action goal (specific congruent) compared to neutral trials, and were lower when the voice commanded the abortion of the action ("stop"!). This pattern deviates from Experiment 1, where specific incongruent distractors also led to reduced FoCs relative to neutral distractors. Given that congruency had no effect on RTs, one might think that the effects of congruency on FoCs were due to perceived (mis)matches between action goals and distractors only. However, the multiple regression analysis showed that FoC judgments also reflected action performance, albeit to a lesser extent than in Experiment 1.

7. General discussion

The present study suggests that the way in which an intention is formed and implemented influences the extent to which external perturbations affect action performance and shapes the experience of control over an action. An external perturbation in the form of a verbal command affected RTs when participants responded to stimuli, but did not affect RTs when participants chose between two actions at their own pace. Importantly, only distractors referring to a possible action goal interfered with action performance in the reactive task, suggesting that the observed effects of facilitation and interference are due to dimensional overlap between actions and distractors (Kornblum et al., 1990).

The reported feeling of control during action performance was greater overall when participants chose between actions than when they reacted to stimuli. Since participants always acted as fast as possible, the difference in the experience of control is likely due to the way in which action plans were anchored in the present situation. According to Pacherie's framework, a crucial function of P-intentions is to implement action plans inherited from F-intentions. In our study, a typical future-directed intention could have taken the form of "I will take part in a psychological experiment to make some money." The most specific possible future-directed intention in Experiment 1 was something like "when a stimulus appears, I will respond to it", and in Experiment 2, "I will decide whether to produce a star or a circle". These descriptive plans need to be transformed into concrete actions at specific points in time. Whereas in Experiment 1, this kind of anchoring was determined by stimulus presentation, in Experiment 2, the anchoring was internally rather than externally guided. The lower FoCs in the reaction task probably reflect the fact that participants could not choose between actions and formed an intention to perform a particular action only upon stimulus presentation.

One could argue that the observed differences are due to differences in task demands rather than differences in the way an intention is formed and sustained. For example, in Experiment 2, participants had ample time to prepare an action, whereas in Experiment 1, they could only prepare for action execution upon stimulus presentation. This argument cannot be rejected on the basis of the current data. However, we would like to point out that the different timing constraints of Experiment 1 and 2 might capture typical characteristics of situations where the implementation of a P-intention is externally triggered or controlled by the actor. For example, when we have the intention of boarding a particular train, we will implement this intention as soon as the gate has been announced. In contrast, if we can choose freely between different trains and destinations, we might simply go to one of the gates without hurry. Nevertheless, it seems an important goal for future studies to differentiate between effects of intentionality and effects of timing constraints on action.

An important question of the present study was whether FoC judgments are based on perceived (mis)matches between distractors and goals or are based on sensorimotor cues. Our findings suggest that both kinds of information were used. Motor performance (RT) was a moderate predictor of FoCs in both experiments, independent of trial type. There was a stronger relation between RTs and FoC judgments in Experiment 1. This is probably due to the fact that RTs were more variable in Experiment 1, where distractors referring to action goals affected performance. It also seems possible that participants were more sensitive to their motor performance because they literally "felt" the influence of the specific distractors. Whether or not a distractor appeared was the second best predictor for FoC judgments in Experiment 1, and the best predictor in Experiment 2. This suggests that participants experienced the voice as distracting even if it did not objectively affect their performance. Likewise, congruency of both specific and nonspecific distractors affected FoC judgments, indicating that FoCs were based in part on perceived (mis)matches between distractors and current action goals.

Taken together, the FoC findings suggest that both contents of P-intentions and M-intentions contribute to the experience of control. FoC judgments drawing on P-intentions are based on perceptual and conceptual information, whereas FoC judgments drawing on M-intentions are based on sensorimotor cues. While sensorimotor information is often not consciously accessible, deviations between predicted and actual sensory consequences of actions can be consciously detected (Blakemore et al., 2002; Fourneret & Jeannerod, 1998; Sato & Yasuda, 2005). Our findings are in line with the internal model theory of motor control, which postulates that for each action that is executed a prediction of its sensory consequences is generated (Davidson & Wolpert, 2003; Wolpert & Kawato, 1998). When a distractor led to a change in the way a particular action is usually performed, the prediction deviated from actual performance. It seems likely that experiencing such discrepancies reduced the FoC. At present, it is still an open question which kind of information the comparisons entail (e.g., between the predicted and actual timing of the action, the movement path etc.).

One could also argue that FoCs reflect post hoc judgments about the timing of the action rather than an experience of control shaped by sensorimotor cues. Participants could have taken into account how long it took them to perform the action and used this information to infer to what extent the action was under their control. We do not think, however, that this is a likely explanation, because it has been shown that individuals have only limited conscious access to motor parameters (Fourneret & Jeannerod, 1998).

Boosts and reductions in FoC resulting only from perceived (mis)matches between action goals and distractors could be called illusions of control, in analogy to Wegner's findings on illusions of conscious will (Wegner, 2002, 2003). Wegner showed that when certain contingencies between actions and effects are given, actions can be experienced as willful even when the actor did not intend to perform them. Interestingly, these effects also seem to arise at the level of P-intentions. For example, in a study by Wegner and Wheatley, participants showed a tendency to experience themselves as the cause of an action effect when a voice referred to the action effect just before it occurred (Wegner & Wheatley, 1999). It seems that people are susceptible to illusions of mental causation and control when they cannot make use of sensorimotor cues to disambiguate who caused an action and how it was performed.

As a final thought, we would like to suggest that the experience of agency, including the experience of control, might be critical for acting in social context (Sebanz, in press). When engaging in joint action, we need to distinguish between action effects produced by ourselves, a partner, or jointly (Sebanz, Bekkering, & Knoblich, 2006). When trying to perform a particular action in the presence of others, we need to shield our intentions against potential perturbations they may cause. The FoC could be an important parameter for rational action control in social context. In particular, a reduction in the FoC could serve as a signal that one needs to monitor one's actions more closely to enhance the chances of future success. This is also in line with our finding of higher FoCs on silent trials compared to trials where a voice was present. However, our attempts to shield our intentions against others may come too late. After all, in psychological experiments and in real life, the intentions in our head have often been implanted by other people. The homunculus, whom some people suspect of guiding our actions, may really be an internalized other giving commands (Roepstorff & Frith, 2004; see also Knoblich & Sebanz, 2006).

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