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Shaking hands: Priming by social action effects

Rüdiger Flach[1†], Clare Press[1,2*], Arnaud Badets[1,3] and Cecilia Heyes[1,4]
[1]Department of Psychology, University College London, UK
[2]Wellcome Trust Centre for Neuroimaging, Institute of Neurology, University College London, UK
[3]Centre de Recherches sur la Cognition et l'Appretissage – CeRCA, CNRS UMR 6234, Poitiers, France
[4]All Souls College, University of Oxford, UK

In a semi-naturalistic response–effect compatibility paradigm, participants were given the opportunity to learn that hand-shaking actions would be followed by social effects (human hand-shaking stimuli from a third-person perspective) or inanimate effects (block arrow stimuli). Relative to the actions, these effects appeared on the same or the opposite side of the screen (positional compatibility), and pointed towards or away from the response hand (directional compatibility). After learning, response times indicated a positional compatibility effect for both social and inanimate effects, but a directional compatibility effect occurred only for social action effects. These findings indicate that actions can be represented, not only by their effects on the inanimate world, but also by their effects on the actions of others. They are consistent with ideomotor theory, and with the view that actions are represented by bidirectional response–effect associations. They also have implications with respect to the origins and on-line control of imitation and the systems supporting imitation.

Ideomotor theory suggests that actions are represented primarily in terms of their sensory effects; according to their impact on the body and the world, rather than the way in which they are produced by the motor system (e.g., Hommel, Müsseler, Ascherschleben, & Prinz, 2001; James, 1890/1981). For example, when we are selecting a right hand over a left hand action, the cognitive system represents each of these actions, not in terms of the muscle movements required for its execution, but in terms of its effects on the hand and on objects lying in or near the hand. A substantial body of empirical work, using response–effect compatibility paradigms, provides evidence that

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[†] *The first author, Rüdiger Flach, died in June 2005 at the age of 33. As his colleagues and co-authors, we publish this paper as a mark of our affection for Rudi and our respect for the quality of his research and scholarship.*

[*] *Correspondence should be addressed to Dr Clare Press, Wellcome Trust Centre for Neuroimaging, Institute of Neurology, University College London, 12 Queen Square, London WC1N 3BG, UK (e-mail: c.press@fil.ion.ucl.ac.uk).*

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actions can be represented in terms of their sensory effects (Elsner & Hommel, 2001, 2004; Koch & Kunde, 2002; Kunde, 2001, 2003, 2004; Kunde, Koch, & Hoffman, 2004). However, all of these studies have examined instrumental, rather than social, action effects; they have manipulated the impact of actions on inanimate features of the world, rather than on the behaviour of other agents. In contrast, the present study used a response–effect compatibility paradigm to ask whether agents can represent their own actions in terms of the effects of those actions on other agents, and, if they can, whether social effects differ from inanimate effects in terms of the readiness with which they are integrated into action representations.

Previous research has supported the ideomotor theory by showing that, when a stimulus has reliably followed a response, anticipation of that stimulus has an influence on response selection; it primes responses with matching or ‘compatible’ features. For example, Kunde (2001) required participants to press one of four keys, arranged in a horizontal line, according to the colour of a centrally presented imperative stimulus. In the compatible blocks of trials, each keypress illuminated a light directly above the key, and in the incompatible blocks, each keypress consistently illuminated one of the other three lights. Reaction times (RTs) were faster in compatible, than incompatible, blocks. Kunde subsequently found that RTs were also faster in blocks where forceful keypresses were followed by loud tones, and light keypresses were followed by soft tones, than blocks where incompatible pressure–tone relationships were presented (Kunde *et al.*, 2004), and that RTs were faster when short keypresses were followed by short tones and long keypresses were followed by long tones, than vice versa (Kunde, 2003). These findings suggest that, in the course of a block of trials in which a response is reliably followed by a particular effect stimulus, a representation of the effect stimulus becomes integrated with the representation of the response. When the newly integrated stimulus is compatible with pre-existing response codes (e.g., in blocks where long responses produce long effects and short responses produce short effects), it facilitates response selection based on task instructions and therefore speeds RTs. However, when it is incompatible with pre-existing response codes (e.g., in blocks where long responses produce short effects and short responses produce long effects), the newly integrated stimulus interferes with response selection and slows RTs.

Using a different experimental paradigm, Elsner and Hommel (2001, see also 2004, and Kunde, 2004) confirmed that inanimate response effects can be integrated into response representations, and provided evidence that the integration is achieved via bidirectional associative learning. In their acquisition phase, Elsner and Hommel required participants freely to execute left- or right-hand keypresses, and presented a high or a low tone after each response (e.g., right actions followed by high tones and left actions by low tones). In a second, test, phase, these tones were presented as imperative stimuli, requiring left- and right-hand keypresses. In this test phase, the congruent group, who were required to execute actions to stimuli with which they had been paired during the acquisition phase, were faster than the incongruent group, that had experienced the opposite action–tone relationship in the acquisition phase. For example, if high tones required right-hand responses in the test phase, these responses were faster when high tones, rather than low tones, had followed right-hand responses in the acquisition phase. Furthermore, the magnitude of this congruency effect varied with the contiguity and contingency between actions and their effects in the acquisition phase; it was stronger when the effects followed their responses more closely in time, and when the responses were better predictors of their effects (Elsner & Hommel, 2004). Given that it is well-known that the rate of associative learning is modulated by contiguity and contingency (Rescorla, 1968), these results imply that the sensory consequences of action acquire the capacity to represent action via associative learning. Furthermore, since effect stimuli were presented after responses in the acquisition phase, but before responses in the test phase, Elsner and Hommel's findings suggest that the associative learning which integrates effect stimuli into action representations is bidirectional rather than unidirectional: it gives rise to links between response and effect stimulus representations which ensure that activation of each is propagated to the other.

In the present study, we used a response–effect compatibility paradigm similar to the one developed by Kunde (2001, 2003; Koch & Kunde, 2002; Kunde *et al.*, 2004) to find out whether social, as well as inanimate, effects can acquire the capacity to represent actions, and to investigate whether associations between responses and their social effects are learned more or less readily than associations between responses and their inanimate effects. Associative learning is a relatively domain-general process, which forges connections between event representations according to their contiguity and contingency, but often regardless of the type or identity of the represented events (Seligman & Hager, 1972; cf. Garcia & Koelling, 1966). Therefore, if the process that generates action effect representations is associative learning, one would not expect it to be biased intrinsically towards the formation of either inanimate or social effect representations (Heyes, Bird, Johnson, & Haggard, 2005; Press, Gillmeister, & Heyes, 2007). However, it is possible that the integration process is biased towards either inanimate or social stimuli by attentional or perceptual mechanisms. For example, if, in everyday life, novel inanimate stimuli are more likely to require action than novel social stimuli, then novel inanimate stimuli may be better able than novel social stimuli to capture attention and therefore to support learning. Alternatively, the components of the perceptual system that are dedicated to the processing of biological movement stimuli (e.g., Oram & Perrett, 1994; Thompson, Clarke, Stewart, & Puce, 2005) may give these stimuli privileged access to associative learning mechanisms, enabling social stimuli to acquire the capacity to represent action more readily than inanimate stimuli. Even if one sets aside the evidence that action effect representations are formed through domain-general processes of associative learning, and assumes that they are formed by dedicated mechanisms of motor learning, it remains unclear whether one would expect more effective learning of social or inanimate effect representations. If the dedicated mechanisms are adapted for instrumental action, then actions are likely to be represented primarily in terms of their inanimate effects, but if they are adapted for communicative functions, they are likely to be represented primarily in terms of their social effects.

We used a semi-naturalistic response–effect paradigm to investigate the representation of hand-shaking responses. In each trial, participants were presented with a male or female face, which indicated whether they should use their left or right hand to 'shake hands' with a centrally located paddle manipulandum. This response produced an action effect. In separate blocks of trials, the action effect varied in its positional compatibility (same, or opposite, side of the screen as the response hand) and its directional compatibility (pointing towards, or away from, the response hand). Separate groups of participants observed social and inanimate effect stimuli. The social stimuli depicted a human hand, in a shaking posture, and in directionally compatible trials the stimuli therefore appeared to shake hands with the participant. The inanimate stimuli were block arrows. We required separate groups of participants to undertake the task with their own responses visible and invisible. This manipulation was used to determine whether exposure to proximal action effects, i.e., direct visual feedback from the response hand, modulated the influence of the distal action effects on performance.

If participants can learn to integrate gross spatial properties of an effect, the left or right position of an image on a computer screen, into their representations of hand-shaking actions, then responses should be faster when effects are positionally compatible, rather than positionally incompatible, with executed responses. Similarly, if participants can learn to incorporate a relatively subtle spatial property of an effect, the direction in which it points, into their representation of hand-shaking actions, then responses should be faster when effects are directionally compatible, rather than directionally incompatible, with executed responses. Finally, if this learning, about gross or subtle spatial features of effect stimuli, occurs more or less readily when the response effect is social than when it is inanimate, one would expect the influence of positional and/or directional compatibility to interact with the type of effect stimulus. For example, a greater disparity between compatible and incompatible trials with hand than with arrow stimuli would suggest that the properties of social stimuli are more readily integrated into effect representations than the properties of inanimate stimuli.

Method

Participants

A total of 128 participants (18–35 years old) took part in this study and were paid a small honorarium. They were randomly assigned in equal numbers to groups who would observe hand effects and groups who would observe arrow effects. Half of the participants in each group could see their responses during testing, and the other half could not see their responses. All were right-handed, had normal or corrected-to-normal vision, and were naive with respect to the purpose of the experiment. The study was approved by the local ethics committee, and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Stimuli

Responses were cued by a static, coloured image of a male or a female face (Max Planck Institute for Biological Cybernetics in Tübingen, Germany, face database), presented in the centre of the screen and occupying approximately 5° of visual angle horizontally and 7° vertically. Correct responses were followed by presentation of a static, coloured image of a human hand or of a block arrow. The hand and arrow stimuli were of similar hue and luminance, and each occupied approximately 4° of visual angle horizontally, and 2° vertically (see Figure 1). The hand stimuli depicted a right or a left hand approaching the participant in the posture that normally precedes hand shaking. The arrow stimuli pointed to the right or to the left. Both hand and arrow stimuli were presented on either the left or the right side of the screen.

Procedure

Participants were tested individually in a dimly lit room. Approximately 1 m in front of where participants were standing was a 40.5 cm CRT computer screen on which the stimuli were presented. Directly in front of the participant, on a table at upper thigh height, was a board bearing two response keys, 27 cm apart. The manipulandum, a paddle, was situated between the response keys and the screen, and aligned with the

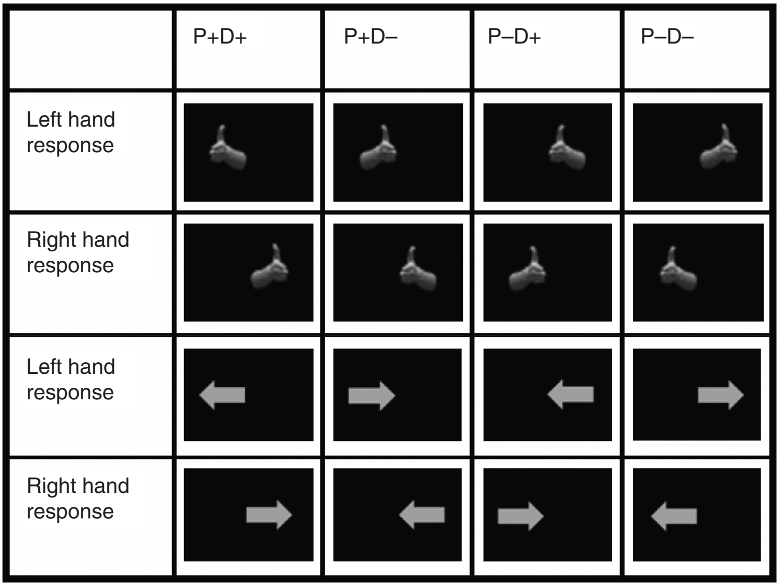

Figure 1. The effect types: in P+D+ blocks, the effect was on the same side of the screen as the response and pointed towards the response; in P+D− blocks, the effect was on the same side of the screen and pointed away from the response; in P−D+ blocks, the effect was on the opposite side of the screen as the response and pointed towards it; in P−D− blocks, the effect was on the opposite side of the screen and pointed away from it. Those in the hand-visible and hand-invisible groups observed hand effects (rows 2 and 3) and those in the arrow-visible and arrow-invisible groups observed arrow effects (rows 4 and 5).

centre of the participant's body. It consisted of a USB logic 3 joystick, padded, and encased in a paddle-shaped envelope of soft, yellow fabric (20 cm high × 7 cm wide × 10 cm deep). The position of the paddle relative to the participant's body was similar to that of another person's hand when shaken.

Between trials, participants depressed the left key with the index finger of their left hand, and the right key with the index finger of their right hand. Each trial began with the words 'Be ready!', which were presented in the centre of the screen for at least 500 ms, or until the participant was depressing both response keys. After a random stimulus onset asynchrony of 500–1,000 ms, a male or a female face was presented. Participants were instructed that their task was to initiate different hand-shaking movements to 'Phil' (the male face) and 'Liv' (the female face), and their attention was not drawn to the visual response effects; therefore they were not explicitly instructed to shake hands with the model (indeed, the instruction was the same regardless of whether there were hand or arrow effects). Half of the participants in each group were told that left-hand responses should be made to Phil's face and right-hand responses to Liv's face. The other half were given the reverse stimulus–response assignment. To make the hand-shaking response, the participant was required to lift their right or left hand from the response key, reach forward with their hand in a posture typical of hand shaking, and touch the side of the centrally located paddle so that it was displaced in the direction of the movement trajectory. Participants then returned their hand to its response key. A correct response (made with the appropriate hand, 100–1,000 ms after stimulus onset) resulted in disappearance of the face stimulus and its replacement, 200 ms later, by a hand or arrow stimulus for 1,000 ms, and a further 500 ms later, by a male voice (in the case of the male stimulus) or a female voice (in the case of the female stimulus) saying 'hello'. Incorrect responses were followed by an error message, displayed for 1,000 ms, and the gender-appropriate voice saying 'oh'. Incorrect response trials were replaced at a random position later in the same block. The inter-trial interval was 1,000 ms.

There were four types of action effect, presented in separate blocks of 50 trials each: position compatible and direction compatible (P+D+), position compatible and direction incompatible (P+D−), position incompatible and direction compatible (P−D+), and position incompatible and direction incompatible (P − D−) (see Figure 1). In P+ conditions, the action effect appeared on the same side of the screen as the responding arm (e.g., left side following left-arm movements), and in P− conditions it appeared on the opposite side of the screen (e.g., right side following left-arm movements). In D+ conditions, the action effect pointed towards the responding arm (e.g., towards the left of the screen following left-arm movements), and in D− conditions it pointed away from the responding arm (e.g., towards the right following left-arm movements).

Participants completed two blocks of each type of trial (8 blocks, consisting of 400 correct trials, in total), and the order of block types was counterbalanced across participants according to a Latin square design. The first block of each type constituted the training block and the second the test block. At the end of each block, participants were told the number of errors they had made in that block and given a score (maximum 100) reflecting their mean RT.

Results

The data from the test blocks were analysed using mean RT, based on correct responses with a latency between 100 and 1,000 ms, as the dependent variable. These data were subjected to mixed-model ANOVA in which the within-subject variables were positional compatibility (P+ and P−) and directional compatibility (D+ and D−), and the between-subject variables were effect type (hand and arrow) and response visibility (visible and invisible). These data are presented in Table 1, separately for P+D+, P+D−, P−D+, and P−D− blocks, and separately for participants who observed the hand and arrow effects, and undertook the experiment with their own responding hands visible or invisible. All significant effects and interactions are reported below. The same analysis applied to error frequency data did not yield any significant effects or interactions.

Table 1. Mean RT (ms) in P+D+, P+D−, P−D+, and P−D− blocks, separately for participants who observed the hand and arrow effects, and undertook the experiment with their own responding hands visible or invisible: Values in brackets indicate the standard error of the mean

	P+D+	P+D−	P−D+	P−D−
Hand (visible)	484.45 (*7.11*)	486.36 (*8.08*)	479.45 (*7.48*)	487.22 (*7.88*)
Hand (invisible)	513.68 (*8.49*)	517.45 (7.99)	518.06 (7.87)	527.11 (*9.82*)
Arrow (visible)	487.35 (6.72)	484.84 (*6.45*)	489.03 (*6.32*)	486.91 (*6.53*)
Arrow (invisible)	484.07 (*8.07*)	482.41 (*8.06*)	494.39 (*7.06*)	486.63 (*6.45*)

Responding was faster when the effect stimulus was positionally compatible, rather than positionally incompatible, with the response [$F(1, 124) = 6.61$, $p = .01$]. This effect did not differ between the groups observing hand and arrow effects [$F < 1$]. However, there was a positional compatibility × visibility interaction [$F(1, 124) = 6.98$, $p = .009$, see Figure 2a], indicating that a positional compatibility effect occurred in the group whose own actions were invisible [$F(1, 124) = 13.59$, $p < .001$], but not in the group whose actions were visible [$F < 1$].

Figure 2b indicates that responding was faster when a hand effect stimulus was directionally compatible, rather than directionally incompatible, with the response [$F(1, 124) = 6.24$, $p = .014$]. This directional compatibility effect varied with effect type [D × effect type interaction: $F(1, 124) = 8.23$, $p = .005$]; it was present when the effects were hand stimuli [$F(1, 124) = 6.24$, $p = .014$] but not when they were arrow stimuli [$F(1, 124) = 2.43$, $p = .1$]. The positional and directional compatibility effects did not interact [$F < 1$].

There was also a significant two-way interaction between effect type and response visibility [$F(1, 124) = 6.03$, $p = .015$, see Figure 2c], indicating that response invisibility slowed responding when the response effects were hands but not when they were arrows. Given this two-way interaction, we repeated the analysis using RT as a covariate, to ensure that the directional compatibility × effect type interaction did not depend on differences in RT between groups. This covariate analysis confirmed that there was a directional compatibility × effect type interaction [$F(1, 123) = 7.07$, $p < .01$], driven by the presence of a directional compatibility effect in the group observing hand effects [$F(1, 123) = 5.57$, $p = .02$], but not in the group observing arrow effects [$F(1, 123) = 2.05$, $p = .16$].

Discussion

In this study of action representation, participants were given the opportunity to learn relationships between hand-shaking responses and novel effect stimuli. The effect stimuli depicted either a hand in a shaking posture (social effect type) or a block arrow (inanimate effect type). They were presented in (positional compatibility), or pointed towards (directional compatibility), the same left–right location as the hand-shaking response, or in the opposite location. After the learning phase, responses with effects that appeared on the same side of space were initiated faster than responses with effects that appeared on the opposite side of space. This positional compatibility effect did not differ across effect types (social and inanimate), but it was present only in the group of participants who did not receive direct visual feedback from their responses. In addition, responses with effects that pointed towards the responding hand were initiated faster than responses with effects that pointed away from the responding hand. This directional compatibility effect was present when the effect stimuli were hands but not when they were block arrows. Unlike the positional compatibility effect, it was not modulated by the availability of direct visual feedback.

The positional compatibility effect observed in this experiment is similar to that reported by Kunde (2001), in which keypress responses followed by the illumination of adjacent lights were initiated faster than keypress responses followed by the illumination of non-adjacent lights. Thus, it confirms that participants can learn relationships between responses and the gross spatial features of their effects, and that, as a consequence of this learning, anticipation of those spatial features can ‘prime’ the

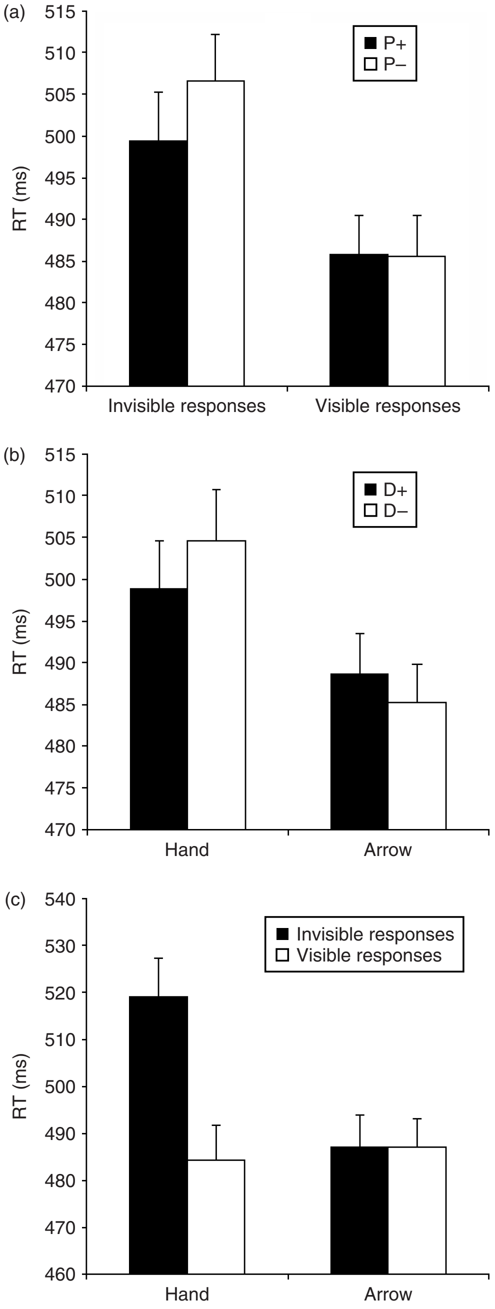

Figure 2. (a) Mean RTs to execute responses when effects were P+ (shaded bars) and P− (open bars), when the participants' own responses were invisible and visible. (b) Mean RTs to execute responses when effects were D+ (shaded bars) and D− (open bars), when the effects were hands and arrows. (c) Mean RTs to execute responses when the participants' own responses were invisible (shaded bars) and visible (open bars), and the effects were hands and arrows. Error bars in all graphs represent the standard error of the mean.

selection of their associated responses. In our study, a positional compatibility effect occurred not only when the effect stimuli were inanimate (arrows), as in Kunde's experiments, but also when they were social (hands). Therefore, our results extend those of previous studies by showing that participants can represent actions in terms of the gross spatial features of their effects even when the effect stimuli depict the actions of others. The magnitude of the positional compatibility effect did not vary with effect type, giving no evidence for social effects being more or less readily integrated into action representations than inanimate effects.

The results of our directional compatibility manipulation showed for the first time that the direction in which a hand is pointing can be integrated within action representations. This is consistent with previous evidence that relatively subtle properties of stimuli are integrated within action representations. For example, in a study investigating object affordances, Tucker and Ellis (1998) showed that participants were faster to elicit right hand, rather than left hand, actions to objects that would be most easily grasped with the right hand (e.g., a saucepan with its handle pointing to the right). Furthermore, the fact that there was a directional compatibility effect in the hand group, where the directionally compatible effects appeared to shake hands with the participant, but not in the arrow group, suggests that in our experiment these subtle features were incorporated in action representations, and therefore influenced response selection, only when they were features of social, rather than inanimate, stimuli. Previous research suggests that the pointing direction of inanimate arrow effects can be incorporated into response representations (Kunde, 2004). Therefore, it is likely that with a longer acquisition phase, the directional effect would also have been observed with arrow stimuli, but social effect stimuli are integrated more rapidly.

There are a number of potential explanations for this difference between social and inanimate effect stimuli. First, it is possible that, within the experiment, participants learned associations between responses and the directional features of social stimuli more rapidly than relationships between responses and the directional features of inanimate stimuli. This could be a consequence of perceptual or attentional mechanisms giving social stimulus features privileged access to associative learning. One reason that attentional mechanisms may have given social features privileged access to learning is that the instruction given to participants was to 'shake hands' with the model. As a consequence of these instructions, whether or not an effect stimulus appeared to shake hands may have been especially salient for participants. Second, the directional features of the social stimuli may have had a 'head start'; there may have been associations between hand-shaking responses and the directional features of their social effects prior to the experiment, either through innate specification or because of learning in circumstances where people shake hands with one another. Finally, if one assumes that action representations are learned via dedicated processes of motor learning, rather than domain-general associative learning, then it is possible that these processes are adapted for communicative functions, and therefore intrinsically biased towards learning relationships between responses and their social effects.

Whatever the exact source of the observed difference between social and inanimate response effects, it is noteworthy that the directional compatibility effect for social stimuli, unlike the positional compatibility for both stimulus types, was strong enough to withstand exposure to direct visual feedback. The positional compatibility effect was absent when participants were able to see their own hand and arm movements, but the directional compatibility effect for social stimuli was not modulated by the visibility of the responses. This suggests that the availability of direct visual feedback interfered with processing of the gross spatial features of the distal response effects (the events on the computer screen), but it did not prevent participants from learning about the subtle spatial features of the social response effects.

The position of an effect stimulus, on the left or right of the screen, can be processed more rapidly than the direction in which an effect stimulus is pointing. Therefore, it is likely that we detected a difference between social and inanimate effect stimuli in the case of directional compatibility, but not in the case of positional compatibility, because the position of the effect stimulus triggered response-compatible or response-incompatible codes before processing of stimulus type (social or inanimate) had been completed. In contrast, it is likely that processing of stimulus type was completed before the subtle, directional features of the effect stimuli had been encoded.

Responses were slower in the invisible condition, but only when the action effects were social. This unexpected finding may indicate that participants imagined the perspective of the agent initiating the hand-shaking effects, but only when the participants' own responses were invisible. Perspective taking may slow responses, and there is some evidence that difficulties in inhibiting knowledge about oneself can interfere with perspective taking (Carlson, Moses, & Hix, 1998; Samson, Apperly, Kathirgamanathan, & Humphreys, 2005). Therefore, it is plausible that perspective taking occurred only in the invisible condition, where participants were deprived of direct visual feedback from their own actions.

In demonstrating that actions can be represented by their social, as well as their inanimate, effects, our findings are consistent with Elsner and Hommel's model of effect anticipation (Elsner & Hommel, 2001, 2004) and with the associative sequence learning (ASL) account of the origins and on-line control of imitation (Brass & Heyes, 2005; Heyes, 2001). Both of these models assume that action representations are formed through the operation of domain-general processes of associative learning, and therefore that responses can be represented by both social and inanimate effect stimuli. However, the representation of actions by their social effects is particularly important in relation to the ASL model because it seeks to explain fundamentally social phenomena. This model suggests that individuals acquire the capacity to imitate predominantly via everyday experience in which their actions have first-person visual effects which resemble the third-person appearance of these actions. Experience of this kind is obtained from self-observation, optical mirrors, and from being imitated. Previous studies have provided support for the ASL model by showing that stimulus–response learning modulates both imitative behaviour and the neurological mechanisms thought to mediate imitation (e.g., Catmur, Walsh, & Heyes, 2007; Catmur *et al.*, 2008; Heyes *et al.*, 2005; Press *et al.*, 2007). In conjunction with Elsner and Hommel's (2001, 2004) evidence that response–effect learning depends on associative mechanisms, the present study provides additional support for the ASL model by demonstrating under carefully controlled conditions that response–effect learning is not limited to inanimate effects, and that, in some circumstances, social effects are more readily integrated into action representations.

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